Pennsylvania

Climate Change Action Plan

October 9, 2009

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

pennsylvania PA
STATE OF INDEPENDENCE

7000-BK-DEP4263 10/2009

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Forward

Anthropogenic climate change and the increase of greenhouse gas emissions is a very real challenge facing each of us. We all contribute to the problem but more importantly we all represent part of the solution. Pennsylvania contributes a full 1 percent of the entire world's greenhouse gas emissions and 4 percent of the United States contribution. However, the Keystone State has faired better than many others. From 2000 through 2005 we saw modest gains in efficiency as our economy grew at a faster pace than the rate of growth in greenhouse gas emissions. Many of the recommendations in this report identify the huge opportunity for gains and commensurate financial savings associated with increased energy efficiency.

This document is notable because it establishes the foundation for Pennsylvania's first climate action plan with very detailed recommendations that were vetted through a stakeholder process and which include detailed economic analyses of each of the recommendations for reductions of greenhouse gases.

From the beginning, the DEP established a transparent process to encourage public participation. We endeavored to inform the public by posting information to the department's Web site and external newsletter, by providing press releases to the media, through notices in the Pennsylvania Bulletin, by encouraging public participation at meetings of the CCAC and via email communications. The department wishes to recognize the dedication of time and effort to all members of the CCAC. The diverse composition of this group has brought many insights and experiences to the process. The members are to be credited for the seriousness with which they deliberated and for conducting the business of the committee in a professional and collegial fashion.

As a result, Pennsylvania possesses many cost-effective opportunities to reduce our contribution to climate change while also helping to grow our economy. The recommendations contained within this report are broad spectrum ensuring that all sectors of our economy play an integral part in resolving the challenge and responsibility that all Pennsylvanian's share in the global effort to reduce greenhouse gas emissions.

This process began with passage of Act 70 on July 9, 2008 but does not end here. Rather this will become a living document, updated every three years.

Executive Summary

The world's climate is changing and Pennsylvania, which is responsible for 1 percent of the planet's man-made greenhouse gas (GHG) emissions, is positioned to become a leader in the fight against this global threat. The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) concluded unequivocally that as a result of the substantial increase in atmospheric concentrations of carbon dioxide (CO_2) and other greenhouse gases (GHG) caused by human activity, the Earth's climate system is warming. The United Nations Environment Programme just released its *Climate Change Science Compendium 2009*[1], an analysis of the latest IPCC science and which provides a further wake-up call for the need to take immediate action. The report identifies impacts that are already underway and will be realized as a result of current atmospheric GHG concentrations including the following:

- Ocean acidification that will damage or destroy coral reefs and many species of marine life that live in or around or otherwise depend upon these ecosystems
- Sea Level Rise over the next millennium, with greater than 3 feet likely in the next century but with 5 or 10 times that in the following centuries
- Tropical and temperate mountain glacier loss that will disrupt irrigation systems, drinking water supplies and hydroelectric installations, as well as alter the socio-economic and cultural lives of perhaps 20-25 per cent of the human population.
- Shifts in the hydrologic cycle that will result in the disappearance of regional climates with associated ecosystem destruction and species extinction as drier regions shift towards the poles
- A global temperature increase of 2.4^oC (4.3^oF.) above pre-industrial temperatures, even if GHG concentrations had been held constant at 2005 levels

The need to reduce GHG emissions is clear. The recommendations of this report identify opportunities that can reduce Pennsylvania's GHG emissions by over a third. Many of these actions can be accomplished at no additional cost or may even result in a net savings.

On July 9, 2008, Governor Rendell signed the Pennsylvania Climate Change Act (Act 70). Among a number of goals, Act 70 required the preparation of this report. Working with the Climate Change Advisory Committee (CCAC) mandated under Act 70, the Department of Environmental Protection (Department) has prepared this Climate Change Action Report. In order to frame the context of this climate change action plan and facilitate monitoring of progress towards reaching the recommended GHG reductions, it was necessary to establish three key elements: a baseline year, target year and a target.

- Target (reduction target) – the percentage of GHG emissions reductions recommended
- Baseline Year – the year by which total emissions reductions would be measured
- Target Year – the year by which forecasted emissions and an emissions reduction target would be established

[1] Climate Change Science Compendium 2009, September 24, 2009, United Nations Environment Programme, available at: http://www.unep.org/compendium2009/

Considered together, these three elements frame the action plan. The recommendation adopted by the CCAC and department is: **30 percent reduction in GHG emissions below year 2000 levels by 2020.** Furthermore, the recommendations of this report are expected to result in the net creation of 65,000 new full-time jobs and add more than $6 billion to the commonwealth's gross state product in 2020.

The action plan identifies 52 specific work plans (recommendations) as well as several recent actions taken by Pennsylvania and the federal government that combined will provide GHG emissions reductions in Pennsylvania of 42 percent below 2000 levels in the year 2020. The 52 recommendations of this report, on their own, are anticipated to yield a 36 percent reduction in emissions by 2020, putting us well on the path to making the critical reductions needed to prevent further impacts on the world's climate. These values are within the range of reductions that is recommended by the Intergovernmental Panel on Climate Change (IPCC) as being necessary to stabilize the effects of climate change.

Overview of Pennsylvania Emissions and Projections

To support the work required under Act 70, the department prepared a GHG emissions inventory covering the period from 1990 to 2020. The inventory and a series of forecasts based on that data provided the department with a comprehensive picture of possible future GHG emissions. The inventory and forecast were provided to the CCAC to support its understanding of past, current, and possible future GHG emissions patterns. CCAC recommended changes were made to the forecasts for electricity generation, transportation and landfills.

The inventory and projections cover the six types of gases included in the United States (U.S.) Greenhouse Gas Inventory:

- Carbon dioxide (CO_2) from burning fossil fuels for electricity, heating and transportation;
- Methane (natural gas) from gas production, leakage in pipe line transportation and inefficient domestic and industrial processes;
- Nitrous oxide (N_2O) from internal combustion engine exhaust, nylon manufacture byproducts, use of agricultural nitrate fertilizers, and use as a aerosol can propellant;
- Hydro fluorocarbons (HFCs) used as replacement refrigerants, fire extinguishing and foam blowing agents for stratospheric ozone depleting chlorofluorocarbons (CFCs);
- Perfluorocarbons (PFCs) also used as a replacement for CFC refrigerants, used directly in medical and electronics manufacturing applications, and formed as a byproduct of aluminum smelting; and
- Sulfur hexafluoride (SF_6) used as a gaseous dielectric medium replacing liquid PCB (polychlorinated biphenol) containing substances, an inert gas in magnesium smelting and as an inert insulator in windows.

In explaining GHG emissions it is important to understand the fundamental concept of CO_2e or carbon dioxide equivalent. This measure is used, rather than carbon dioxide (CO_2) alone, because there are a number of gases that affect the world's climate. For example, natural gas (methane) has a climate changing impact that is 23 times that of an equal volume of CO_2. In order to make comparison possible, all climate changing gases are converted to their impact if they were CO_2.

In 2000, Pennsylvania emitted approximately 284 $MMtCO_2e$ of gross emissions (consumption basis), an amount equal to about 4.0 percent of total U.S. gross GHG emissions (based on 2000 U.S. data).[1] On a net emissions basis (i.e., including carbon sinks such as forestlands), Pennsylvania accounted for approximately 263 $MMtCO_2e$ of emissions in 2000, an amount equal to 4.1 percent of total U.S. net GHG emissions. On a per-capita basis, Pennsylvania residents emitted about 23 metric tons (t) of gross CO_2e in 2000, less than the national average of about 25 tCO_2e. Both Pennsylvania and national per capita emissions remained relatively flat from 1990 to 2000. In both Pennsylvania and the nation as a whole, economic growth exceeded emissions growth throughout the 1990–2000 period. From 1990 to 2000, emissions per unit of gross product dropped by 19 percent nationally, and by 35 percent in Pennsylvania.[2]

If no action other than the recent state and federal government actions is taken to reduce GHG emissions, we project that Pennsylvania's emissions will increase slightly to 295 $MMtCO_2e$ by 2020, or about 1.8 percent above 2000 levels. This equates to a 0.1 percent annual rate of growth from 2000 to 2020. The most significant contributor to Pennsylvania's emissions growth is the electricity generation sector, two-thirds of which are the result of activities in residential and commercial buildings (primarily heating and cooling). Emissions from waste management and agriculture are modest contributors to future emissions growth, while emissions from all other sectors are expected to decrease or remain relatively constant from 2000 to 2020. These increases are driven in large part by the electricity sales projections from the electric distribution companies (EDCs) and further by applying their historic annual rates of growth for years 2014 through 2020. This methodology and data set was considered to be the best available state-specific source for Pennsylvania's emissions forecast associated with electricity consumption. Under these assumptions, it is anticipated that the most significant contributor to Pennsylvania's emissions growth is the electricity generation sector. However, the department believes that recent trends will alter this forecast, at least in terms of the magnitude of the emissions increase. Data reported by the PJM Interconnection indicates that electricity sales for the first six months of 2009 are down 5 percent below 2008 levels and that 2008 sales were 2.7 percent below 2007 levels.

Data from the U.S. Environmental Protection Agency's (EPA) Division of Clean Air Markets confirms that CO_2 emissions from Pennsylvania's electric power plants have decreased. While this decrease is in large part due to recessionary impacts there also has been a shift to the utilization of more natural gas to displace coal for the generation of electricity in the commonwealth. The department believes that natural gas will continue to play a more significant role in electricity production than was the case in 2000 and even 2005. Though the initial analysis incorporated EDC sales forecasts in an attempt to use the most state-specific data sources, the department believes the annual growth rate of electricity sales to be more modest.

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[1] The national emissions used for these comparisons are based on 2005 emissions from *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*, April 15, 2008, US EPA #430-R-08-005, (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

[2] Based on real gross domestic product (millions of chained 2000 dollars) that excludes the effects of inflation. U.S. Department of Commerce, Bureau of Economic Analysis. "Gross Domestic Product by State." Available at: http://www.bea.gov/regional/gsp/.

Specifically, the department believes that it is more likely that electricity sales will grow at a rate of about 1 percent per year rather than the historical rate of approximately 1.6 percent, which will have a profound and beneficial impact on GHG emissions by 2020. Assuming the department's assertions are correct, a sensitivity analysis indicates there will be an approximate 10 percent reduction in GHG emissions from electricity consumption forecasted in 2020.

Recommendations and Key Points about Micro-Economic Analyses

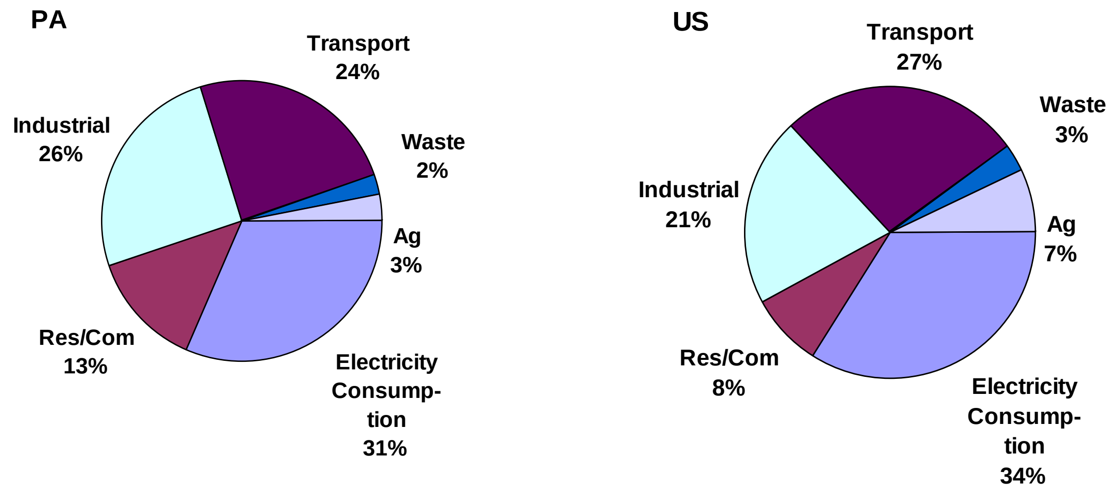
- The CCAC and DEP reviewed over 100 multi-sector GHG mitigation actions and approved for inclusion in this report a package of 52 work plan recommendations to reduce GHG emissions and address related energy and commerce issues in Pennsylvania. The recommended work plans cover a wide range of costs and GHG reduction potentials.

- The CCAC approved work plan recommendations are estimated to generate a net cumulative savings of about $11.7 billion between 2009 and 2020.

- The approved work plan recommendations (if all are implemented) are estimated to reduce gross GHG emissions (consumption basis) by approximately 95.6 $MMtCO_2e$ emissions in 2020, representing a 36 percent reduction in GHG emissions below 2000 levels. The combination of emission reductions associated with the work plan recommendations and recent state and federal actions suggest that Pennsylvania has the potential to reduce its annual GHG emissions in 2020 to about 42 percent below 2000 levels.

Figure ExS-2 compares the distribution of gross GHG emissions by sector in 2000 in Pennsylvania and the U.S. The principal sources of Pennsylvania's GHG emissions in 2000 are electricity consumption, industrial activities, and transportation, accounting for 30 percent, 28 percent and 24 percent of Pennsylvania's gross GHG emissions, respectively. The next largest contributor is the residential and commercial fuel use sectors, accounting for 14 percent of gross GHG emissions in 2000. However, a significant point of clarification needs to be made to better understand this data. These charts illustrate the direct source of emissions. For the Residential and Commercial Sector this includes the onsite combustion of fossil fuels for heating, hot water and cooking. Here electricity consumption is not attached to the end users; rather it reflects the contribution of electricity generation that is consumed within Pennsylvania. Residential and commercial buildings are responsible for sixty-six percent of all electricity consumed; the remaining one-third is consumed by all other sectors. Therefore, buildings are responsible for approximately 34 percent of all gross GHG emissions in Pennsylvania.

Figure ExS-2. Gross GHG Emissions by Sector, 2000: Pennsylvania and U.S.



Res/Com = residential and commercial sectors.

Recent State and Federal Actions

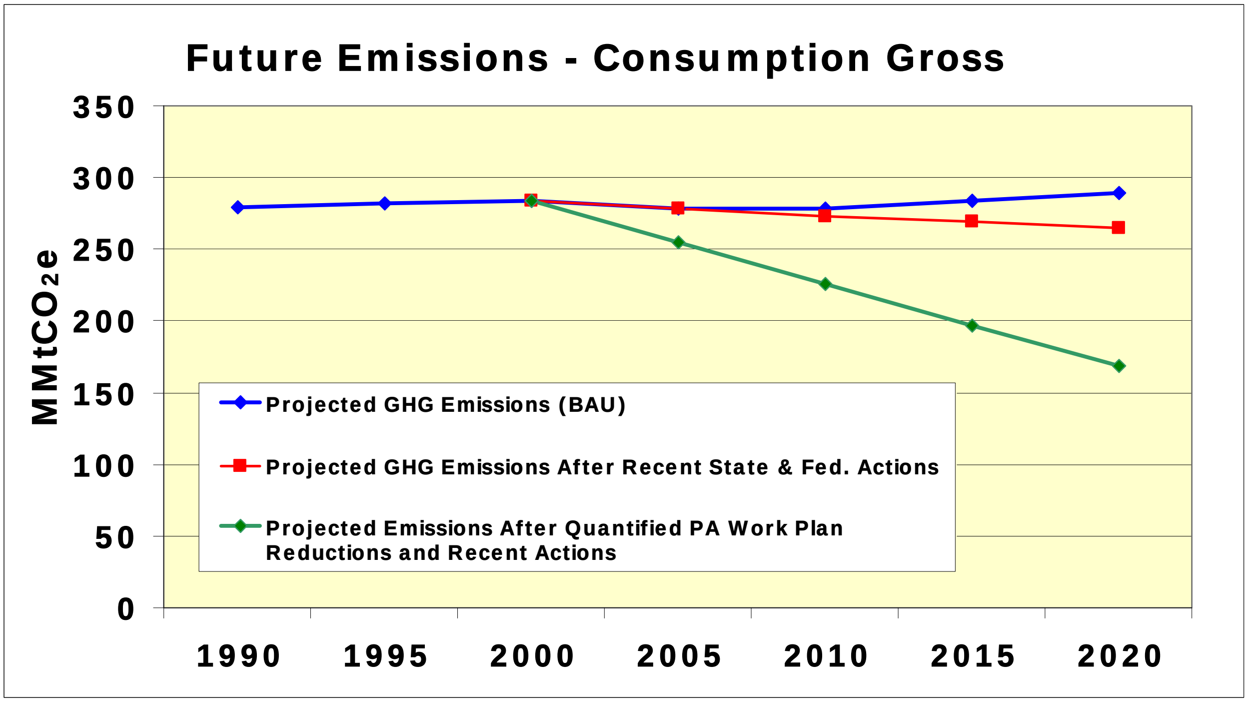
The significant overall reduction in GHG emissions predicted here would be significantly less without several actions already taken by Pennsylvania and the federal government. The report examines seven recent actions for their impact on emission reductions and costs. The result is a projected reduction of approximately 24.6 $MMtCO_2e$ in 2020 or an 8.7 percent reduction in the state's GHG emissions below 2000 levels.

The most important impacts from policies already being implemented include:

- The renewable energy requirements in Pennsylvania Alternative Energy Portfolio Act and Act 129, mandating electric utility energy efficiency programs, will reduce emissions by 15 MMtCO2e;
- Pennsylvania's adoption of the 2008 Biofuel Development and In-State Production Incentive Act, the Diesel-Powered Motor Vehicle Idling Act, and the Pennsylvania Clean Vehicles (PCV) Program will reduce emissions by an additional 16 MMtCO2e; and
- Recently enacted federal appliance efficiency standards as well as improved efficiency for new light-duty vehicles. These will further reduce emissions by 5 MMtCO2e by 2020.

The graph in Figure ExS-1 below depicts potential impacts on emissions. The top line shows emissions if nothing is done. Actions already under way, including Pennsylvania's renewable portfolio requirement and federal appliance efficiency standards are shown in the middle line. The proposals in this report include a wide variety of actions many of which will have positive economic impacts and are represented by the bottom line. The actions recommended here will have a very significant impact on emissions.

Figure ExS-1. Annual GHG Emissions: Reference Case Projections, Recent Actions and Work Plan Recommendations (Consumption Basis, Gross Emissions)



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; GHG = greenhouse gas; BAU = business-as-usual.

Recommendations

The department developed this Climate Action Report based on the recommendations of the (CCAC) as an initial step in establishing a basis for moving forward on the implementation of climate change actions in Pennsylvania. Evaluation of key factors such as cost effectiveness, economic impacts, and harmonization with other Pennsylvania programs and policies will be critical to the next stage of climate policy implementation. The following key elements and recommendations were identified by the CCAC during this initial process:

The CCAC and the department reviewed over 100 GHG mitigation actions covering a wide range of emissions impacts and cost-benefit results. 52 mitigation actions were recommended by CCAC. Of these 52 recommendations, the CCAC approved 28 unanimously, 11 with only three or less not in support, and 13 plans were voted at least 13 in-support to eight not-in-support. These 52 recommendations or work plans that have the potential to reduce our GHG emissions by approximately 96 $MMtCO_2e$ or by roughly 36 percent below 2000 while providing cumulative savings of about $11.7 billion between 2009 and 2020. The weighted-average cost-effectiveness of these recommendations is estimated to be a savings of about $20 per metric ton of carbon dioxide equivalent (tCO_2e) emissions reduced.

Pennsylvania has already undertaken steps to reduce GHG emissions associated with the generation of electricity and the use of fossil fuels for the transportation sector. In addition, recent federal programs for on-road vehicles and appliances will reduce GHG emissions. Analysis of these recent state and federal actions indicate that in 2020, they are estimated to reduce Pennsylvania's gross[3] GHG emissions (consumption basis) by approximately 24.6 million metric tons of carbon dioxide equivalent ($MMtCO_2e$), representing an 8.7 percent reduction in GHG emissions below 2000 levels. The combination of emission reductions associated with the work plan recommendations and recent state and federal actions suggest that Pennsylvania has the potential to reduce its annual GHG emissions in 2020 to about 42 percent below 2000 levels.

The results shown in Table ExS-2 indicate that the work plan recommendations support significant opportunities for Pennsylvania to reduce GHG emissions at a cost savings economy-wide. Although the cumulative results for the Land Use & Transportation sector indicate a significant cost, savings are expected to be realized on an annual basis by 2020.

Table ExS-2. Summary by Sector of Estimated Impacts Associated with Implementing All of the CCAC Work Plan Recommendations (cumulative reductions and costs/savings)

	Annual Results (2020)			Cumulative Results (2009-2020)		
Sector	**GHG Reductions (MMtCO2e)**	**Costs (Million $)**	**Cost-Effectiveness ($/tCO2e)**	**GHG Reductions (MMtCO2e)**	**Costs (NPV, Million $)**	**Cost-Effectiveness ($/tCO2e)**
Residential Commercial	32	-$538	-$17	215	-$3,668	-$17
Electricity Generation, Transmission, and Distribution	32	$1,006	$31	131	$1,060	$8
Industry	5.8	-$365	-$62	33	-$1,072	-$33
Waste	5.9	-$49	-$8	37	-$298	-$8
Land Use & Transportation	7	-$494	-$75	60	$2,805	$47
Agriculture	1.4	-$62	-$44	10	-$380	-$37
Forestry	11.3	-$1,376	-$121	98	-$10,177	-$104
Total (includes all adjustments for overlaps)	**96**	**-$1,879**	**-$296**	**583**	**-$11,729**	**-$20**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.

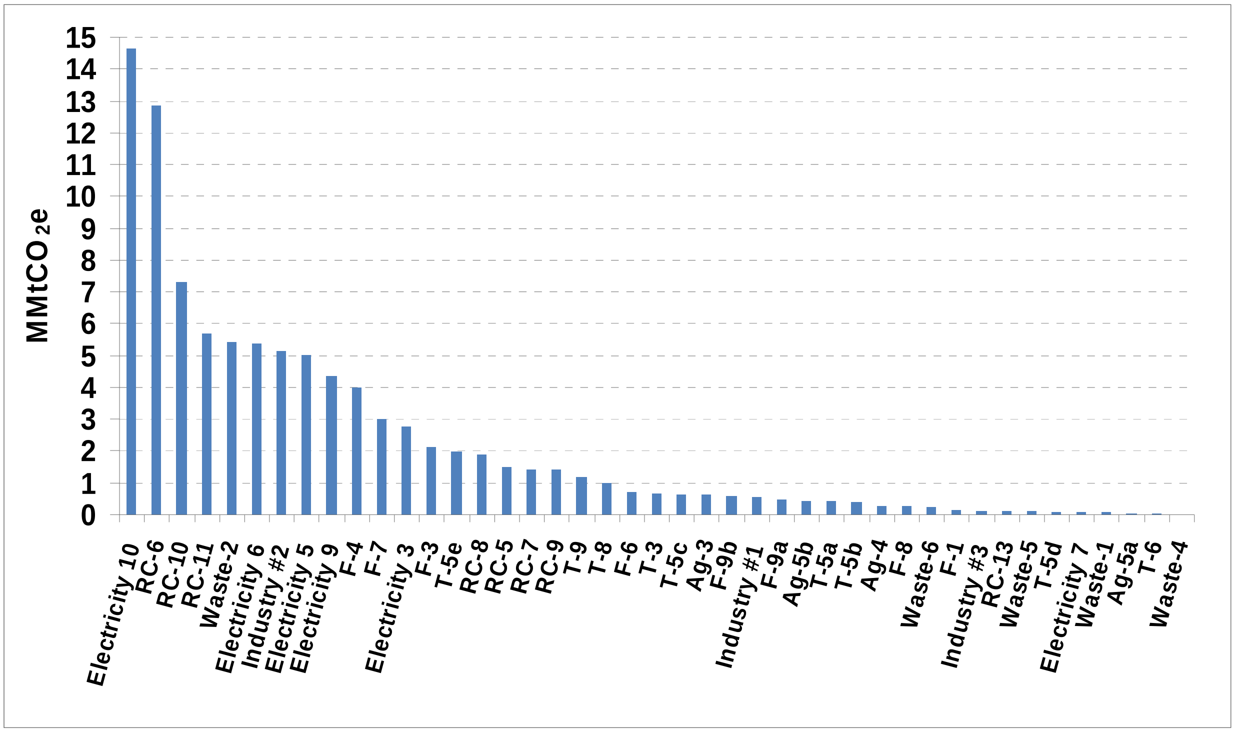
Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings associated with the policy options.

Within each sector, values have been adjusted to eliminate double counting for work plan recommendations or elements of work plan recommendations that overlap. In addition, values associated with work plan recommendations or elements of work plan recommendations within a sector that overlap with recommendations or elements of recommendations in another sector have been adjusted to eliminate double counting.

[3] Excluding GHG emissions removed due to forestry and other land uses and excluding GHG emissions associated with exported electricity.

As explained previously, the CCAC considered the estimates of the GHG reductions that could be achieved and the costs or cost savings for the work plan recommendations that were quantifiable. Figure ExS-3 presents the annual GHG emission reductions in 2020 for each of the 43 work plan recommendations for which GHG emission reductions were quantified. Figure ExS-4 presents the estimated dollars-per-ton cost (or cost savings, shown as a negative number) for each of the 42 work plan recommendation for which emission reductions and costs or cost savings were quantified.[4] The dollars per ton value is calculated by dividing the net present value of the cost of the work plan recommendation by the cumulative GHG reductions, all for the period 2009–2020.

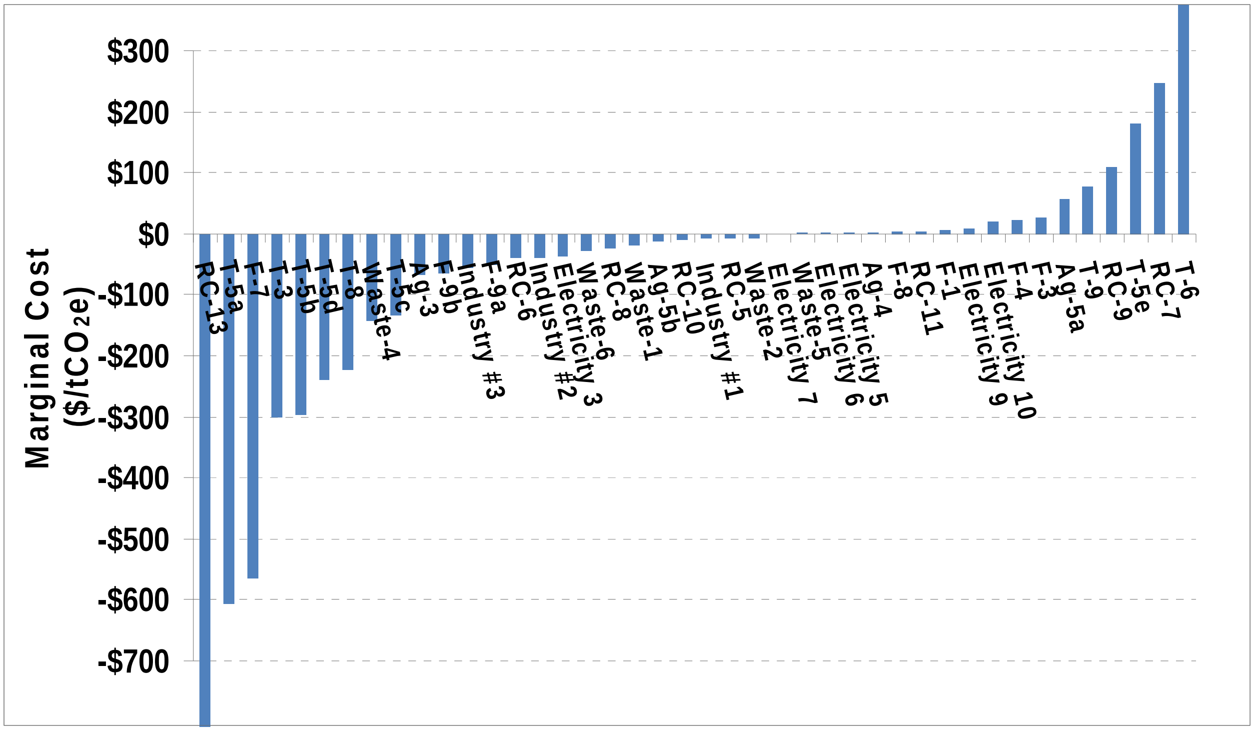
Figure ExS-3. Work Plan Recommendations Ranked by 2020 GHG Reduction Potential After Adjusting for Overlaps



GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; Ag = agriculture; RC – residential commercial; F = forestry; T= land use and transportation.

[4] Costs were not quantified for Forestry 6 (Durable Wood Products) due to the lack of data.

Figure ExS-4. Work Plan Recommendations Ranked by Cumulative (2009–2020) Net Cost/Cost Savings per Ton of GHG Removed



GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; Ag = agriculture; RC – residential commercial; F = forestry; T= land use and transportation.

Summary of Macroeconomic Modeling Results

Chapter 11 summarizes the macroeconomic analysis of the impacts of the recommended 52 work plans. Among these 52 work plans, 42 have been analyzed quantitatively in terms of GHG reduction potentials and associated costs or savings. Two work plans completely overlap with each other and those for which microeconomic data was not available were not included in the macroeconomic analysis.

Different from the microeconomic analyses of each work plan, the macroeconomic analysis considers the impact to Pennsylvania's economy associated with the interrelationship of these work plans being implemented. The results of this analysis reveal a net present value impact on total gross state product, for the period 2009-2020, of about $5.13 billion dollars and that by year 2020 these measures will stimulate the creation of 54,000 new full-time jobs. Two recent actions taken by the commonwealth, the passage of the Alternative Energy Portfolio Standard and electricity conservation measures approved with the passage of Act 129 of 2008 (Act 129) were also analyzed. These recent actions coupled with the work plan recommendations are expected to result in the net creation of 65,000 new full-time jobs and add more than $6 billion to the commonwealth's GSP by 2020.

Need and Plan to Address Adaptation

The department believes a climate change action plan must address both mitigation and adaptation. Act 70 identifies the need for mitigation and prescribes the manner by which mitigation options should be developed however, it is silent on the matter of climate change adaptation. The need to understand and plan for adaptation is equally as significant as our need to mitigate our contribution to the impacts.

Understanding climate change adaptation requires additional consideration because, as illustrated in the Pennsylvania Climate Change Impacts Assessment report, the issues are very far reaching and require comprehensive discussion. The department is very interested is coordinating these discussions, but believes that it is not within the scope or timeline of Act 70 to facilitate such discussion until after this first action plan has been prepared and delivered. The department believes that a much broader group of stakeholders must be consulted, specific to the topical areas of discussion.

The natural resource agencies of the commonwealth have already held informal discussions of adaptation, but this must be expanded and many other topical areas must be properly addressed, too. For instance, at a minimum, separate focus groups should be established for public health, transportation and energy planning. The CCAC also agrees that adaptation is critical and a missing element of the requirements of Act 70 having raised concerns at various times throughout the current planning process. During the February 27, 2009 meeting of the CCAC, a motion was made and passed with unanimous support that the action should plan include a recommendation to Governor Rendell and the Pennsylvania General Assembly to address adaptation.

The department anticipates that it will begin the process of framing up potential pathways to identify the necessary focus groups and potential respective stakeholders to engage in future discussions. The department will solicit the opinions of the CCAC and further consult with other commonwealth agencies to forge a path forward. The department expects that any recommendations will be reported to the CCAC for its consideration.

Chapter 1
Background and Overview

Report Overview

The DEP prepared this report to fulfill the requirements of the Pennsylvania Climate Change Act (Act 70, Senate Bill 266) adopted by the state legislature and signed into law by Governor Edward G. Rendell on July 9, 2008.

This chapter provides an overview of the CCAC the CCAC subcommittees, and the process they followed (including opportunities for public participation) to develop a set of sector-specific recommendations to the DEP for mitigating GHG emissions. It also provides a brief overview of Pennsylvania's GHG emissions inventory and forecast for 1990 through 2020, followed by a summary of recent state and federal actions that are currently being implemented to mitigate Pennsylvania's GHG emissions. This chapter also summarizes the CCAC's 52 recommendations (work plans) to the DEP for mitigating GHG emissions that will provide important information for supporting the selection of a statewide GHG emissions reduction target. The basis for setting a statewide GHG reduction target and pathways for implementing the work plan recommendations are discussed at the end of this chapter.

The remainder of this report includes 10 chapters and 12 appendices. Chapter 2 provides a summary of the impacts assessment report. Chapter 3 provides a more detailed presentation of Pennsylvania's GHG emissions inventory and forecast initially prepared by DEP and revised to incorporate comments from the CCAC and its subcommittees. Chapters 4 through 10 summarize the sector-specific work plan recommendations developed by the CCAC including the micro-economic impacts (emission reductions and costs) on an individual work plan and cumulative basis. Chapter 11 describes the methods, data sources, and results of the macro-economic modeling analysis of the work plans recommended by the CCAC.

Appendix A to this report contains Act 70, Appendix B provides the membership of the CCAC and its subcommittees, Appendix C contains the CCAC's voting record on the work plans it considered and recommended, and Appendix D provides a memorandum documenting the overall methods that were followed for the micro-economic impact analysis of the work plan recommendations. Appendices E through K provide the detailed documentation of the sector-specific work plans including the design of the recommendation, quantification methods, data sources, assumptions, results, and uncertainties. Appendix L contains minority reports prepared by CCAC members.

Act 70 Overview

The Pennsylvania Climate Change Act, Act 70 of 2008, was signed into law by Governor Edward G. Rendell on July 9, 2008. Act 70 requires the following actions, among others, of the Department of Environmental Protection:

- Develop a report on the climate change impacts and opportunities for Pennsylvania

- Develop a greenhouse gas (GHG) inventory and establish a baseline from which future emissions projections can made
- Create a GHG inventory for emissions and emissions reductions
- Develop a climate change action plan

Climate Change Advisory Committee

To assist the department in meeting these obligations, Act 70 required the establishment of a Climate Change Advisory Committee (CCAC). Act 70 stipulated that the CCAC be established within 30 days of the bill signing and that the first of its meetings be held within 60 days of passage. Membership of the CCAC was to be based upon a person's interest, knowledge or expertise on climate change issues. The composition of the advisory committee was to include representatives that could offer a diversity of viewpoints from the scientific, business and industry, transportation, environmental, social, outdoor and sporting, labor and other affected communities. The Act identified that 18 members would be appointed as follows and would further include three ex-officio (cabinet-level) members:

- 6 members appointed by the Governor
- 6 members appointed by the Senate
    - 4 members appointed by the majority party
    - 2 members appointed by the minority party
- 6 members appointed by the House of Representatives
    - 4 members appointed by the majority party
    - 2 members appointed by the minority party
- 3 ex-officio members include:
    - Secretary, Department of Conservation and Natural Resources
    - Secretary, Department of Community and Economic Development
    - Chair, Public Utility Commission

Appendix B of this report provides further details of the CCAC membership.

Climate Change Advisory Committee (CCAC) Process Overview

The CCAC began its deliberative process at its first meeting on September 5, 2008. CCAC met in person a total of 15 times, with the final decisional meeting held on July 17, 2009. An additional 40 teleconference meetings of CCAC's five subcommittees were also held to identify and analyze more than 100 potential mitigation actions.

The five subcommittees considered information and potential mitigation actions for the following sectors:

- Energy Generation, Transmission, and Distribution (EGTD);
- Residential and Commercial (RC);
- Industry and Waste (IW);
- Land Use and Transportation (LUT); and
- Agriculture and Forestry (AF).

The Center for Climate Strategies provided technical assistance for the micro- and macro-economic analysis of the work plan recommendations to the CCAC and each of the Subcommittees under contract to DEP. The subcommittees served as advisors to the CCAC and consisted of CCAC members and additional individuals with interest and expertise. Members of the public were invited to observe and provide input at all meetings of the CCAC and subcommittees. The subcommittees assisted the CCAC by generating initial options on Pennsylvania-specific mitigation actions to be considered for analysis including existing state and federal actions. Where members of a subcommittee did not fully agree on the recommendations to the CCAC, the summary of their efforts was reported to the CCAC as a part of its consideration and actions. The CCAC reviewed the subcommittee's proposals, modified the proposals, if necessary, and made final decisions on the items before them.

Subcommittees

Appendix B lists the members and chairs of the subcommittees. All subcommittees have a chair who serves in addition to membership on the full committee. On December 5, 2008, the committee voted to approve the chairs for the subcommittees. The department identified technical leads and administrative staff to serve as resources for the subcommittees.
A scoring template for rating work plans was discussed as a basis for evaluating and recommending specific work plans to the full committee. On January 22, 2009, the final scoring template for use by the subcommittees to score the work plans was approved by the committee.

Center for Climate Strategies was contracted to provide technical services for the development of work plans, including the microeconomic analysis and macroeconomic modeling. Technical staff assisted the subcommittees by participating in weekly meetings throughout April, May and June 2009. The open meetings were held in a conference room with conference call capability for subcommittee members, technical staff from Center for Climate Strategies and the public. Discussion covered all aspects of the work plans, including goals, implementation steps, data requirements, data review, implementation steps, and identifying overlaps. There was active participation by stakeholders and experts during public comment segment of the meetings. The work plans were then evaluated by members of the subcommittee and recommendations were made to the full committee. Most of the evaluations were based on the costs or cost savings and GHG reductions criteria, rather than use of a scoring template.

On June 29, 2009, the five subcommittee chairs provided the results of recommendations to the full committee. On July 17, 2009, the full committee voted to recommend 52 work plans to the department for consideration in the Climate Change Action Plan.

Public Participation & Notification Process

All CCAC meetings were open to the public and conducted in compliance with the Pennsylvania Sunshine Act. Notification of meetings is through publication in the *Pa. Bulletin* and via the committee's Web site. The meeting schedule, agenda, meeting materials, drafts of work plans and further detailed information is provided on the committee's Web site. A summary of actions taken at CCAC meetings is distributed through the DEP Daily Update. The public is encouraged to post comments or questions for the committee or the department by using an electronic mail portal available on the Web site. Comments received through this process will be complied and forwarded to the CCAC for its consideration. A public comment period is on the agenda for all meetings.

Voluntary Registry

Act 70 required that the voluntary greenhouse gas registry be created within 90 days of enactment. Establishing a meaningful and useful emissions registry is very time consuming as there are a great many issues that must be worked through. The department had already been engaged with other states in a shared interest to establish a single registry platform designed on a common set of protocols. This effort would provide the greatest level of assurance and recognition among the states that the reporting of emissions and emissions reductions was being performed in a complete, consistent and transparent fashion. This would also provide a level of certainty that industry and other reporters could rely upon for documenting their actions. This effort rapidly expanded well beyond the initial group of states and has resulted in the establishment of The Climate Registry, a voluntary emissions reporting registry that now boasts signatories and board members from 41 states (including Pennsylvania), 4 native sovereign nations, 12 Canadian provinces and 6 Mexican states. 340 reporting entities (businesses, governments, institutions) are currently members of The Climate Registry.

Because the Act also identified the need to recognize emissions reductions, the department briefed the CCAC on several registry and/or registry platforms focused on reporting of emissions reductions as well as issuing and tracking emissions offsets. Numerous variables were considered by the committee. At the October 1, 2008 meeting the CCAC voted unanimously to recommend not one, but three registry programs or platforms that it believed represented the best and most credible of those available with the hope that this recommendation would help guide Pennsylvanian's interested in registering project-based emissions reductions. The recommended registry platforms included the Climate Action Reserve, The Gold Standard and the Voluntary Carbon Standard. At this same meeting the CCAC endorsed The Climate Registry as the voluntary GHG emission registry. The department concurs with these recommendations of the CCAC. We believe it strengthens the credibility and marketability of emissions offsets as compared to any effort that would be restricted to only Pennsylvania emissions reductions and believe this fulfills the intent of Act 70.

Impacts Assessment

The department was required to prepare a climate change impacts assessment report within 9 months of enactment of Act 70 and to revise this report every three years. The following three major points of consideration were required to be included within the report. In all cases, the report was to identify the diversity of views and speak to any significant uncertainties.

- Provide scientific predictions regarding changes in temperature and precipitation patterns and amounts in Pennsylvania that could result from climate change.
- Discuss the "potential impact of climate change on human health, the economy and the management of economic risk, forests, wildlife, fisheries, recreation, agriculture and tourism" in Pennsylvania.
- Discuss economic opportunities for Pennsylvania created by the potential need for alternative sources of energy, climate-related technologies, services and strategies; carbon sequestration technologies; capture and utilization of fugitive greenhouse gas emissions from any source; and other mitigation strategies.

The department held numerous discussions with the CCAC, beginning at the September 5, 2008 meeting to discuss options to produce this report, the estimated time to prepare a report associated with each option and potential contract pathways. The department proposed to enlist the services of Pennsylvania's academic research community. The CCAC concurred with this idea. The department in turn, contacted the Pennsylvania Environmental Resource Consortium to inquire of the relative strengths among the researchers of the different academic institutions. It was determined that staff at the Pennsylvania State University, Carnegie Mellon University and Dickinson College possessed the experience and expertise to collaborate in developing an impacts assessment report. The larger challenge however, was to assemble a team of academicians that could work well together in a very compressed period of time to produce the report. On March 2, 2009 a cooperative agreement was entered into with a team of researchers within the Environment and Natural Resources Institute of the Pennsylvania State University. The final report was released on June 29, 2009.

Greenhouse Gas Inventory

The department is required to prepare an annual inventory of GHG emissions. The Act states that the inventory show the "relative contribution of major sectors, including, but not limited to, the transportation, electricity generation, industrial, commercial, mineral and natural resources, production of alternative fuel, agricultural and domestic sectors." The department has experience with GHG inventories having prepared such a report for years 1990 and 2000. The inventory serves as one of several tools to help inform the process to develop the action plan.

The inventory was prepared using standardized methodology prescribed by the United States Environmental Protection Agency and in accordance with international standards. A draft of the inventory was presented to the CCAC on February 27, 2009. Establishment of a baseline year with which to compare future emissions projections is also a requirement of Act 70. On March 27, 2009 the CCAC voted unanimously to recommend 2000 as the baseline year. Since the initial presentation in February the inventory has undergone minor revisions based upon the availability of a limited set of refined data. This data was from within the waste and transportation sectors and was unveiled during the subcommittee deliberation process as the committee undertook efforts to help develop the required action plan. The final inventory was presented to the committee during the September 16, 2009 meeting.

Action Plan

The action plan represents the culmination of the work efforts of the CCAC and the department through an informed process that also includes the above referenced products of Act 70. The plan was required to be delivered within 15 months of the date of enactment and will be updated every three years. Report requirements include:

- Identification of GHG emissions, an emissions baseline and trends
- Trends of GHG emissions sequestration
- Evaluation of cost-effective strategies that can help reduce GHG emissions
- Identification of costs, cost savings, benefits and co-benefits associated with emissions reductions strategies with emphasis on meeting future energy needs of Pennsylvania
- Recognition of agreement and disagreement among the CCAC members with regard to the specifics of the action plan

- Recommendations to the General Assembly for necessary actions to be taken for the implementation of the action plan

As was the case with the impacts assessment report, the department held numerous discussions with the CCAC to discuss options to produce this report, the estimated time to prepare a report associated with each option, potential contract pathways and minimum requirements to be established. An Invitation to Bid was issued on December 24, 2008 to solicit proposals for technical analyses in support of developing the action plan. The solicitation process closed on January 14, 2009. On February 25 the department signed off on a contract with The Center for Climate Strategies, who was the only qualified bidder.

The draft action plan was presented to the CCAC on September 4, 2009 for their review. Comments from the committee were accepted through September 16. The draft final report was delivered to the General Assembly and Governor on October 9, followed by the announcement of a 30 day public comment period beginning on October 10.

In addition to the major requirements previously discussed the department has other obligations under the Pennsylvania Climate Change Act. These and other details can be read in their entirety as a copy of Act 70 in included in Appendix A of this report.

Consumer Driven Opportunities

There are several pathways available for achieving greenhouse gas reductions and removing barriers for reductions. These can be grouped into either market-based incentives or regulatory-based incentives. Market-based incentives are non-regulatory. The regulatory incentive is a broad category that includes legislative process, agency rulemaking and administrative policies.

Public education is an important and low-cost pathway to increase energy efficiency. There are simple steps that people can learn to conserve energy, save money on energy bills and, at the same time, reduce greenhouse gas emissions. The work plans expand on these concepts. Some examples that can be used to inform the public of ways to reduce energy consumption are as follows:

- Adjust home thermostats to about 76 degrees in summer and 66 degrees in winter;
- Turn off appliances and electronic devices when not in use;
- Turn off lights when possible and increase use of day lighting;
- Add insulation in attic, basement, floors and walls;
- Replace single pane windows with energy efficient double pane windows;
- Recycle at home and away from home;
- Lower transportation costs by purchasing more fuel efficient vehicles; and
- Buy local products whenever possible.

It is also important to note that while the GHG reductions and cost savings associated with the work plans have been developed according to best estimates, there remains some uncertainty (e.g., due to timing, technology development, and/or more refined analysis) regarding the actual GHG reductions and costs or savings that will be revealed in their ultimate implementation. This uncertainty should be considered in the course of the state's prioritization and implementation decisions.

Discussion of Comment Integration

Public comment period will be 30 days in length from October 10, 2009 through November 9, 2009.

Pennsylvania GHG Emissions Inventory and Reference Case Projections

The DEP, in consultation with the CCAC, prepared Pennsylvania's GHG emissions inventory and reference case projections covering the period from 1990 to 2020. The inventory and reference case projections (forecast) provided the DEP with an initial, comprehensive understanding of current and possible future GHG emissions (hereafter referred to as the I&F). The I&F was provided to the CCAC and its subcommittees to assist them in understanding past, current, and possible future GHG emissions in Pennsylvania, and thereby inform the work plan development process. The CCAC and its subcommittees have reviewed, discussed, and evaluated the draft I&F resulting in revisions to the forecast for the electricity generation and transportation sectors and the I&F for landfills.[1]

The inventory and projections cover the six types of gases included in the U.S. Greenhouse Gas Inventory: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these GHGs are presented using a common metric, CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential- (GWP-) weighted basis.[2]

As illustrated in Figure 1-1, activities in Pennsylvania accounted for approximately 284 $MMtCO_2e$ of gross[3] GHG emissions (consumption basis) in 2000, an amount equal to about 4.0 percent of total U.S. gross GHG emissions (based on 2000 U.S. data). On a net emissions basis (i.e., including carbon sinks), Pennsylvania accounted for approximately 263 $MMtCO_2e$ of

[1] A copy of the GHG Inventory can be retrieved from the Pennsylvania Department of Environmental Quality, Office of Energy & Technology Deployment web site: http://www.depweb.state.pa.us/energy/cwp/view.asp?a=1532&q=539829.

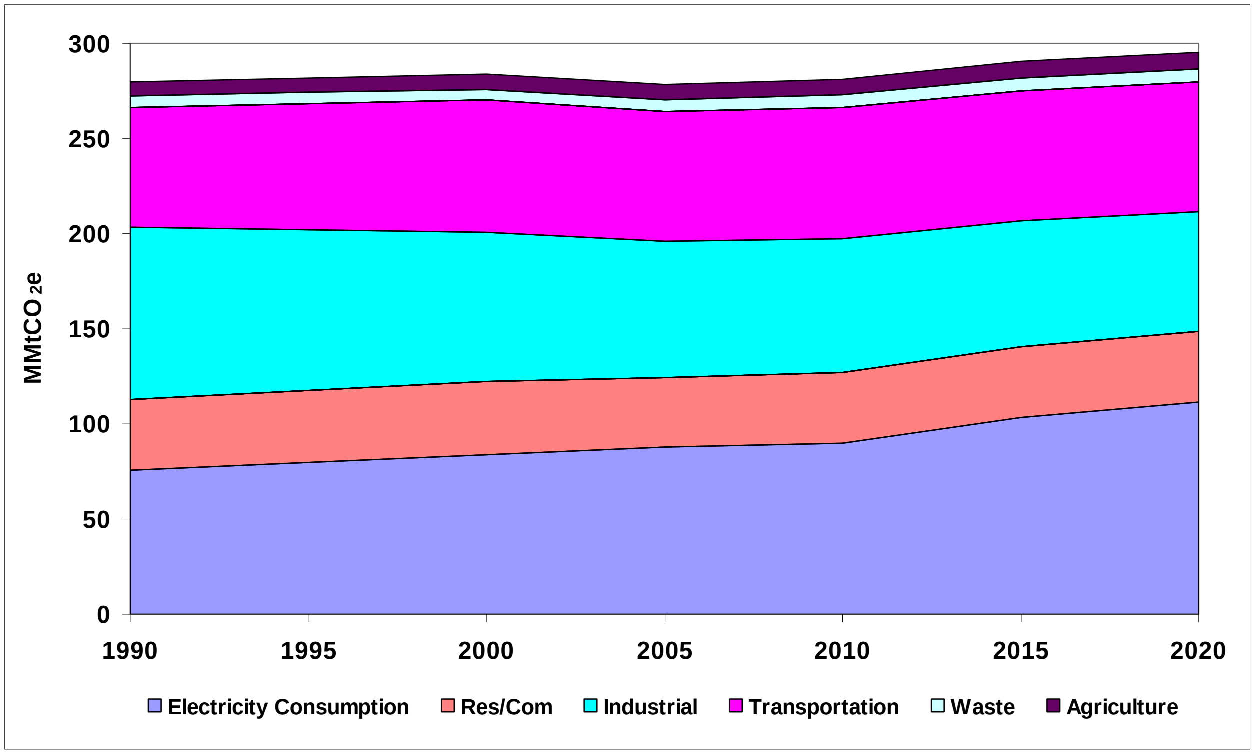
[2] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth-atmosphere system (IPCC, 2001). Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth), See: Boucher, O., et al. "Radiative Forcing of Climate Change." Chapter 6 in *Climate Change 2001: The Scientific Basis*. Contribution of Working Group 1 of the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge, United Kingdom. Available at: http://www.grida.no/climate/ipcc_tar/wg1/212.htm.

[3] Excluding GHG emissions removed due to forestry and other land uses and excluding GHG emissions associated with exported electricity.

emissions in 2000, an amount equal to 4.1 percent of total U.S. net GHG emissions.[4] Pennsylvania's GHG emissions remained flat in comparison with those of the nation as a whole. From 1990 to 2000, Pennsylvania's gross GHG emissions increased by only 2 percent, while national gross emissions rose by 14 percent.[5]

On a per-capita basis, Pennsylvania residents emitted about 23 metric tons (s/c) of gross CO_2e in 2000, less than the national average of about 25 tCO_2e. Both Pennsylvania and national per capita emissions remained relatively flat from 1990 to 2000. In both Pennsylvania and the nation as a whole, economic growth exceeded emissions growth throughout the 1990–2000 period. From 1990 to 2000, emissions per unit of gross product dropped by 19 percent nationally, and by 35 percent in Pennsylvania.[6]

Figure 1-1. Gross GHG Emissions by Sector, 1990–2025: Historical and Projected (Consumption-Based Approach) Business-as-Usual / Base Case



MMtCO_2e = million metric tons of carbon dioxide equivalent; Res/Com = residential and commercial.

[4] The national emissions used for these comparisons are based on 2005 emissions from *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006*, April 15, 2008, US EPA #430-R-08-005, (http://www.epa.gov/climatechange/emissions/usinventoryreport.html).

[5] During this period, population grew by 3.2 percent in Pennsylvania and by 13 percent nationally. However, Pennsylvania's economy grew by 57 percent versus 40 percent for the nation.

[6] Based on real gross domestic product (millions of chained 2000 dollars) that excludes the effects of inflation. U.S. Department of Commerce, Bureau of Economic Analysis. "Gross Domestic Product by State." Available at: http://www.bea.gov/regional/gsp/.

Also illustrated in Figure 1-1 under the reference case projections, Pennsylvania's gross GHG emissions are projected to increase to approximately 295 $MMtCO_2e$ by 2020, or about 4.0 percent above 2000 levels. This equates to a 1.0 percent average annual rate of growth in emissions from 2000 to 2020. Relative to 2000, the share of emissions associated with electricity consumption increases to 38 percent by 2020. The share of emissions from the industrial sector drops to 21 percent by 2020. The shares of emissions from the residential and commercial fuel use sectors and the transportation sector both decrease slightly (i.e., 1.0 percent each) from their relative share of emissions in 2000. The share of emissions from the waste management and agriculture sectors remain the same in 2020 as their shares in 2000.

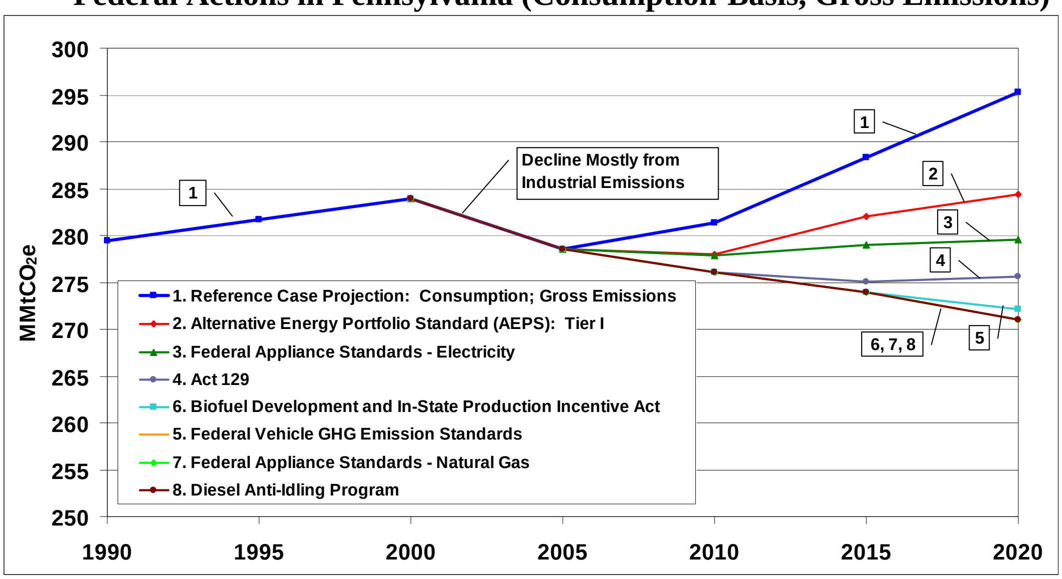
Emissions associated with electricity consumption are projected to be the largest contributor to future GHG emissions growth by far; emissions from waste management and agriculture are modest contributors to future emissions growth as shown in Figure 1-1, while emissions from all other sectors decrease from 2000 to 2020.

Recent State and Federal Actions

GHG Reductions Associated With Recent Federal and State Actions

Recent state and federal actions include state and federal programs or policies that are not included in the GHG emissions forecast. The DEP and CCAC recognized the importance of these recent actions as essential for formulating the baseline from which it considered and developed its wide range of recommendations. The DEP and CCAC identified and analyzed a total of seven recent actions that were quantified for their emission reductions and costs. These GHG emission reductions are summarized in Figure 1-3. Table 1-1 provides the numeric estimates underlying Figure 1-3. Together the seven actions are projected to reduce GHG emissions in Pennsylvania by approximately 24.6 $MMtCO_2e$ in 2020, representing an 8.7 percent reduction in GHG emissions below 2000 levels.

Figure 1-2. Estimated Emission Reductions Associated with the Effect of Recent State and Federal Actions in Pennsylvania (Consumption-Basis, Gross Emissions)



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table 1-1. Estimated Annual GHG Emission Reductions ($MMtCO_2e$) Associated with the Effect of Recent State and Federal Actions in Pennsylvania (Consumption-Basis, Gross Emissions)

	Emissions Reductions ($MMtCO_2e$)				
Recent Actions*	**2000**	**2005**	**2010**	**2015**	**2020**
State Alternative Energy Portfolio Standard (AEPS): Tier I			3.40	6.29	11.00
Federal Appliance Standards - Electricity			0.14	3.05	4.77
State Act 129			1.74	3.99	3.99
Federal Vehicle GHG Emission Standards			0.00	0.02	1.05
State Biofuel Development and In-State Production Incentive Act			0.02	1.07	3.47
Federal Appliance Standards - Natural Gas			0.00	0.07	0.30
State Diesel Anti-Idling Program			0.06	0.06	0.06
Total GHG Reductions from Recent Actions			**5.36**	**14.55**	**24.64**
	Emissions ($MMtCO_2e$)				
	2000	**2005**	**2010**	**2015**	**2020**
Reference Case Projection: Consumption; Gross Emissions	**283.9**	**278.6**	**281.4**	**288.4**	**295.3**
Reference Case Projection after Subtracting Reductions from Recent Actions	**283.9**	**278.6**	**276.0**	**273.8**	**270.7**

Recent actions are listed in descending ordered by their emission reductions (i.e., highest to lowest).

For the electricity sector, Pennsylvania recently adopted an Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard (AEPS) and Act 129 of 2008 (House Bill 2200). The AEPS, signed into law on November 24, 2004, requires that all electricity sold in Pennsylvania at retail by regulated electric utilities include prescribed levels of renewable and sustainable energy. Act 129, signed into law on October 15, 2008, requires that each major electric distribution company in Pennsylvania achieve specific levels of energy savings and demand reduction. For the transportation sector, Pennsylvania has adopted the Biofuel Development and In-State Production Incentive Act (Act 78 of 2008, previously referred to as the PennSecurity Fuels Initiative), the Diesel-Powered Motor Vehicle Idling Act (Act 124 of 2008), and the Pennsylvania Clean Vehicles (PCV) Program (implemented in 2009).

Recent federal actions include federal energy efficiency requirements for new appliances and, for new light-duty vehicles, approval of California's waiver to establish more stringent tail-pipe standards and align federal requirements with the California standards. Emission reductions associated with the corporate average fuel economy requirements included in the federal Energy Independence and Security Act of 2007 are incorporated in the emissions forecast for Pennsylvania; therefore, they are not reported as a recent action.

CCAC Work Plan Recommendations (Beyond Recent Actions)

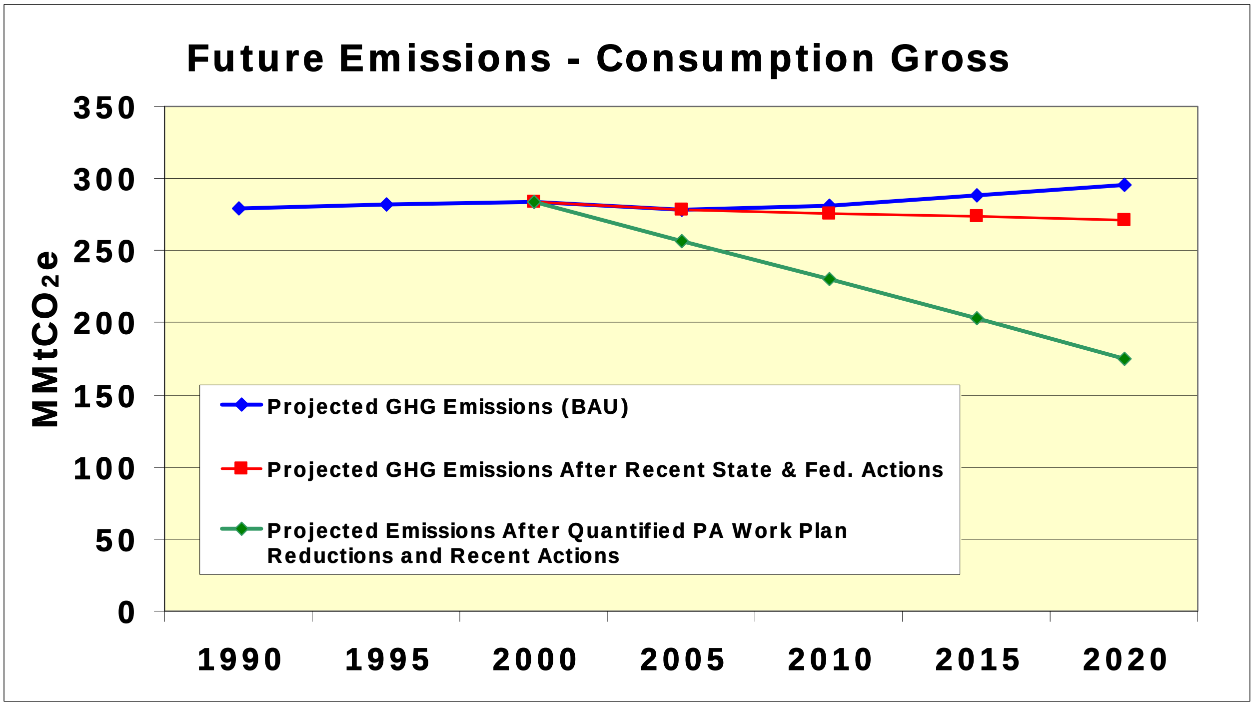
The CCAC and DEP reviewed over 100 multi-sector GHG mitigation actions and approved for inclusion in the Climate Action Plan a package of 52 work plan recommendations to reduce GHG emissions and address related energy and commerce issues in Pennsylvania. Of these 52 recommendations, the CCAC approved 32 unanimously, nine with only one objection or abstention, and seven with five or fewer objections or abstentions. Of these, 45 were analyzed quantitatively to calculate both emission reductions and either costs or savings. Based on this analysis, the 45 quantified work plans have the effect of reducing annual GHG emissions by approximately 95.6 $MMtCO_2e$ in 2020, and the cumulative effect of reducing emissions by 583 $MMtCO_2e$ from 2009 through 2020. The additional work plan recommendations were not readily quantifiable but are considered valuable recommendations to support the overall Climate Action Plan. Several of the non-quantified recommendations may have the potential to achieve GHG emission reductions.

The CCAC approved work plan recommendations are estimated to generate a net cumulative savings of about $11.7 billion between 2009 and 2020. The weighted-average cost-effectiveness of these recommendations is estimated to be a savings of about $20 per metric ton of carbon dioxide equivalent (tCO_2e) emissions reduced. The approved work plan recommendations (if all are implemented) are estimated to reduce gross GHG emissions (consumption basis) by approximately 95.6 $MMtCO_2e$ emissions in 2020, representing a 36 percent reduction in GHG emissions below 2000 levels. The combination of emission reductions associated with the work plan recommendations and recent state and federal actions suggest that Pennsylvania has the potential to reduce its annual GHG emissions in 2020 by about 42 percent below 2000 levels. Note that these estimates of the cumulative impacts of the work plans include adjustments to remove potential double counting of emission reductions and costs associated with work plans that overlap. Documentation of the adjustments for overlaps is provided in the sector-specific appendices containing the work plan recommendations.

Figure 1-3 presents a graphical summary of the potential cumulative emission reductions associated with the 45 quantified work plans and federal actions relative to the business-as-usual reference case projections.

- The blue line shows actual (for 1990, 1995, 2000, and 2005) and projected (for 2010, 2015, and 2020) levels of Pennsylvania's gross GHG emissions on a business-as-usual basis.
- The red line shows the projected emissions adjusted for the recent state and federal actions described in Figure 1-2.
- The green line shows the projected emissions if all of the work plans recommended by the CCAC are implemented and the estimated reductions are fully achieved. It is important to note, to yield these emission reductions from the 45 work plan recommendations; implementation must be timely, aggressive, and thorough.

Figure 1-3. Annual GHG Emissions: Reference Case Projections and Work Plan Recommendations (Consumption Basis, Gross Emissions)



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; GHG = greenhouse gas; BAU = business-as-usual.

Table 1-2 provides the numeric estimates underlying Figure 1-3. Table 1-3 depicts the work plan recommendations of the CCAC and their associated GHG reductions and costs or savings for each sector. What do the numbers mean? In Table 1-3 and throughout this report, positive cost figures ($) indicate costs; negative cost (- $) figures indicate cost savings.

The results shown in Table 1-3 indicate that the work plan recommendations support significant opportunities for Pennsylvania to reduce GHG emissions at a cost savings economy-wide. Although the cumulative results for the Land Use & Transportation sector indicate a significant cost, savings are expected to be realized on an annual basis by 2020.

Table 1-2. Annual Emissions: Reference Case Projections and Impact of Work Plan Recommendations (Consumption Basis, Gross Emissions)

Consumption Basis - Gross Emissions	1990	2000	2005	2010	2015	2020
Projected GHG Emissions (BAU)	279.5	283.9	278.6	281.4	288.4	295.3
Reductions from Recent State and Federal Actions			0.0	5.4	14.6	24.6
Projected GHG Emissions After Recent State and Federal Actions			278.6	276.0	273.8	270.7
Total GHG Reductions from PA Work Plans						95.6
Percent Below 2000 Levels from PA Work Plans						34 percent
Projected Emissions After Quantified PA Work Plan Reductions and Recent Actions						175.1
Percent Below 2000 Levels from PA Work Plans and Recent State and Federal Actions						42 percent

GHG = greenhouse gas; BAU = business-as-usual.

Table 1-3. Summary by Sector of Estimated Impacts Associated with Implementing All of the CCAC Work Plan Recommendations (cumulative reductions and costs/savings)

	Annual Results (2020)			Cumulative Results (2009-2020)		
Sector	GHG Reductions (MMtCO2e)	Costs (Million $)	Cost-Effectiveness ($/tCO2e)	GHG Reductions (MMtCO2e)	Costs (NPV, Million $)	Cost-Effectiveness ($/tCO2e)
Residential Commercial	32	-$538	-$17	215	-$3,668	-$17
Electricity Generation, Transmission, and Distribution	32	$1,006	$31	131	$1,060	$8
Industry	5.8	-$365	-$62	33	-$1,072	-$33
Waste	5.9	-$49	-$8	37	-$298	-$8
Land Use & Transportation	7	-$494	-$75	60	$2,805	$47
Agriculture	1.4	-$62	-$44	10	-$380	-$37
Forestry	11.3	-$1,376	-$121	98	-$10,177	-$104
Total (includes all adjustments for overlaps)	**96**	**-$1,879**	**-$296**	**583**	**-$11,729**	**-$20**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.
Negative values in the Net Present Value and the Cost-Effectiveness columns represent net cost savings associated with the work plans.

Within each sector, values have been adjusted to eliminate double counting for work plan recommendations or elements of work plan recommendations that overlap. In addition, values associated with work plan recommendations or elements of work plan recommendations within a sector that overlap with recommendations or elements of recommendations in another sector have been adjusted to eliminate double counting.

Table 1-4 provides a tabular summary of GHG reductions and costs/savings for each sector. Note: The numbering used to denote the work plan recommendation in Table 1-4 and in other parts of this report is for reference purposes only; it does not reflect prioritization among these important recommendations. Negative values in the cost and the cost-effectiveness columns represent net cost savings.

Table 1-4. Summary List of CCAC Work Plan Recommendations for all Sectors Energy Generation, Transmission, and Distribution (EGTD) Work Plan Recommendations

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained) [1]
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/tCO_2e$)	
2	Reduced Load Growth	7	-$432	-$64	23	-$849	-$36	13 / 8 / 0
3	Stabilized Load Growth	9	-$593	-$64	27	-$990	-$36	13 / 8 / 0
5	Carbon Capture and Sequestration in 2014	5	$291	$58	13	$391	$31	20 / 1 / 0
6	Improve Coal-Fired Power Plant Efficiency by 5 %	5	$82	$1	55	$903	$1	13 / 8 / 0
7	Sulfur Hexafluoride (SF_6) Emission Reductions from the Electric Power Industry	0.1	$0.1	$0.6	0.7	$0.3	$0.4	20 / 1 / 0
8	Analysis to Evaluate Potential Impacts Associated with Joining RGGI	See Appendix D						NA
9	Promote Combined Heat and Power (CHP)	4	$53	$12	23	$209	$9	21 / 0 / 0
10	Nuclear Capacity	15	$832	$57	31	$655	$21	20 / 1 / 0
11	Greenhouse Gas Performance Standard for New Power Plants	Qualitative Work Plan--Not Quantified						21 / 0 / 0
12	Transmission and Distribution Losses	Qualitative Work Plan--Not Quantified						21 / 0 / 0
Sector Total After Adjusting for Overlaps		**32**	$**1,006**	$**31**	**131**	$**1,060**	$**8**	
Recent State Actions[2]		**15**	**-$1,001 to $285**	**-$91 to 26**	**116**	**-$2,790 to $1,560**	**-$37 to $21**	
1	Act 129 of 2008 (HB 2200) (Already in Electricity Baseline Forecast)	4	-$258	-$65	40	-$1,409	-$35	NA
4a	Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard (No Price Suppression)	11	$285	$26	76	$1,560	$21	NA
4b	Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard (Moderate Price Suppression)	11	-$358	-$33	76	-$615	-$8	NA
4c	Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard (Full Price Suppression)	11	-$1,001	-$91	76	-$2,790	-$37	NA
Sector Total Plus Recent Actions		47	See Ranges above	See Ranges above	247	See Ranges above	See Ranges above	

[1] NA in this column means "not applicable." Electricity 1 and 4 are recent Commonwealth of Pennsylvania actions. For Electricity 8, the CCAC analyzed the potential impacts associated with joining the RGGI initiative only and, therefore, was not considered as a work plan recommendation.

[2] Totals are shown as a range reflecting the estimated GHG emission reductions and cost savings associated with Act 129 and the GHG emission reductions and range of costs / savings associated with the three Alternative Energy Portfolio Standard scenarios (i.e., without price suppression effects and with a moderate and high price suppression effects scenario).

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; RGGI = Regional Greenhouse Gas Initiative.

Residential and Commercial Work Plan Recommendations

Work Plan No.	Work Plan Name	Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $)	Annual Results (2020) Cost-Effectiveness ($/$tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $)	Cumulative Results (2009-2020) Cost-Effectiveness ($/$tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)
1-4	High-Performance Buildings (Total for RC-1 Through RC-4)	31.9	-$256.3	-$8.0	139.7	-$1,653	-$11.8	21 / 0 / 0
1	High-Performance State and Local Government Buildings	2.7			11.3			
2	High-Performance School Buildings	1.9			7.8			
3	High-Performance Commercial (Private) Buildings	9.0			37.4			
4	High-Performance Homes (Residential)	18.3			83.1			
5	Commissioning and Retrocommissioning PA Buildings	1.5	-$17	-$11.2	9.6	-$71	-$7.4	21 / 0 / 0
6	Re-Light Pennsylvania	12.9	-$823	-$64	103.2	-$4,020	-$39	20 / 0 / 1
	Residential	3.5	-$328	-$95	30.0	-$1,887	-$63	
	Commercial—lighting power density	5.3	-$367	-$69	30.7	-$806	-$26	
	Commercial—fixture performance	4.0	-$136	-$34	33.9	-$1,039	-$31	
	Commercial—daylighting	0.8	-$64	-$82	5.0	-$204	-$41	
	Commercial—controls	2.1	$108	$52	14.3	$511	$36	
	Commercial—parking lot lighting	1.1	-$117	-$103	10.5	-$613	-$58	
	Commercial—exit signs	0.0	-$1	-$64	0.1	-$6	-$44	
7	Re-Roof Pennsylvania	1.4	$472	$327	4.3	$1,064	$247	14 / 7 / 0
	Light-colored, insulated roofs	0.2	-$4	-$18	0.8	$13	$17	
	Green roofs	0.1	$77	$614	0.3	$147	$462	
	PV roof	1.1	$399	$359	3.2	$903	$282	
8	PA buys EE appliances	1.9	-$68	-$36	12.4	-$291	-$24	13 / 8 / 0
9	Geothermal Heating and Cooling	1.4	$224	$158	8.0	$879	$109	21 / 0 / 0
10	DSM - Natural Gas	7.3	-$51	-$7	40.5	-$357	-$9	21 / 0 / 0
11	Conservation and Fuel switching for Heating Oil	5.7	-$21	-$4	35.8	$140	$4	21 / 0 / 0
13	DSM - Water	0.1	-$255	-$1,944	0.8	-$1,011	-$1,285	21 / 0 / 0
14	Renew PA buildings PA Values Embodied Energy in Building Materials, Including Historic Structures	Not quantified						17 / 1 / 2
15	Sustainability Education Programs	Not quantified						17 / 1 / 2
16	Adaptive Building Reuse	Not quantified						17 / 1 / 2
Sector Total After Adjusting for Overlaps		32.25	-$538	-$17	214.5	-$3,668	-$17	
Reductions From Recent Federal		5.07	-$145	-$28	29.9	-$567	-$19.0	
Federal Appliance Standards - Electricity		4.77			28.7			
Federal Appliance Standards - Natural Gas		0.3			1.2			
Sector Total Plus Recent Actions		37.4	-$683	-$18	244.4	-$4,235	-$17	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Land Use and Transportation (LUT) Work Plan Recommendations

Work Plan No.	Work Plan Name		Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $)	Annual Results (2020) Cost-Effectiveness ($\$/tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $)	Cumulative Results (2009-2020) Cost-Effectiveness ($\$/tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)[1]
3	Low-Rolling-Resistance Tires		0.68	-$212	-$310	4.1	-$1,244	-$300	16 / 5 / 0
5	Eco-Driving	PAYD	0.43	-$277	-$651	1.76	-$1,065	-$605	13 / 8 / 0
		Feebates	0.41	-$133	-$320	2.74	-$810	-$296	13 / 8 / 0
		Driver Training	0.62	-$129	-$206	4.53	-$605	-$134	13 / 8 / 0
		Tire Inflation	0.09	-$27	-$282	0.58	-$137	-$238	13 / 8 / 0
		Speed Reduction	1.96	$185	$94	23.0	$4,153	$181	13 / 8 / 0
6	Utilizing Existing Public Transportation Systems		0.05	$300	$6,000	0.55	$3,000	$5,454	13 / 8 / 0
7	Increasing Participation in Efficient Passenger Transit		0.12	<$0	<$0	2.02	<$0	<$0	21 / 0 / 0
8	Cutting Emissions From Freight Transportation		0.99	-$293	-$295	6.67	-$1,495	-$224	15 / 6 / 0
9	Increasing Federal Support for Efficient Transit and Freight Transport in PA		1.17	$92	$78	12.87	$1,008[2]	$78	20 / 1 / 0
10	Enhanced Support for Existing Smart Growth/Transportation and Land-Use Policies		0.76-1.84	<$0	<$0	3.79-9.18	<$0	<$0	13 / 8 / 0
11	Transit-Oriented Design, Smart Growth Communities, & Land-Use Solutions		Included in T-10	<$0	<$0	Included in T-10	<$0	<$0	13 / 8 / 0
Sector Total After Adjusting for Overlaps			6.6	-$494	-$75	60.1	$2,805	$47	
Reductions From Recent State and Federal Actions			15.7	-$109[3]	-$31[3]	72.0	-$380[3]	-$25[3]	
1	Pennsylvania Clean Vehicles (PCV) Program		0.095	0.0	0.0	1.27	0.0	0.0	NA
	Federal Vehicle GHG Emissions and CAFE Standards		12.2	NQ	NQ	57.3	NQ	NQ	NA
2	Biofuel Development and In-State Production Incentive Act		3.47	-$89	-$26	14.8	-$203	-$14	NA
4	Diesel Anti-Idling Program		0.07	-$20	-$273	0.7	-$177	-$238	NA
Sector Total Plus Recent Actions			22.3	-$603	-$27	132	$2,425	$18	

[1] NA in this column means "not applicable." Work plan numbers 1, 2, and 4 are recent state actions that are being implemented by the state; and the federal government will be implementing national vehicle GHG emissions and corporate average fuel economy (CAFÉ) standards starting in 2012.
[2] Because T-9 uses federal dollars exclusively, it should be noted that the cost figures for T-9 are calculations of how many federal dollars—not state dollars—would be required to implement the work plan.
[3] This cost per ton value excludes the emission reductions associated with the "Federal Vehicle GHG Emissions and CAFE Standards" since costs (savings) were not quantified for this recent federal action.
GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; NQ = not quantified; PA = Pennsylvania; PAYD = Pay-As-You-Drive; CAFE = Corporate Average Fuel Economy.

Industry Sector Work Plan Recommendations

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)	
1	Coal Mine Methane (CMM) Recovery	0.57	-$5.9	-$10.3	6.38	-$51.8	-$8.03	21 / 0 / 0
2	Industrial Natural Gas and Electricity Best Management Practices	5	-$348	-$68	25	-$972	-$38	18 / 3 / 0
3	Reduce Lost and Unaccounted for Natural Gas	0.1	-$11	-$84	1	-$48	-$55	21 / 0 / 0
Sector Total After Adjusting for Overlaps		**6**	**-$365**	**-$62**	**33**	**-$1,072**	**-$33**	
Reductions From Recent State and Federal Actions		0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Sector Total Plus Recent Actions		**6**	**-$365**	**-$62**	**33**	**-$1,072**	**-$33**	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Waste Sector Work Plan Recommendations

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)	
1	Landfill Methane Displacement of Fossil Fuels	0.1	-$0.1	-$0.8	0.56	-$11	-$19	21 / 0 / 0
2	Statewide Recycling Initiative	5.44	-$41	-$8	34.4	-$246	-$7	21 / 0 / 0
4	Improved Efficiency at Wastewater Treatment Facilities	3.8×10^{-3}	-$0.5	-$126	0.023	-$3.2	-$143	21 / 0 / 0
5	Waste-to-Energy Digesters	0.1	$0.1	$1.0	0.60	$0.7	$1.2	21 / 0 / 0
6	Waste-to-Energy MSW	0.24	-$8.1	-$34	1.42	-$40	-$28	19 / 1 / 1
Sector Total After Adjusting for Overlaps		5.9	-$50	-$8	37	-$299	-$8	
Reductions From Recent State and Federal Actions		0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Reductions From Recent State and Federal Actions		5.9	-$50	-$8	37	-$299	-$8	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; NQ = not quantified; MSW = municipal solid waste.

Agriculture Sector Work Plan Recommendations

Work Plan No.	Work Plan Name		Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
			GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/t$CO_2$e)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2$e)	
1	Foodshed Development Strategy		Not Quantified[1]						21 / 0 / 0
2	Next-Generation Biofuels		Costs and GHG savings from biofuels are considered in Transportation-2 and Residential-11 Work Plans						21 / 0 / 0
3	Management-Intensive Grazing		0.62	-$59	-$95	5.50	-$369	-$67	21 / 0 / 0
4	Manure Digester Implementation Support	Dairy	0.26	-$0.3	-$1	1.46	$2	$2	21 / 0 / 0
		Swine	0.04	$0.1	$4	0.23	$1	$5	21 / 0 / 0
5	Regenerative Farming Practices		0.059	$2.1	$36	0.30	$17	$56	21 / 0 / 0
	Soil Sequestration from Continuous No-Till Agronomic Systems		0.44	-$5	-$11	2.7	-$31	-$12	21 / 0 / 0
Sector Total After Adjusting for Overlaps			1.42	-$62	-$44	10.2	-$380	-$37	
Reductions From Recent State and Federal Actions			0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Sector Total Plus Recent Actions			1.42	-$62	-$44	10.2	-$380	-$37	

[1] The CCAC recommends that this be a research and analysis work plan.

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/t$CO_2$e = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Forestry Work Plan Recommendations

Work Plan No.	Work Plan Name		Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $2007)	Annual Results (2020) Cost-Effectiveness ($/$tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $2007)	Cumulative Results (2009-2020) Cost-Effectiveness ($/$tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)
Forest Growth and Protection/Avoided Conversion									
1*	Forest Protection Initiative -- Easement		0.178	$0	$0	12.22	$67.5	$5.53	21 / 0 / 0
3*	Forestland Protection and Avoided Conversion -- Acquisition								21 / 0 / 0
Option	Total acreage protected	Develop-ment threat							
A	80,000	100 %	0.178	$0	$0	14.60	$236.4	$16.19	
A	80,000	50 %	0.178	$0	$0	8.23	$236.4	$28.71	
A	80,000	20 %	0.178	$0	$0	4.41	$236.4	$53.58	
A	80,000	10 %	0.178	$0	$0	3.14	$236.4	$75.33	
A	240,000	100 %	3.72	$37.1	$9.99	41.68	$590.9	$14.18	
A*	240,000	50 %	2.13	$37.1	$17.47	22.57	$590.9	$26.18	
A	240,000	20 %	1.17	$37.1	$31.74	11.11	$590.9	$53.20	
A	240,000	10 %	0.85	$37.1	$43.62	7.28	$590.9	$81.12	
A	400,000	100 %	7.26	$72.2	$10.23	68.76	$945.3	$13.75	
A	400,000	50 %	4.07	$72.2	$18.23	36.91	$945.3	$25.61	
A	400,000	20 %	2.16	$72.2	$34.35	17.80	$945.3	$53.11	
A	400,000	10 %	1.52	$72.2	$48.70	11.43	$945.3	$82.71	
B	64,745	100 %	1.7	$18.50	$10.69	10.98	$226.6	$13.22	
B	129,556	100 %	3.5	$36.99	$10.69	21.97	$453.4	$13.22	
B	259,046	100 %	6.9	$73.99	$10.69	43.94	$906.7	$13.22	
B	129,556	20 %	0.9	$36.99	$40.11	5.47	$453.4	$53.14	
B	129,556	10 %	0.6	$36.99	$61.16	3.40	$453.4	$85.35	
Increased Utilization of Durable Wood Products									
2	Woodnet		*Qualitative work plan*						14 / 6 / 1
6*	Durable Wood Products								21 / 0 / 0
	1.12 Bbf/year (2006 PA harvest)*		0.73	NQ	NQ	8.77	NQ	NQ	
	1.5 Bbf/year		0.98	NQ	NQ	11.74	NQ	NQ	
	80 Mbf/year (2006 State Forest harvest)		0.04	NQ	NQ	0.46	NQ	NQ	

Work Plan No.	Work Plan Name	Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $2007)	Annual Results (2020) Cost-Effectiveness ($/t$CO_2$e)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $2007)	Cumulative Results (2009-2020) Cost-Effectiveness ($/t$CO_2$e)	CCAC Voting Results (Yes / No / Abstained)
Reforestation, Afforestation, Regeneration								
4	Reforestation, Afforestation, Regeneration	3.98	$41.9	$10.52	25.89	$568.7	$21.97	21 / 0 / 0
5	Improved Forest Management							21 / 0 / 0
Scenario	Shift to uneven-aged management							
2	Shift 20 percent of even-aged management to uneven-aged	0.26	NQ	NQ	0.82	NQ	NQ	
3	Shift 50 percent of even-aged management to uneven-aged	0.65	NQ	NQ	2.04	NQ	NQ	
4	Shift 75 percent of even-aged management to uneven-aged	0.97	NQ	NQ	3.07	NQ	NQ	
Scenario	Restock understocked forestland**							
1	Restock 100 percent of poorly stocked forest	(5.1)	$66.8	$13.08	(75.1)	$1,063	$14.15	
2	Restock 100 percent of poorly stocked forest and 50 percent of moderately stocked forest	(26.3)	$264.4	$10.04	359.1)	$4,209	$11.72	
3	Restock 100 percent of poorly stocked forest and 100 percent of moderately stocked forest	(47.6)	$462.1	$9.71	(643.1)	$7,355	$11.44	
Urban Forestry								
7*	Urban Forestry							21 / 0 / 0
	Increment existing urban forest by 10 percent	1.20	-$560	-$468.15	7.78	-$4,399	-$565.74	
	Increment existing urban forest by 25 percent*	2.99	-$1,400	-$468.15	19.44	-$10,997	-$565.74	
	Increment existing urban forest by 50 percent	5.98	-$2,800	-$468.15	38.88	-$21,994	-$565.74	
Wood-based Energy								
8*	Wood to Electricity	0.26	$0.18	$0.67	1.71	$2.8	$3.14	21 / 0 / 0
9*	Biomass Thermal Energy Initiatives							21 / 0 / 0
	Combined heat and power*	0.47	-$21.1	-$45.30	3.03	-$151.5	-$50.03	
	Fuels for Schools*	0.61	-$33.9	-$55.23	3.99	-$258.8	-$64.78	
Sector Total After Adjusting for Overlaps*		11.3	-$1,376	-$121	98	-$10,177	-$104	
Reductions From Recent State and Federal Actions		0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Sector Total Plus Recent Actions		11.3	-$1,376	-$121	98	-$10,177	-$104	

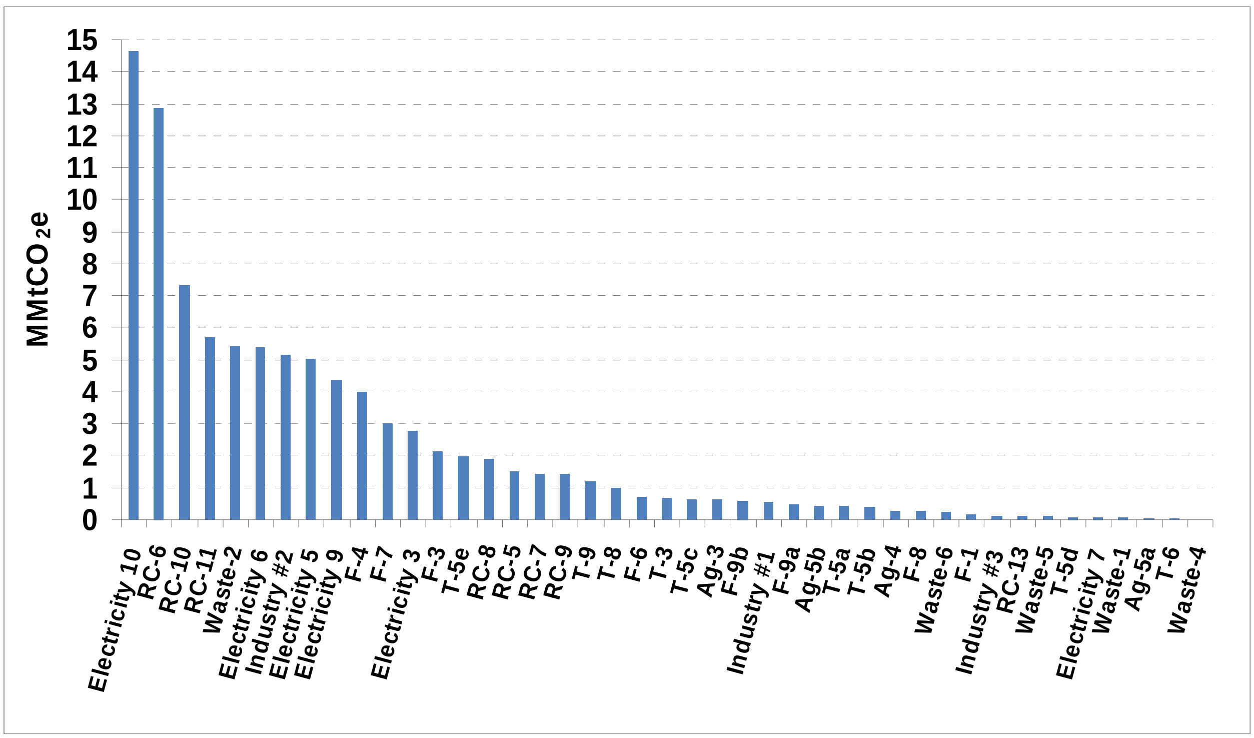
GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/t$CO_2$e = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; Mbf = thousand board feet; Bbf = billion board feet; NQ = Not Quantified.

* An asterisk identifies the work plan number and name included in the “Sector Total after Adjusting for Overlaps.”

** For the F-5 scenario (i.e., restocking of undestocked forestlands), the analysis estimates an emissions increase relative to baseline conditions associated with site preparation and planting, and these increases are recorded in parenthesis.

As explained previously, the CCAC considered the estimates of the GHG reductions that could be achieved and the costs or cost savings for the work plan recommendations that were quantifiable. Figure 1-5 presents the annual GHG emission reductions in 2020 for each of the 43 work plan recommendations for which GHG emission reductions were quantified. Figure 1-6 presents the estimated dollars-per-ton cost (or cost savings, shown as a negative number) for each of the 42 work plan recommendation for which emission reductions and costs or cost savings were quantified.[7] The dollars per ton value is calculated by dividing the net present value of the cost of the work plan recommendation by the cumulative GHG reductions, all for the period 2009–2020.

Figure 1-4. Work Plan Recommendations Ranked by 2020 GHG Reduction Potential After Adjusting for Overlaps



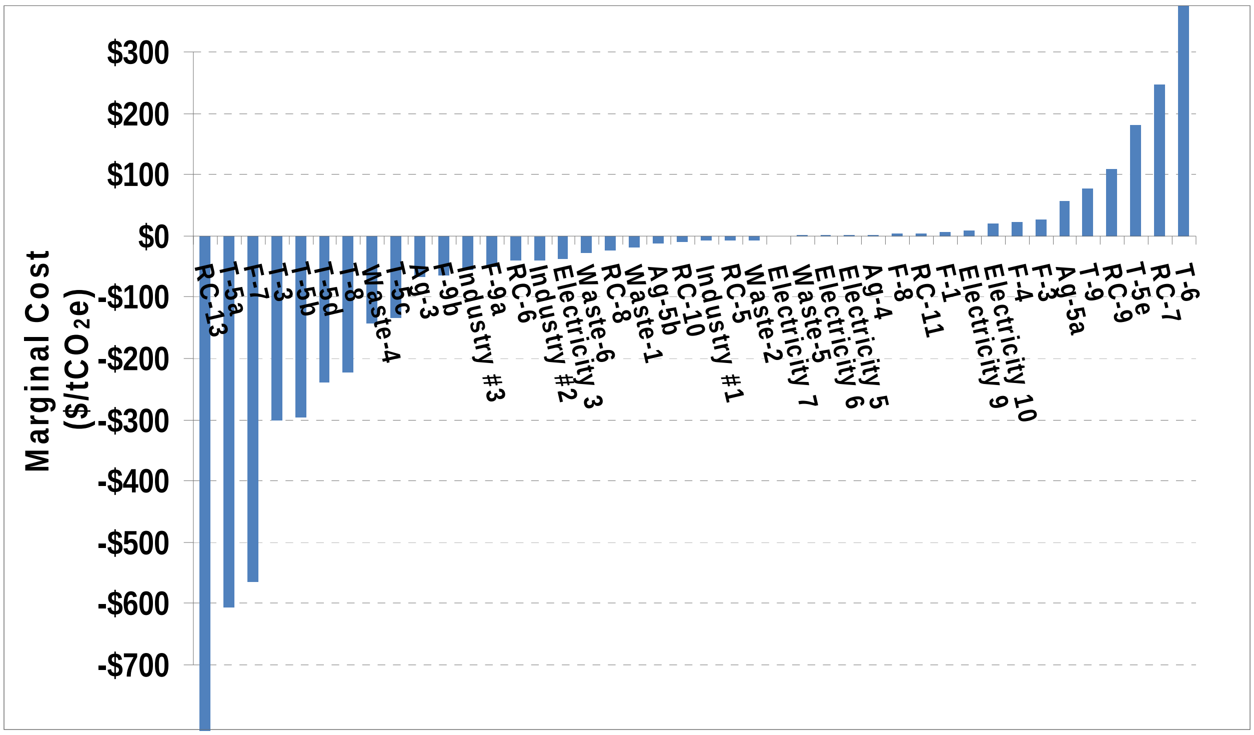
GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; Ag = agriculture; RC – residential commercial; F = forestry; T= land use and transportation.

Figure 1-6 presents a stepwise marginal cost curve for Pennsylvania. The horizontal axis represents the percentage of GHG emissions reduction in 2020 for each work plan relative to the BAU forecast. The vertical axis represents the marginal cost of mitigation (expressed as the cost-effectiveness of each work plan on a cumulative basis, 2009-2020). In the figure, each horizontal segment represents an individual work plan. The width of the segment indicates the

[7] Costs were not quantified for Forestry 6 (Durable Wood Products) due to the lack of data.

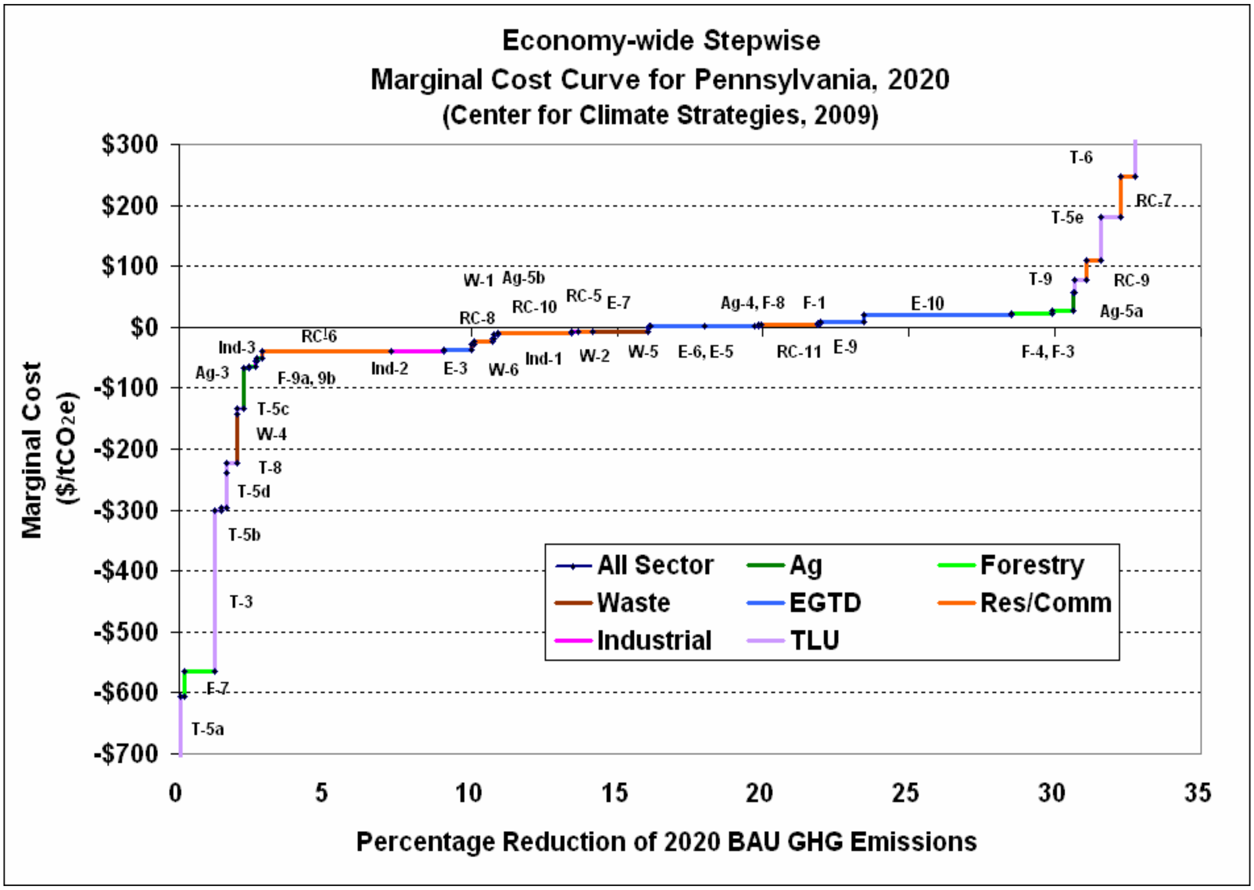
GHG emission reduction potential of the work plan in percentage terms. The height of the segment relative to the horizontal x-axis shows the average cost (saving) of reducing one $MMtCO_2e$ of GHG emissions through implementation of the work plan. For instance, for RC6 (Re-Light PA) this work plan recommendation is estimated to result in approximately a 12.8 $MMtCO_2e$ (4.5 percent) reduction of GHG emissions in 2020 below the BAU reference case with an average cost savings of approximately $39/$tCO_2e$.

Figure 1-5. Work Plan Recommendations Ranked by Cumulative (2009–2020) Net Cost/Cost Savings per Ton of GHG Removed



GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; Ag = agriculture; RC – residential commercial; F = forestry; T= land use and transportation.

Figure 1-6. Stepwise Marginal Cost Curve for Pennsylvania, 2020



BAU = business-as-usual; GHG = greenhouse gas; tCO_2e = metric tons of carbon dioxide equivalent; Ag = agriculture; E = electricity generation, transmission, and distribution; Ind. = industry; RC – residential commercial; F = forestry; T = land use and transportation.

Negative values represent net cost savings and positive values represent net costs associated with the work plan recommendations.

Note: Results have been adjusted to remove overlaps between work plans. For example, RC-I through RC-4 reductions overlap with RC-5 through RC-11 and RC-13 assuming all of these work plans are implemented. The curve, therefore, excludes RC-I through RC-4 to avoid overstating the combined emission reductions and costs of the recommendations.

Baselines, Targets and Recommended Actions

Establishment of Baseline and Targets

At the March 27, 2009 meeting, the CCAC voted unanimously to recommend that the DEP establish 2000 as the baseline year from which to establish targeted GHG emission reduction levels. At this same meeting the committee deliberated on recommending a target year. The committee voted unanimously to recommend that 2020 and 2050 be established as years of analysis for what can be achieved through the development of the work plan recommendations. In reaching these decisions the CCAC considered the recommendations of the IPCC, actions taken by other states and input from the DEP. The growth in GHG emissions from 1990 through 2000 was relatively flat in Pennsylvania. The department further suggested that it is far easier to obtain detailed records to support emissions and emissions reduction calculations if 2000 were chosen as the baseline rather than 1990.

The CCAC elected to wait until all of the analysis of the work plans and macroeconomic modeling was complete before agreeing to recommend a target for GHG reductions. As previously referenced, the CCAC initially suggested a mid-century target year with which to estimate possible emissions and emissions reductions. Because of uncertainties and the limitation of only a simple linear extrapolation out to 2050, a mid-century focus was removed from consideration. During the September 16, 2009 meeting of the CCAC, the DEP provided a recommendation to the committee for their consideration in helping the department establish a GHG reduction target, baseline year and target year. At this meeting, the CCAC approved the following recommendation:

> "The Committee agrees to DEP's proposed target of a 30 percent reduction from 2000 greenhouse gas emission levels by 2020 as a reasonable, aspirational, non-binding goal for implementation of the programs and policies recommended by the DEP, and that this goal should be used to assess the progress of the implementation of the Committee's recommendations."

The department accepts the recommendation above noting that the recommendations of the committee identify the opportunity to reduce GHG emissions by 42 percent below 2000 levels by 2020. The department and the committee acknowledge that changes to how the recommendations may be considered for implementation as well as additional GHG reduction opportunities will become apparent over time but that the target appears to be reasonably attainable goal that should be pursued.

Scientific Basis for Targets or Comparison of Targets to Other States

The climate models employed by the IPCC indicated that in order to avoid significant disturbance of physical and biological systems caused as a result of global climate change, it would be necessary to maintain global average atmospheric CO_2e concentrations to around 450 parts per million (ppm) and no more than 550 ppm. In order to achieve and stabilize a 450 ppm CO_2 target, early action is critical as CO_2 and other GHG's have measurable residence times in the atmosphere and annual anthropogenic GHG emissions continue to rise across the globe.

To meet a goal of a stabilized 450 ppm CO_2 equivalent atmospheric concentration, GHG emissions would need to be reduced by 60 to 85 percent below 2000 levels by 2050. In response many U.S. states have set goals to reduce emissions to 1990 levels or below. The IPCC recommended reductions 25 to 40 percent below 1990 levels by 2020 and 80 to 95 percent below 1990 levels by 2050, however, in the United Nations Environment Programme's *Climate Science Compendium 2009* it has been recognized that the annual global growth rate of GHG emissions since 2000 has exceeded even the IPCC's worst-case modeling scenarios.

Recognizing the global nature of GHG emissions many states have the used the IPCC global recommendations as a starting point to establish science-based reduction targets that take into consideration a state's economy, geography, population and other factors. The 2020 target recommended in this report was developed using similar considerations. Given this variability, of the 26 states that have adopted targets, none have adopted those exactly as recommended by the IPCC. However, a states adopted goal could provide overall the same or additional reduction benefits as the IPCC recommended levels.

Table 1-5 summarizes the actions taken by other states as of August 6, 2009.

Table 1-5. Summary of GHG Emission Reduction Targets Adopted by U.S. States

State	GHG Reduction Target
AR	20 % below 2000 by 2020; 35 % below 2000 by 2025; 50 % below 2000 by 2035
AZ	2000 by 2020; 50 % below 2000 by 2040
CA	2000 by 2010; Emissions capped at 1990 levels by 2020; target of 80 % below 1990 by 2050
CO	20 % below 2005 by 2020; 80 % below 2005 by 2050
CT	10 % below 1990 by 2020; 80 % reduction below 2001 by 2050
FL	2000 by 2017; 1990 by 2025; 80 % below 1990 by 2050
HI	1990 by 2020
IL	1990 levels by 2020 and 60 % below 1990 levels by 2050.
MA	80 % below 1990 levels by 2050; interim targets to be set at 10 % to 25 % below 1990 levels by 2020, as well as targets for 2030 and 2040
MD	1990 levels by 2020; 80 % of 2006 levels by 2050
ME	1990 by 2010; 10 % below 1990 by 2020; 75 % to 80 % below 2003 in the long term
MN	15 % below 2005 by 2015; 30 % below 2005 by 2025; 80 % below 2005 by 2050
MI	20 % below 2005 by 2025; 80 % below 2005 by 2050
MT	1990 levels by 2000
NH	1990 by 2010; 10 % below 1990 by 2020; 75 % - 85 % below 2001 in the long term

State	GHG Reduction Target
NJ	1990 by 2020; 80 % below 2006 by 2050; limits GHG emissions from electricity imported into state
NM	2000 by 2012; 10 % below 2000 by 2020; 75 % below 2000 by 2050
NY	5 % below 1990 by 2010; 10 % below 1990 by 2020
OR	Zero growth in GHG emissions by 2010; 10 % below 1990 by 2020; 75 % below 1990 by 2050
RI	1990 levels by 2010; 10 % below 1990 by 2020; 75 % - 85 % below 2001 in the long term
SC	5 % below 1990 by 2020
UT	2005 by 2020
VA	30 % below business as usual by 2025
VT	1990 by 2010; 10 % below 1990 by 2020; 75 % - 85 % below 2001 in the long term
WA	1990 levels by 2020; 25 % below 1990 by 2035; 50 % below 1990 by 2050
WI	2005 levels by 2014; 22 % below 2005 levels by 2022; 75 % below 2005 levels by 2050

Consumption vs. Generation

Consistent with the actions of most states having developed similar reports, we emphasize consumption rather than generation. This is a significant point of consideration only with regard to electricity. Many states are significant importers of electricity having not supported or facilitated sufficient in-state generation. Pennsylvania is among the largest electricity generating states in the nation. To further avoid confusion of various reporting metrics, such as consumption vs. generation and gross vs. net emissions, the department believes it best to stress consumption-related data because it reflects behavior patterns that only Pennsylvanian’s have control of. Other states have taken the same approach and which affect the portion of generation not associated with consumption from within the commonwealth.

Chapter 2
Overview of Climate Impacts for Pennsylvania

Recently two climate change impacts assessment reports have been prepared for Pennsylvania, the first being prepared by the Union of Concerned of Scientists[1] in the fall of 2008 and more recently the DEP had contracted with researchers at the Pennsylvania State University (PSU) to conduct an assessment report as directed by the Pennsylvania Climate Change Act (Act 70 of 2008). The results of this later assessment report are the focus of this section of this report. Act 70 requires the impact assessment report to address potential impacts of global climate change on Pennsylvania's climate, human health, the economy and the management of economic risk, forests, wildlife, fisheries, recreation, agriculture and tourism. Act 70 also requires the identification of opportunities and barriers to the realization created by the need for alternative sources of energy, climate-related technologies, services and strategies, carbon sequestration technologies, capture and utilization of fugitive greenhouse gas emissions, and other mitigation strategies.

For this first Act 70 assessment report the climate impacts were based on readily available data, literature, and some preliminary quantitative analyses. The department worked with the research staff at PSU to conduct a detailed macroeconomic impacts assessment that goes beyond the scope of Act 70 but which will exceed the statutory requirements of Act 70. This work involves the creation of a general computational equilibrium model (CGE) that is estimated to be complete near the end of 2009.

As expressed within the Pennsylvania Climate Impacts Assessment Report from June 29, 2009, the researchers compared several climate models using two modeling scenarios as established by the Intergovernmental Panel on Climate Change (IPCC). The first (higher emissions) scenario considers a continual increase in global greenhouse gas emissions through this century while the second (lower emissions) scenario considers the impacts of moderated growth of greenhouse gas emissions through mid-century coupled with declining emissions post 2050. Based on their analyses of both models, the researchers provide the following conclusions for the future of Pennsylvania's climate:

- It is very likely that Pennsylvania will warm throughout the 21st century; not a single model simulates cooling under either emissions scenario;
- It is likely that annual precipitation will increase in Pennsylvania and very likely that winter precipitation will increase in both emissions scenarios;
- By the end of the century, the median projected trend according to the higher emissions scenario is almost 7 degrees Fahrenheit warmer, which is nearly twice that of the lower emissions scenario; and

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[1] *Climate Change in Pennsylvania: Impacts and Solutions for the Keystone State*, October 2008. Available at http://www.climatechoices.org/pa

- Warming will lead to a longer growing season, with median projections for the lower and higher emissions scenarios of nearly three and five weeks lengthening, respectively, by late century. Correspondingly, frost days are projected to decrease from nearly four to six weeks;
- By late century, the median projected trend in annual precipitation is an increase by six and 10 percent, respectively for the lower and higher emissions scenarios. Most of this increase is expected to occur during winter, but coupled with warmer temperatures translates into significant decreases in snowfall;
- It is likely that Pennsylvania's precipitation will become more extreme in the future, with longer periods of drought interspersed by an increased frequency of extreme precipitation events; and
- Projected climate change for the commonwealth over the next 20 years does not differ between the high and low emissions scenarios. Pennsylvania's projected climate by the end of the century differs significantly between the two scenarios.

Aquatic resources and ecosystems will be impacted through likely changes in precipitation, as noted above, run-off, water quality and quantity. Increases in the frequency of severe weather events, in which heavier than normal precipitation is experienced should increase the number and severity of flash floods along smaller streams. This would likely have impacts on soil and nutrient runoff, increases in rates of soil erosion and translate into infrastructure concerns for state and local government regarding stormwater management (e.g. culvert, road and bridge sizing/construction, combined sewer overflows, etc.). There may be an increased utilization and reliance on irrigation systems for residential, commercial and agricultural purposes. Industry and power generation are consumptive users of water for process needs and cooling. The commonwealth can expect increased periods of demand for water resources at times when the supply is constrained relating to resource allocation and/or limitation issues.

Surface water temperatures are anticipated to increase, directly impacting species with lower tolerances to warming conditions, such as brook trout. Indirect consequences such as changes in available oxygen content (warm water holds less oxygen) of surface waters may limit the variety and quantity of other species not immediately sensitive to increases water temperatures. Periods of low water flow and increased surface water temperatures can promote the development of bacterial and other disease infestations and render populations of some aquatic organisms more susceptible to other environmental stressors. The Pennsylvania Fish and Boat Commission already linked such conditions with the recent die-off of large numbers of very young smallmouth bass in the Susquehanna River. These conditions could become more prevalent.

A warming climate will result in changes to the composition of Pennsylvania's woods. Some cooler climate-oriented species, which produce some of our most spectacular fall foliage, will suffer poor seedling regeneration and/or be stressed by the changes and loose their prominence within the ecosystem. For instance, the bright orange fall foliage of the sugar maple, the source of much maple syrup and a source of income in northern-tier counties, will decline through the later parts of the century. As climate change affects not only species distribution and plant vigor, it will impact the quality of lumber. Pennsylvania has already lost much of its manufacturing associated with wood products due to global competition. The effects of climate change may cause Pennsylvania to lose its prized black cherry timber industry near the end of this century.

Though no loss of forest acreage is expected, a change to forest composition will result in changes to the understory and animal species inhabiting this environment. The climate and habitat favorable for the existence of the snowshoe hare, for example, and therefore the extent of its range and survivability is expected to decline. As a result of climate change, the conditions better suited for survival of bobwhite quail may improve in the southern counties at the same time.

Similar to the forest-related climate change impacts, changes to ideal growing conditions for certain crops and other agricultural commodities are expected. Overall, agriculture may benefit through a lengthening growing season, but this comes with a trade off because a warming climate also favors an increase in the type, number and extent of severity of insect pests and plant pathogens. Some crops may no longer be well-suited for cultivation. Farmers will need to adapt by possibly growing new crops or more resistant and tolerant varieties of existing crops. Animal agriculture is also expected to be impacted. For instance, milk production decreases if milking cows are under heat stress. Producers may need to provide additional ventilation and cooling for livestock that will necessitate additional energy expenditures.

Climate change will impact Pennsylvania's energy sector in varied ways. Opportunities will abound for the creation of energy, in all forms (electricity, transportation and heating fuels) from alternative sources. Manufacturing, sales, installation, maintenance and transportation associated with renewable energy provide sources of new jobs and additional growth in revenue for the commonwealth. However, Pennsylvania will be challenged by the need to manage the greenhouse gas emissions associated with coal-fired electricity generation. Coal will continue to be a major fuel by which much of Pennsylvania's and this nation's electricity is generated for the foreseeable future. Therefore, it is necessary to explore opportunities and technologies that allow for the most efficient and wisest use of this fossil fuel. Pennsylvania boasts some of the most promising opportunities to sequester (permanently store) carbon dioxide emissions from power generation and industry in very stable and deep geologic formations, similar to the way that natural gas is stored underground. Many researchers continue to seek out the best combination of technologies that capture and store this greenhouse gas in the geologic strata. While it remains technically possible to capture and geologically sequester carbon dioxide now, it is cost prohibitive and carbon sequestration has never been performed on the scale of implementation that would be required to affect a difference from Pennsylvania's power generation. At the opposite extreme, abundant opportunities exist for increasing energy efficiency and conservation which also provide the most cost-effective measures for reducing greenhouse gas emissions. Efficiency and conservation provide other benefits too, such as decreases in other air pollutants that otherwise contribute to the formation of acid rain, smog and ground-level ozone that is particularly harmful to the respiratory health of the very young and elderly.

Human health concerns will include the management of heat-related stress and risk of increased heat-related mortalities. This may be particularly true for Pennsylvania's urban centers, which are expected to see increases in the number of days above 90 degrees Fahrenheit and even 100 degrees Fahrenheit . This may require the establishment or expansion of public health alerts for high-heat weather advisories. This impact is expected to be slightly offset by warmer winter temperatures, resulting in reduced energy needs for heating and potentially fewer cold-related mortalities. Reported cases of vector-borne diseases, such as West Nile Virus and water-borne disease pathogens may increase as our climate changes particularly as the number of warm days commensurately increases the risk to exposure. Education and risk management efforts may become highly effective measures to adapting to these and other potential impacts.

Projected climate change for Pennsylvania is very likely to be warmer and wetter over the next 20 years. The warming trend will lead to a longer growing season with fewer frost days. A warming climate will lead to declines in some plant and animal species, yet at the same time, habitats will improve for different plant and animal species.

Chapter 3
Inventory and Projections of GHG Emissions

Introduction

This chapter summarizes Pennsylvania's greenhouse gas (GHG) emissions and sinks (carbon storage) from 1990 to 2020. The DEP prepared Pennsylvania's GHG emissions inventory and reference case projections. The inventory and reference case projections (forecast) provided the DEP with an initial, comprehensive understanding of current and possible future GHG emissions (hereafter referred to as the I&F). The I&F was provided to the CCAC and its Subcommittees to assist them in understanding past, current, and possible future GHG emissions in Pennsylvania, and thereby inform the work plan development process. The CCAC and its subcommittees have reviewed, discussed, and evaluated the draft I&F resulting in revisions to the forecast for the electricity generation and transportation sectors and the I&F for landfills. The information in this chapter reflects the most recent values of the GHG inventory and reference case projections.[1]

Historical GHG emission estimates (1990 through 2005)[2] were developed using a set of generally accepted principles and guidelines for state GHG emission inventories, relying to the extent possible on Pennsylvania-specific data and inputs. The reference case projections (2006-2020) are based on a compilation of various existing projections of electricity generation, fuel use, and other GHG-emitting activities, along with a set of simple, transparent assumptions.

The I&F covers the six types of gases included in the U.S. GHG inventory: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Emissions of these GHGs are presented using a common metric, CO_2 equivalence (CO_2e), which indicates the relative contribution of each gas, per unit mass, to global average radiative forcing on a global warming potential-weighted basis.[3]

It is important to note that the I&F estimates reflect the GHG emissions associated with the electricity sources used to meet Pennsylvania's demands, corresponding to a consumption-based approach to emissions accounting. Another way to look at electricity emissions is to consider the GHG emissions produced by electricity generation facilities in the state—a production-based method. The I&F covers both methods of accounting for emissions, but for consistency, emissions for all sectors are reported as consumption-based.

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[1] A copy of the GHG Inventory can be retrieved from the Pennsylvania Department of Environmental Quality, Office of Energy & Technology Deployment web site: http://www.depweb.state.pa.us/energy/cwp/view.asp?a=1532&q=539829.

[2] The last year of available historical data for each sector varies between 2000 and 2007.

[3] Changes in the atmospheric concentrations of GHGs can alter the balance of energy transfers between the atmosphere, space, land, and the oceans. A gauge of these changes is called radiative forcing, which is a simple measure of changes in the energy available to the Earth–atmosphere system. Holding everything else constant, increases in GHG concentrations in the atmosphere will produce positive radiative forcing (i.e., a net increase in the absorption of energy by the Earth). See: Boucher, O., et al. "Radiative Forcing of Climate Change." Chapter 6 in *Climate Change 2001: The Scientific Basis*. Contribution of Working Group 1 of the Intergovernmental Panel on Climate Change Cambridge University Press. Cambridge, United Kingdom. Available at: http://www.grida.no/climate/ipcc_tar/wg1/212.htm.

Pennsylvania GHG Emissions: Sources and Trends

Table 3-1 provides a summary of GHG emissions estimated for Pennsylvania by sector for 1990, 2000, 2005, 2010, and 2020. As shown in this table, Pennsylvania is estimated to be a net source of GHG emissions (positive, or gross, emissions). Pennsylvania's forests serve as sinks of GHG emissions (removal of emissions, or negative emissions). Pennsylvania's net emissions subtract the equivalent GHG reduction from emission sinks from the gross GHG emission totals. The following sections discuss GHG emission sources and sinks, trends, projections, and uncertainties.

Historical Emissions

Overview

In 2000, on a gross emissions consumption basis (i.e., excluding carbon sinks), Pennsylvania accounted for approximately 284 million metric tons (MMt) of CO_2e emissions, an amount equal to 4 percent of total U.S. gross GHG emissions. On a net emissions basis (i.e., including carbon sinks), Pennsylvania accounted for approximately 263 $MMtCO_2e$ of emissions in 2000, an amount equal to 4.1 percent of total U.S. net GHG emissions.[4] Pennsylvania's GHG emissions remained flat in comparison with those of the nation as a whole. From 1990 to 2000, Pennsylvania's gross GHG emissions increased by only 2 percent, while national gross emissions rose by 14 percent.[5]

On a per-capita basis, Pennsylvania residents emitted about 23 metric tons (t) of gross CO_2e in 2000, less than the national average of about 25 tCO_2e. Figure 3-1 illustrates the state's emissions per capita and per unit of economic output. Both Pennsylvania and national per capita emissions remained relatively flat from 1990 to 2000. In both Pennsylvania and the nation as a whole, economic growth exceeded emissions growth throughout the 1990–2000 period. From 1990 to 2000, emissions per unit of gross product dropped by 19 percent nationally, and by 35 percent in Pennsylvania.[6]

[4] The national emissions used for these comparisons are based on 2000 emissions from U.S. Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2006*, April 15, 2008, EPA430-R-08-005. Available at: http://www.epa.gov/climatechange/emissions/usinventoryreport.html.

[5] During this period, population grew by 3.2% in Pennsylvania and by 13% nationally. However, Pennsylvania's economy grew by 57% versus 40% for the nation.

[6] Based on real gross domestic product (millions of chained 2000 dollars) that excludes the effects of inflation. U.S. Department of Commerce, Bureau of Economic Analysis. "Gross Domestic Product by State." Available at: http://www.bea.gov/regional/gsp/.

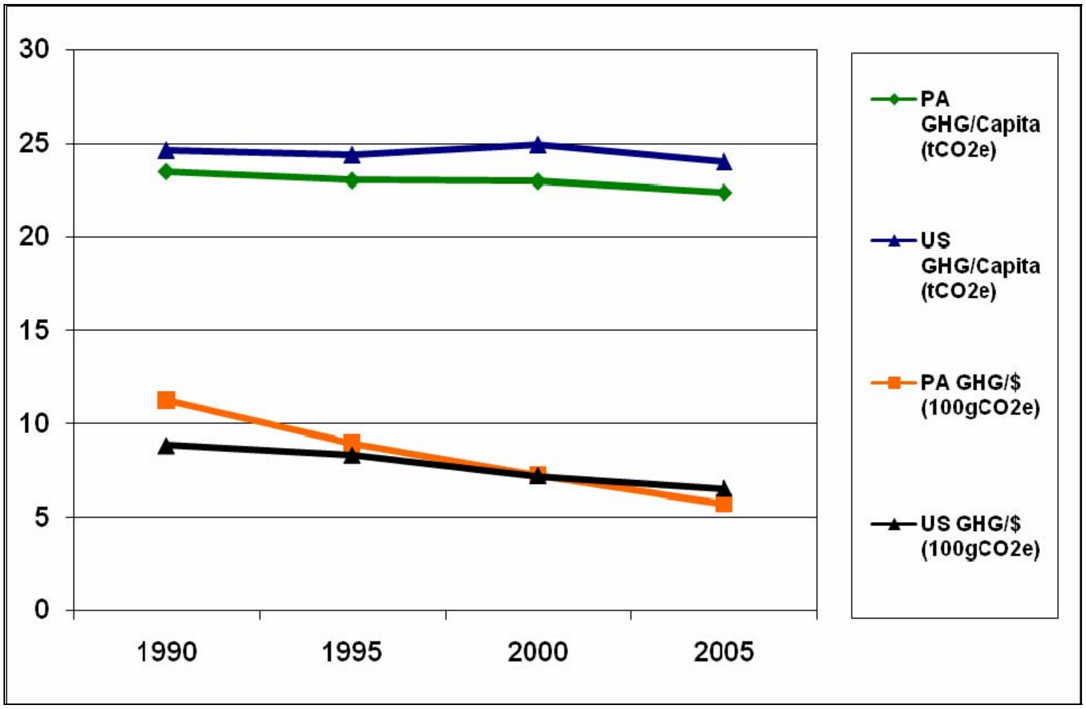
Table 3-1. Pennsylvania Historical and Reference Case GHG Emissions, by Sector*

Sector / Emission Source ($MMtCO_2e$)	1990	2000	2005	2010	2020
Residential	**23.94**	**25.91**	**24.12**	**24.45**	**23.48**
Commercial	**13.25**	**12.83**	**12.81**	**13.14**	**13.50**
Industrial	**91.02**	**78.03**	**71.11**	**69.75**	**63.05**
Combustion of Fossil Fuels (CO_2, CH_4 & N_2O)	65.21	50.25	46.68	47.05	44.15
Industrial Processes (CO_2, N_2O, HFC, PFC & SF_6)	12.15	15.27	14.13	13.60	13.00
Coal Mining and Abandoned Coal Mines (CH_4)	9.82	9.58	7.25	5.90	2.50
Natural Gas and Oil Systems (CH_4)	3.83	2.93	3.05	3.20	3.40
Transportation	**62.30**	**69.49**	**68.22**	**69.29**	**67.89**
On-road Gasoline	NA	44.58	44.30	44.75	38.98
On-road Diesel	NA	10.8	11.4	12.3	14.5
Marine Vessels	NA	3.00	2.65	2.64	2.71
Rail, Natural Gas, LPG, Other	NA	3.38	3.02	3.42	4.54
Jet Fuel and Aviation Gasoline	NA	7.78	6.87	6.14	7.17
Electricity (Consumption)	**75.40**	**83.69**	**87.69**	**89.68**	**111.60**
Electricity Production (in-state)	104.72	116.23	121.80	122.61	149.23
Coal (CO_2, CH_4 & N_2O)	*NA*	*NA*	*NA*	*96.64*	*120.08*
Waste Coal (CO_2, CH_4 & N_2O)	*NA*	*NA*	*NA*	*14.00*	*14.91*
Natural Gas (CO_2, CH_4 & N_2O)	*NA*	*NA*	*NA*	*9.43*	*11.53*
Oil (CO_2, CH_4 & N_2O)	*NA*	*NA*	*NA*	*1.13*	*1.21*
MSW/LFG (CO_2, CH_4 & N_2O)	*NA*	*NA*	*NA*	*1.41*	*1.50*
Net Imported (Exported) Electricity (CO_2, CH_4 & N_2O)	-29.32	-32.55	-34.11	-32.93	-37.63
Agriculture	**6.89**	**8.38**	**8.57**	**8.63**	**8.99**
Enteric Fermentation	2.70	3.00	2.97	2.90	2.79
Manure Management	0.99	1.55	1.70	1.80	2.05
Agricultural Soil Management	3.20	3.82	3.89	3.93	4.14
Burning of Agricultural Crop Waste	0.01	0.01	0.01	0.01	0.01
Waste Management	**6.67**	**5.57**	**6.04**	**6.44**	**6.80**
Municipal Solid Waste (CO_2, CH_4 & N_2O)	5.09	2.74	2.80	3.04	3.38
Industrial Landfills	0.36	0.19	0.20	0.21	0.24
Waste Combustion	0.23	1.61	2.00	2.14	2.14
Wastewater (CH_4 & N_2O)	0.99	1.03	1.04	1.05	1.05
Total Statewide Gross Emissions (Consumption Basis)	**279.46**	**283.91**	**278.57**	**281.39**	**295.32**
Increase relative to 1990		*1.6%*	*-0.3%*	*-0.7%*	*5.7%*
Increase relative to 2000			*-1.9%*	*-0.9%*	*4.0%*
Total Statewide Gross Emissions (Production Basis)	**308.79**	**316.46**	**312.67**	**314.32**	**332.95**
Increase relative to 1990		*2.5%*	*1.3%*	*1.8%*	*7.8%*
Increase relative to 2000			-1.2%	-0.4%	5.2%
Forestry and Land Use	**-29.86**	**-21.25**	**-20.90**	**-20.44**	**-19.58**
Total Statewide Net Emissions (Consumption Basis) (including forestry and land use sinks)	**249.60**	**262.66**	**257.67**	**260.95**	**275.74**
Increase relative to 1990		*5.2%*	*3.2%*	*4.5%*	*10.5%*
Increase relative to 2000			*-1.9%*	*-0.7%*	*5.0%*
Total Statewide Net Emissions (Production Basis) (including forestry and land use sinks)	**278.93**	**295.21**	**291.77**	**293.88**	**313.37**
Increase relative to 1990		*5.8%*	*4.6%*	*5.4%*	*12.3%*
Increase relative to 2000			*-1.2%*	*-1.6%*	*6.2%*

* Totals may not equal exact sum of subtotals shown in this table due to independent rounding. NA = information was not available.

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MSW = Municipal Solid Waste; LFG = Landfill Gas; LPG = Liquefied Petroleum Gas; CH_4 = Methane; N_2O = Nitrous Oxide.

Figure 3-1. Pennsylvania and U.S. Gross GHG Emissions, Per-Capita and Per-Unit Gross Product

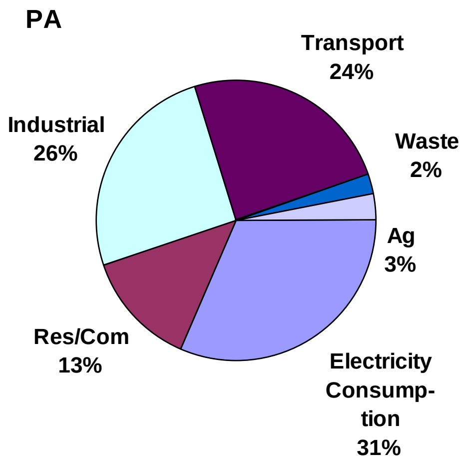


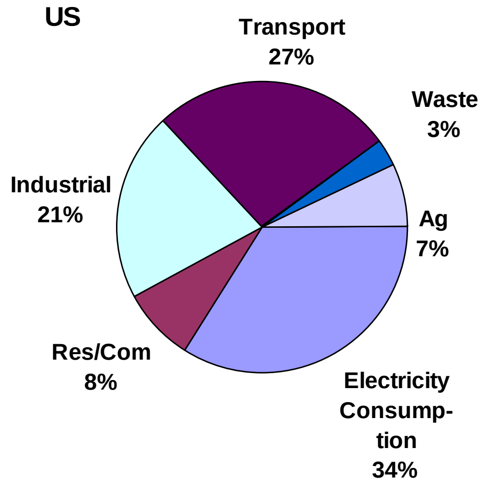
GHG = greenhouse gas; tCO_2e = metric tons of carbon dioxide equivalent.; g = grams.

The principal sources of Pennsylvania's GHG emissions in 2000 are electricity consumption, the industrial sector, and transportation, accounting for 30 percent, 28 percent and 24 percent of Pennsylvania's gross GHG emissions, respectively, as shown in Figure 3-2. The next largest contributor is the residential/commercial fuel use sector, accounting for 14 percent of gross GHG emissions in 2000.

Figure 3-2 also shows that the emissions from the agricultural sector accounted for 3 percent of the gross GHG emissions in Pennsylvania in 2000. These CH_4 and N_2O emissions primarily come from agricultural soils, enteric fermentation, manure management, and agricultural soil cultivation practices. Also, landfills, waste combustion, and wastewater management facilities produce emissions that accounted for 2 percent of total gross GHG emissions in Pennsylvania in 2000.

Figure 3-2. Gross GHG Emissions by Sector, 2000: Pennsylvania and U.S.





Notes: Res/Com = Residential and commercial fuel use sectors. Emissions for the residential fuel use sector are associated with the direct use of fuels (natural gas, petroleum, coal, and wood) to provide space heating, water heating, cooking, and other energy end-uses. The commercial sector accounts for emissions associated with the direct use of fuels by, for example, hospitals, schools, government buildings (local, county, and state) and other commercial establishments. The industrial sector accounts for emissions associated with manufacturing, emissions from fossil fuel processing and emissions included in the industrial fuel use sector. The transportation sector accounts for emissions associated with fuel consumption by all on-road and non-highway vehicles. Non-highway vehicles include jet aircraft, gasoline-fueled piston aircraft, railway locomotives, boats, and ships. Emissions from non-highway agricultural and construction equipment are included in the industrial sector. Electricity = Electricity generation sector emissions on a consumption basis, including emissions associated with electricity imported from outside of Pennsylvania and excluding emissions associated with electricity exported from Pennsylvania to other states.

Forestry emissions refer to the net CO_2 flux[7] from forested lands in Pennsylvania, which account for about 59 percent of the state's land area.[8] Pennsylvania's forests are estimated to be net sinks of CO_2 emissions in the state, reducing GHG emissions by 21.3 $MMtCO_2e$ in 2000.

Reference Case Projections

Relying on a variety of sources for projections, a simple reference case projection of GHG emissions through 2020 was developed. As illustrated in Figure 3-3 and shown numerically in Table 3-1, under the reference case projections, Pennsylvania's gross GHG emissions are projected to increase slightly to about 295 $MMtCO_2e$ by 2020, or 5.7 percent above 1990 levels and 4.0 percent above 2000 levels. This equates to a 1.0 percent average annual rate of growth in emissions from 1990 to 2020 and 1.4 percent from 2000 to 2020. Relative to 2000, the share of emissions associated with electricity consumption increases to 38 percent by 2020. The share of emissions from the industrial sector drops to 21 percent by 2020. The shares of emissions

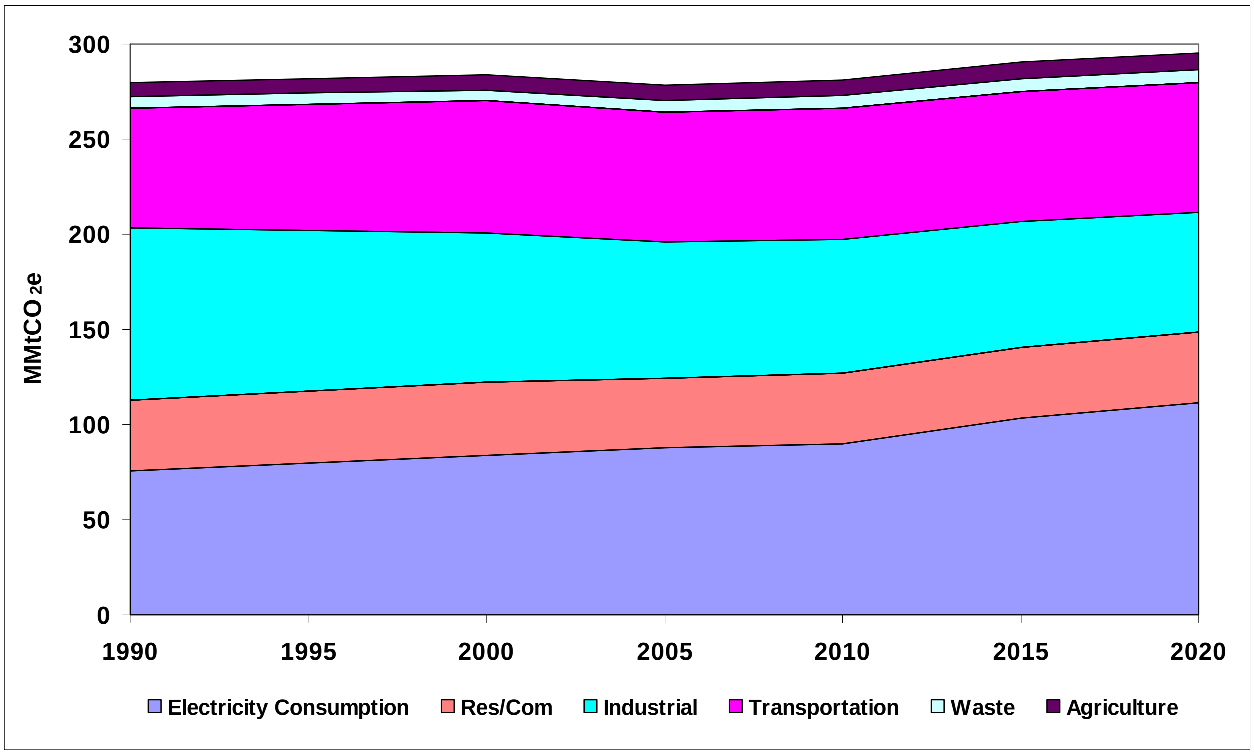
[7] "Flux" refers to both emissions of CO_2 to the atmosphere and removal (sinks) of CO_2 from the atmosphere.

[8] Total forested acreage in Pennsylvania is 16.9 million acres. For acreage by forest type, see: Richard A. Birdsey and George M. Lewis. "Carbon in United States Forests and Wood Products, 1987–1997: State-by-State Estimates." Pennsylvania Estimate for 1987–1997. Available from the U.S. Department of Agriculture, Forest Service, Northern Global Change Research Program, at: http://www.fs.fed.us/ne/global/pubs/books/epa/states/PA.htm. The total land area in Pennsylvania is 28.7 million acres (http://www.statemaster.com/state/PA-pennsylvania/geo-geography).

from the residential/commercial fuel use sectors and the transportation sector both decrease slightly (i.e., 1.0 percent) from their relative share of emissions in 2000. The share of emissions from the waste management and agriculture sectors remain the same in 2020 as their shares in 2000.

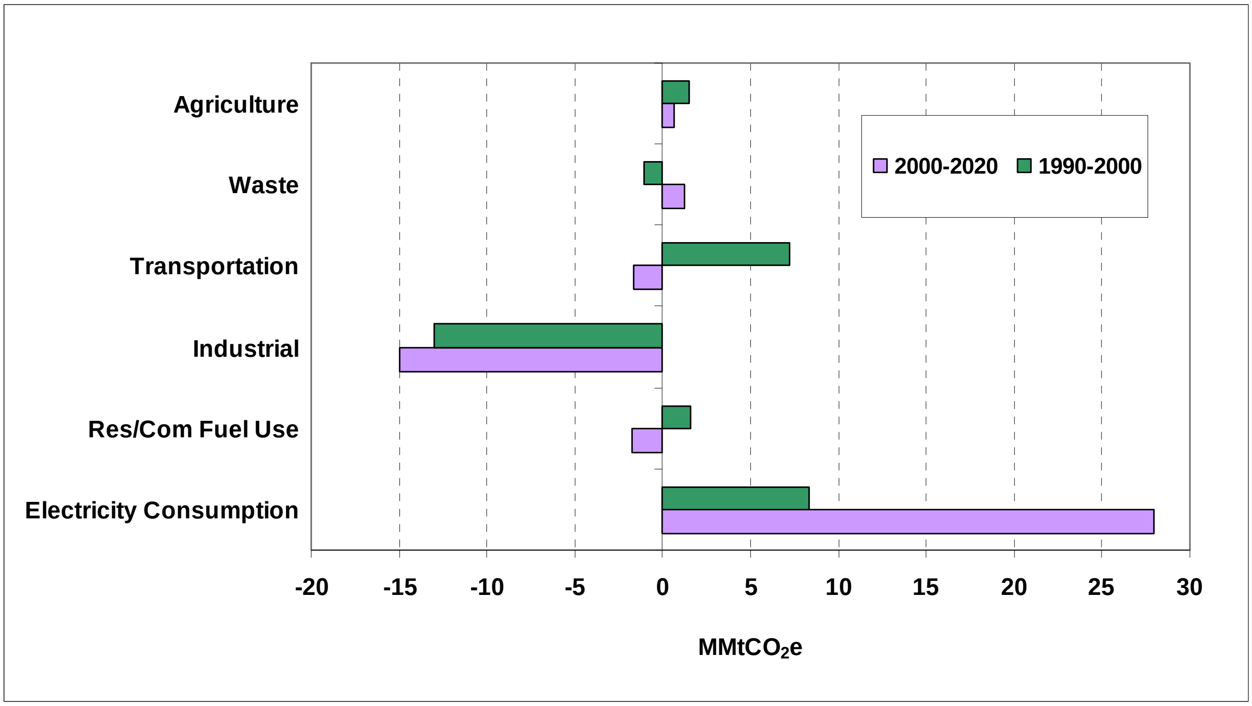
Emissions associated with electricity consumption are projected to be the largest contributor to future GHG emissions growth by far; emissions from waste management and agriculture are modest contributors to future emissions growth as shown in Figure 3-4, while emissions from all other sectors decrease from 2000 to 2020. Table 3-2 summarizes the growth rates that drive the growth in the Pennsylvania reference case projections, as well as the sources of these data.

Figure 3-3. Pennsylvania Gross GHG Emissions by Sector, 1990–2020: Historical and Projected



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; Res/Com = residential/commercial.

Figure 3-4. Sector Contributions to Gross Emissions Growth in Pennsylvania, 1990–2020: Reference Case Projections



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; Res/Com = residential/commercial.

Table 3-2. Key Annual Growth Rates for Pennsylvania, Historical and Projected

	1990-2000	2000-2020	Sources
VMT	1.8%	1.4%	Based on Pennsylvania Department of Transportation Roadway Management System Data and Forecasted Growth Rates
Population	0.30%	0.13%	Pennsylvania population statistics for 1990 through 2000, compiled by U.S. Census Bureau, are available at http://www.census.gov/popest/states/states.html.
			Population data for 2000 to 2020 are available from Pennsylvania State Data Center at http://pasdc.hbg.psu.edu/pasdc/PA_Stats/profiles_tables_and_charts/pennsylvania/pop_other/04XT1-16.html.
Electricity Sales	1.22%	1.35%	For 1990-2000, the average annual growth rate is calculated from actual PA sales (source: email from Blaine Loper to Hal Nelson dated 15 May 2009). For 2000-2020, the average annual growth rate is based on PA sales over the period 1973 to 2007.

EIA = Energy Information Administration; SIT = State (GHG) Inventory Tool; VMT = vehicle miles traveled.

A Closer Look at the Three Major Sources: Electricity Supply, Industrial Sector, and Transportation Sector

As shown in Figure 3-2, electricity use in 2000 accounted for 30 percent of Pennsylvania's gross GHG emissions (about 84 $MMtCO_2e$), which was slightly lower than the national average share of emissions from electricity consumption (31 percent).[9] On a per-capita basis, Pennsylvania's GHG emissions from electricity consumption are lower than the national average (in 2005, 6.8 tCO_2e per capita in Pennsylvania, versus 8.1 tCO_2e per capita nationally).

In 2000, emissions associated with Pennsylvania's electricity consumption (84 $MMtCO_2e$) were about 33 $MMtCO_2e$ lower than those associated with electricity production (116 $MMtCO_2e$). The higher level for production-based emissions reflects GHG emissions associated with net exports of electricity to other states to meet their electricity demand.[10] Emissions from electricity exports are projected to increase to a level of about 38 $MMtCO_2e$ by the year 2020. The reference case projection indicates that production-based emissions (associated with electricity generated in-state) will increase by about 33 $MMtCO_2e$, and consumption-based emissions (associated with electricity consumed in-state) will increase by about 28 $MMtCO_2e$ from 2000 to 2020. Electricity generation in Pennsylvania is dominated primarily by units powered by coal and nuclear fuel.

Projections of electricity sales for 2007 through 2020 indicate that Pennsylvania will remain a net exporter of electricity. Projected increases for in-state sales are driven in large part by reports provided by the electric distribution companies (EDCs) to the Public Utility Commission and further by applying historic annual rates of growth for each EDC for years 2014 through 2020. However, the department believes that recent trends will alter this forecast, at least in terms of the magnitude of the emissions increase. Data reported by the PJM (need to cite source) indicates that electricity sales for the first six months of 2009 are down 5 percent below 2008 levels and that 2008 sales were 2.7 percent below 2007 levels.

Data from the U.S. Environmental Protection Agency's (EPA) Division of Clean Air Markets confirms that CO_2 emissions from Pennsylvania's electric power plants have decreased. While this decrease is in large part due to recessionary impacts there has been a shift to the utilization of more natural gas to generate electricity in the Keystone State. The department believes that natural gas will continue to play a more significant role in electricity production than was the case in 2000 and even 2005. Though the initial analysis incorporated EDC sales forecasts in an attempt to use the most state-specific data sources, the department believes the annual growth rate of electricity sales to be more modest. Specifically, the department believes that it is more likely that electricity sales will grow at a rate of about 1 percent per year rather than the historical rate of approximately 1.6 percent, which will have a profound and beneficial impact on GHG emissions by 2020. Assuming the department's assertions are correct, a sensitivity analysis indicates there will be an approximate 10 percent reduction in GHG emissions from electricity consumption forecasted in 2020.

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[9] For the U.S. as a whole, there is relatively little difference between the emissions from electricity use and emissions from electricity production, as the U.S. imports only about 1% of its electricity, and exports even less.

[10] Estimating the emissions associated with electricity use requires an understanding of the electricity sources (both in-state and out-of-state) used by utilities to meet consumer demand.

While estimates are provided for emissions from both electricity production and consumption, unless otherwise indicated, tables, figures, and totals in this report reflect electricity consumption emissions. The consumption-based approach can better reflect the emissions (and emission reductions) associated with activities occurring in the state, particularly with respect to electricity use (and efficiency improvements), and is particularly useful for decision making. Under this approach, emissions associated with electricity exported to other states would need to be covered in those states' inventories in order to avoid double counting or exclusions.

The industrial sector accounts for 28 percent of Pennsylvania's gross GHG emissions in 2000, higher than the national average of 23 percent. This is not surprising given Pennsylvania's history of heavy industry. Fuel combustion to provide space heating, water heating, process heating, cooking, and other energy end-uses makes up the majority (63 percent) of industrial emissions. Emissions from industrial processes account for 20 percent of the state's industrial emissions in 2020. These emissions include: the use of HFCs and PFCs as substitutes for ozone-depleting chlorofluorocarbons,[11] CO_2 released by cement and lime manufacturing; CO_2 released during soda ash, limestone, and dolomite use; CO_2 released during iron and steel production; SF_6 used in electricity transmission and distribution systems; and HFCs, PFCs, and SF_6 released during semiconductor manufacturing. The fossil fuel production sector accounts for the remaining 16 percent of emissions from the industrial sector. These emissions come primarily from coal mining although there are also emissions associated with the natural gas industry.

Under the reference case projections, GHG emissions from the industrial sector are projected to decline by 19 percent from 2000 to 2020, to 63 $MMtCO_2e$ in 2020. This sector shows the greatest decline of all the sectors during this period. Over 7 $MMtCO_2e$ of this decrease is attributed to a reduction in emissions from coal mining. Another 6 $MMtCO_2e$ of this decrease is accounted for by a decrease in industrial combustion emissions.

GHG emissions from transportation fuel use have risen from 1990 to 2000 at an average annual growth rate of 1.1 percent. In 2000, gasoline-powered on-road vehicles accounted for about 64 percent of transportation GHG emissions; on-road diesel vehicles for 15 percent; jet fuel and aviation gasoline for 11 percent and marine vessels, rail, and other sources (natural gas- and liquefied petroleum gas-fueled vehicles used in transport applications) for the remaining 9 percent.

Overall emissions from the transportation sector are expected to decline at a rate of about 0.1 percent annually from 2000 to 2020 to 68 $MMtCO_2e$. This overall decrease is driven by the decrease in on-road gasoline emissions, declining at a rate of 0.7 percent per year from 2000 to 2020, reaching 39 $MMtCO_2e$ in 2020. In contrast, the vehicle miles traveled (VMT) by gasoline vehicles is expected to increase at a rate of 1.4 percent per year in the same time period. The decrease in on-road gasoline emissions is driven by the assumed increase in vehicle fuel economy resulting from the Energy Independence and Security Act of 2007 which increase

[11] Chlorofluorocarbons are also potent GHGs; however, they are not included in GHG estimates because of concerns related to implementation of the Montreal Protocol on Substances That Affect the Ozone Layer.

Corporate Average Fuel Economy (CAFE) standards. Emissions from on-road diesel vehicles are projected to increase by 1.5 percent annually from 2000 to 2020.

Key Uncertainties

Some data gaps exist in this inventory, and particularly in the reference case projections. Key tasks for future refinement of this inventory and forecast include review and revision of key drivers, such as the transportation, electricity demand, and industrial and residential/commercial fuel use growth rates that will be major determinants of Pennsylvania's future GHG emissions (see Table 3-2 and Figure 3-4). These growth rates are driven by uncertain economic, demographic, and land use trends (including growth patterns and transportation system impacts), all of which deserve closer review and discussion.

Chapter 4
Electricity Generation, Transmission, and Distribution

Sector Overview

Overview of GHG Emissions

The electricity generation, transmission, and distribution (EGTD) sector includes greenhouse gas (GHG) emissions from all generation, transmission, and distribution of electricity. Pennsylvania is a net exporter of electricity. Pennsylvania power plants are expected to continue to produce significantly more electricity than is consumed in the state[1]for residential, commercial, and industrial uses while also providing electricity to meet the demands of other Mid-Atlantic States. This sector is the largest source of GHG emissions in the state. In 2000, on an electricity production basis, the sector contributed about 116.2 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) emissions (about 37 percent) to Pennsylvania's total statewide gross GHG emission. On a consumption basis, in 2000 the sector contributed about 83.7 $MMtCO_2e$ of emissions (about 30 percent) to Pennsylvania's total gross GHG emissions.

Figure 4-1 shows historical and projected GHG emissions from sources in this sector. Overall, emissions for the sector are expected to increase by 40 percent on a consumption basis between 1990 and 2020. Specifically, the production-based GHG emissions associated with Pennsylvania's electricity sector increased by 11.5 $MMtCO_2e$ between 1990 and 2000. This accounted for 11.5 percent of the state's total growth in gross GHG emissions during this period. On a consumption basis, GHG emissions associated with Pennsylvania's electricity sector increased by 8.3 $MMtCO_2e$ between 1990 and 2000, accounting for 11 percent of the state's growth in gross GHG emissions during this period. By 2020, consumption-based emissions are expected to increase from 2000 levels by approximately 26 percent, from roughly 83.7 $MMtCO_2e$ in 2000, to about 105.4 $MMtCO_2e$ in 2020. In other words, GHG emissions from electricity consumption will increase as a share of the state's total.

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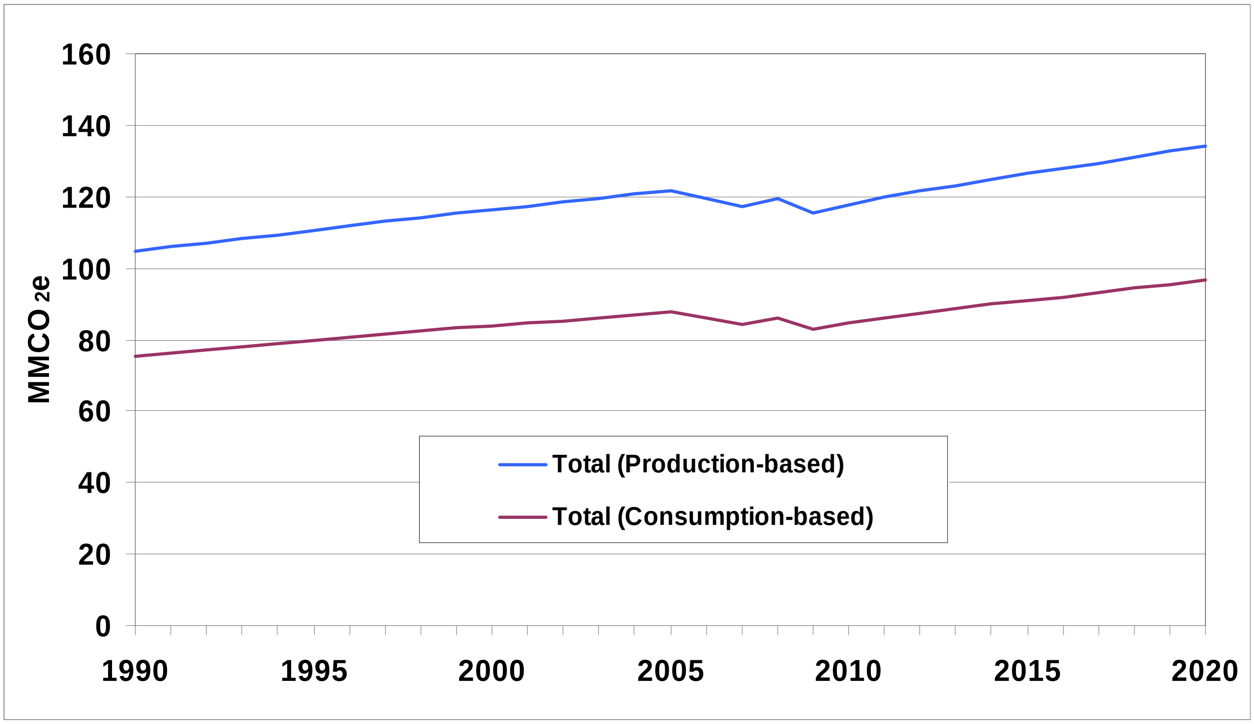
[1] Estimating GHG emissions associated with electricity production and use (consumption) requires an understanding of the electricity sources used by utilities to meet consumer demand (both in-state and out-of-state). The production-based approach accounts for emissions associated with all electricity generated by facilities located in Pennsylvania. Much of this is consumed by Pennsylvanians but about 30 percent is exported. The consumption-based approach accounts for emissions associated with electricity generated by facilities located in Pennsylvania and consumed by end-users that reside in Pennsylvania. Estimating emissions based on these two accounting methods can be helpful for understanding approaches to mitigate GHG emissions from the electricity sector. Note, however, that for other sectors, data are not typically available to support development of emission estimates for the production-based method. Therefore, the emission estimates discussed elsewhere in this report (including the inventory and forecast in Chapter 3) reflect the GHG emissions associated with the electricity sources used to meet Pennsylvania's demands, corresponding to a consumption-based approach. The consumption-based approach better reflects the emissions that can be affected by the behavior of Pennsylvania's consumers and is consistent with the methodology used in other state action plan reports.

Figure 4-1. Recent and Projected GHG Emissions from the Electricity Generation Sector, Pennsylvania, 1990–2020 (Production and Consumption Basis)



Source: 1990, 2000, and 2005 values are from the PA DEP (interpolation in other years); 2007-2030 values are from the spreadsheet entitled FINAL - PA Electricity GHG Forecast 6-24-09.xls...

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Almost all GHG emissions from electricity production in Pennsylvania are from coal-fired generation. Figure 4-2 shows the breakdown of in-state gross electricity generation and in-state GHG emissions by fuel type for 2000. Nuclear accounts for over a third of total generation, with coal comprising most of the balance. There are almost no GHG emissions associated with nuclear generation and a relatively small volume of emissions from most other sources. As a result, coal-fired generation contributes nearly all of the states GHG emissions from electricity generation.

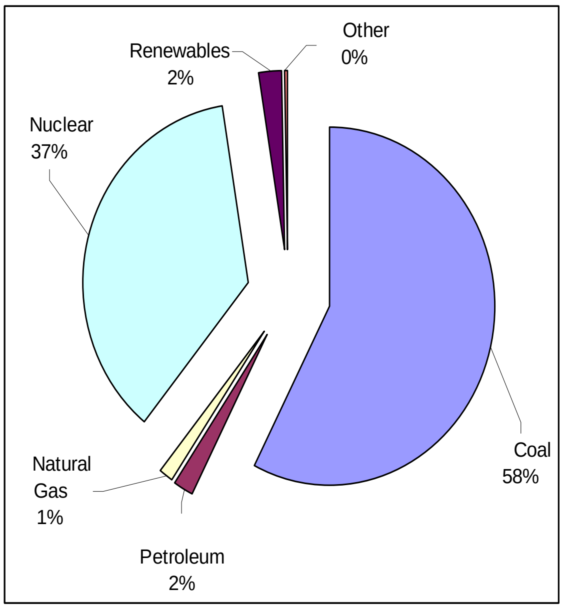
Key Challenges and Opportunities

There are significant opportunities to reduce GHG emissions growth associated with energy production and supply in Pennsylvania. These include promoting distributed, renewable generation; investing in technology research and development; and diminishing the carbon intensity of electrical generation through greater use of nuclear power and natural gas.

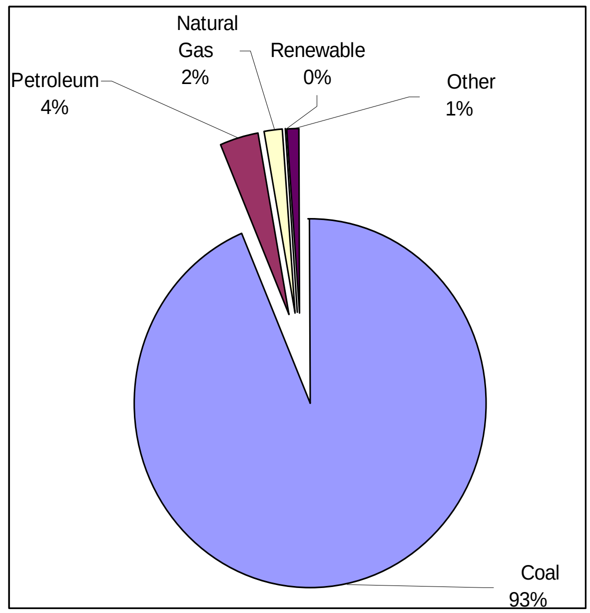
Clearly, the biggest GHG reduction challenge facing Pennsylvania is electricity production. GHG emissions from the combustion of coal for the generation of electricity represent 93 percent of all electricity emissions. So, within the electricity sector, the largest single contribution is from coal-fired generation. Also, continued growth in electricity demand and the age of the state's coal generation fleet are issues of concern. Finally, Pennsylvania is the second largest exporter of electricity in the nation, supplying electricity to the regional energy market area, known as PJM. This means that approaches to reducing Pennsylvania's GHG emissions will need to take into consideration demand patterns and electric reliability considerations in a market area with about 51 million people.

Figure 4-2. Breakdown of Pennsylvania In-state Generation and CO_2 Emissions—2000 Base Year

Gross Generation (201,688 gigawatt-hours)



Emissions ($116.23 MMtCO_2e$)



Increasing electricity demand in Pennsylvania is projected at 1.25 percent per year during the forecast period (2009–2020) even after the demand side management effects of Act 129. There are significant opportunities to reduce GHG emissions through the work plan recommendations addressing electricity consumption. In addition, conservation generally results in significant energy cost savings. The department and the CCAC are recommending two work plans that address improvements for demand-side energy efficiency, while several other opportunities to promote and develop energy efficiency and conservation measures are identified in the residential, commercial, and industrial (RCI) sector, discussed in Chapter 7.

While the age of Pennsylvania's coal-burning power generation fleet is a challenge, it is also an opportunity. Older coal plants are typically less efficient than new plants and many will be candidates for retrofit or replacement within the forecast period. The opportunities to move to lower carbon intensity-based fuels and highly efficient, advanced coal combustion technologies are substantial. In addition, Pennsylvania is endowed with significant, potential renewable energy sources principally from wind and biomass. The region also contains geologic formations that offer significant potential for in-ground CO_2 storage as carbon capture and sequestration technologies become commercially competitive.

Co-firing Coal with Biomass

Co-firing with biomass can play a useful role in reducing plants' net greenhouse gas emissions**.** Even if carbon capture and storage were to become viable, co-firing could still play a role since the CO_2 captured from combustion of biomass would in effect amount to a net withdrawal from the atmosphere.

In recent years there has been increasing interest in the use of biomass for power generation. This has been due to several reasons, the principal one being that the co-utilization of biomass with coal represents a least-cost option for reducing CO_2 emissions.

A number of studies have acknowledged the benefits of sustainably produced biomass in future energy scenarios. A recent study projected that, if only 3 percent of the current coal-fired power generating capacity in Pennsylvania were co-fired, it would amount to 540 MWe of biomass power and offset CO_2 emissions by almost 3.3 Mt per year. Similarly, a National Renewable Energy Laboratory (NREL) study estimated an 18 percent reduction in CO_2 emissions for 15 percent biomass energy co-firing in existing pulverized-coal plants.

Data suggests that if all Pennsylvania coal plants were to co-fire biomass at a 10 percent rate (thermal basis), it would double the current total demand for Pennsylvania woody biomass. This level of demand may impact woody biomass availability, existing wood industries, and potential wood energy projects with higher efficiency of conversion, such as district/industrial CHP projects. However, co-firing of these facilities would potentially produce positive benefits to these alternative biomass markets, and forest management opportunities, if constrained to a more moderate level, in the range of 2-4 percent by thermal input.[2]

Co-firing Coal with Natural Gas

Co-firing with natural gas can provide a useful means of reducing not only CO_2 but also SO_2 and NOx emissions, providing a flexible response to emissions requirements and seasonal fuel prices. Reburning with 20 percent natural gas can reduce CO_2 emissions by up to 10 percent, equaling 9.5 MMt per year in Pennsylvania.

Description of Recent State Actions

Existing policies influence in-state electricity consumption. These include mandates for reduced electricity consumption under Act 129, renewable energy investments under the Alternative Energy Investment Act, and the Alternative Energy Portfolio Standard requiring the procurement of low- to zero-emissions generation resources. Also, renewable energy and energy efficiency projects will be supported through Pennsylvania programs established under the American Recovery and Reinvestment Act.

[2] Personal communication, Dr. Charles Ray, Pennsylvania State University

Electricity 1. Act 129 of 2008 (HB 2200)

The state has an energy efficiency standard in place to secure cost-effective reductions in electricity consumption. The standard, set as part of Act 129 of 2008, was signed into law on October 15, 2008. The Act requires that each major electric distribution company in Pennsylvania achieve specific levels of energy savings and demand reduction:

- A reduction in electricity consumption, by May 31, 2011, of 1 percent below consumption levels for the period June 1 2009, through May 31, 2010.
- A reduction in electricity consumption, by May 31, 2013, of 3 percent below consumption levels for the period June 1, 2009 through May 31, 2010 (additional reduction of 2 percent from the June 2009 through May 2010 baseline for a net total reduction of 3 percent).
- A reduction in peak demand, by May 31, 2013, of 4.5 percent of the highest 100 hours of historical demand for the period June 1, 2007 through May 31, 2008.

The Pennsylvania Public Utility Commission must approve cost-effective energy efficiency and conservation programs for each electric distribution company (EDC) by October 29, 2009. Act 129 does not apply to the very modest consumption and demand of the numbers of municipalities that are authorized to distribute electricity to its residents, the thirteen rural electric cooperatives, and four small regulated electric utilities. It is anticipated that these programs will be in operation at the very end of 2009 or the beginning of 2010.

Electricity 4. Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard

The Alternative Energy Portfolio Standard (AEPS) was signed into law on November 24, 2004. It requires that all electricity sold in Pennsylvania at retail by regulated electric utilities include prescribed levels of renewable and sustainable energy. The required levels of AEPS resources by 2021, and all future years, are at least 0.5 percent solar photovoltaic (PV) technology, 7.5 percent from other renewable (Tier I) sources, and 10 percent from other alternative energy (Tier II) sources. Successive amendments to the AEPS have made clear that electric utilities must make a good faith effort to procure renewable and sustainable energy sources and have added additional resources to the list of those eligible under Tier I.

This analysis of the AEPS requirement includes an understanding of the impact of “price suppression effects” of renewables deployment. The deployment of new renewables drives down the wholesale price of electricity. Known as price effects, or price suppression, any new energy source in the wholesale market at either a low or zero prices will tend to reduce locational marginal prices. This pricing strategy is generally used by resources that must run for various reasons. Renewable resources, including hydroelectric power generally fall into this category. For renewable resources, the intermittent nature of the “fuels” makes it necessary that they operate whenever the sun is shining or the wind is blowing or, for run-of-river hydro, when there is adequate water flow. In other words, they cannot choose to operate according to a set operating schedule or strategy that is determined by fuel prices. For nuclear generation, the operating characteristics make it impossible to cycle these units on and off in response to prices. As a result, they operate as much as 93 percent of the time knowing that, on average, they will make money.

In wholesale electricity markets, prices are set according to marginal offers from generation sources. The market operator, Pennsylvania-New Jersey-Maryland Interconnection, directs entities to turn generation on to meet load. It does this by taking offers from least expensive to most expensive. In practice, this generally means that the most expensive generating source needed to supply electricity demand sets the price. When a very low or zero offer is added to the mix of available units, as is the case with renewables, a more expensive generating unit need not be brought on line and the market price – the price paid by all purchasers in the wholesale market – is lower than it would otherwise have been.

New electric generation resources, including renewables, generally cost less to operate than most existing resources because of improvements in efficiency and lower operating/production costs. Renewables have the lowest operating costs of all power plants. Nuclear power plants have lower operating costs than coal and natural gas-fired power plants. Conversely, renewables have typically had higher capital costs than fossil energy power plants. Capital costs for wind energy are above that of natural gas power plants but are on par with that of coal and less expensive as compared to the estimated costs of a coal-fired power plant equipped with carbon capture and sequestration. Generally, high capital cost generators are low production cost generators and low capital cost generators are high production cost generators. From a consumer's perspective, the effect on the wholesale energy market will be felt in relationship to production costs, not as to their capital cost. For renewables, the price will be lower due to the operating necessities noted above. Their high costs will be recovered from other sources including other PJM markets, monetized tax credits, and renewable energy credits. Thus, the addition of renewables is expected to reduce wholesale electricity market prices in this region (see Appendix E for assumptions).

The price suppression analysis here of the AEPS in Pennsylvania draws upon a PJM study examining such effects for the region.[3] In their study, the PJM estimates savings of $4-4.5 billion from the 43,000 gigawatt hours (GWh) of wind generation in 2013. This equates to approximately $100 per megawatt hour (MWh) of wind generation ($4.25 billion / 43,000 GWh) in the study. The PJM study base case indicates a gas price assumption of $6.44/MMBtu, along with a comparable 2008 coal price, that drives a $100/MWh price suppression effect.[4] If fossil fuel prices increase, the price suppression effect will correspondingly increase. Since fossil fuel prices have since fallen below the levels used in the PJM study (Jan. 2009), a lower price of $50/MWh for each MWh of renewable generation added to the system is used for this analysis. This analysis also examines a scenario of no price suppression associated with renewables deployment—that is, $0/MWh price suppression effect for each MWh of renewables. The two price suppression scenarios lead to a range of potential costs of the AEPS, ranging from a low of -$615 million to $1.56 billion from 2009 to 2020.

[3] PJM (2009). Potential Effects of Proposed Climate Change Policies on PJM's Energy Market. http://www.pjm.com/documents/~/media/documents/reports/20090127-carbon-emissions-whitepaper.ashx
[4] PJM (2009). p. 7 footnote 7. http://www.pjm.com/documents/~/media/documents/reports/20090127-carbon-emissions-whitepaper.ashx.

Overview of Work Plan Recommendations and Estimated Impacts

The Electricity Generation, Transmission and Distribution Subcommittee membership includes Wayne Williams (former Chair), David Cannon (Chair), Richard Allan, Robert Barkanic, George Ellis, Sarah Hetznecker, Jan Jarrett, John Quigley, Nathan Willcox and Ed Yancovich. The department and the CCAC recommend a set of nine work plans for the EGTD sector. Taken together, these offer the potential for significant GHG emission reductions. Of the nine work plans, seven were analyzed for their potential emission reduction and cost impacts and two are recommended as non-quantified work plans. In addition, the CCAC analyzed two recent state actions (documented in the work plan format) to estimate their potential emission reduction and cost impacts. Table 4-1 presents the analytical results for the seven quantified work plans and two recent actions discussed above. Impacts are presented on an annual basis for 2020 and on a cumulative basis for the 2009 to 2020 period. The last column of Table 4-1 summarizes the number of CCAC members that voted to approve, disapprove, or abstained from recommending that DEP include the work plans in the Pennsylvania Climate Action Plan.

In addition to the GHG emissions reductions the work plan recommendations provide other co-benefits. Several of the work plans will provide decreases in emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), mercury, other hazardous air pollutants and fine particulate matter. Reductions in NOx emissions foster a decrease in the formation of ground-level ozone that contributes to a variety of respiratory ailments, particularly among children and the elderly. Implementation of recommendations that result in reductions of criteria air pollutants, such as SO_2 and NO_x can also make it easier and more cost-effective for power generators to comply with federal clean air standards. Self-generating electrical and thermal energy through the operation of combined heat and power (CHP) systems maximizes the efficient use of energy reducing overall energy expenditures. CHP systems also provide increased power reliability and can help decrease congestion mitigation concerns.

The analysis of the two recent actions show that Pennsylvania is already making significant progress in mitigating GHG emissions associated with the EGTD sector. As shown at the bottom of Table 4-1, the two recent actions together are estimated to reduce annual emissions in 2020 by 15 $MMtCO_2e$, and cumulative emissions by 116 $MMtCO_2e$ over the 2009-2020 period. Act 129 (Electricity-1) is expected to result in a net cost savings while the effects of the AEPS (Electricity-4) could result in a net cost or cost savings depending on the previously discussed impact of “price effects” of renewable energy deployment.

Table 4-1. Summary Results for Electricity Generation, Transmission, and Distribution Work Plan Recommendations and Recent Actions (noted at bottom of table)

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained) [1]
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)	
2	Reduced Load Growth	7	-$432	-$64	23	-$849	-$36	13 / 8 / 0
3	Stabilized Load Growth	9	-$593	-$64	27	-$990	-$36	13 / 8 / 0
5	Carbon Capture and Sequestration in 2014	5	$291	$58	13	$391	$31	20 / 1 / 0
6	Improve Coal-Fired Power Plant Efficiency by 5%	5	$82	$1	55	$903	$1	13 / 8 / 0
7	Sulfur Hexafluoride (SF_6) Emission Reductions from the Electric Power Industry	0.1	$0.1	$0.6	0.7	$0.3	$0.4	20 / 1 / 0
8	Analysis to Evaluate Potential Impacts Associated with Joining RGGI	See Appendix D						NA
9	Promote Combined Heat and Power (CHP)	4	$53	$12	23	$209	$9	21 / 0 / 0
10	Nuclear Capacity	15	$832	$57	31	$655	$21	20 / 1 / 0
11	Greenhouse Gas Performance Standard for New Power Plants	Qualitative Work Plan--Not Quantified						21 / 0 / 0
12	Transmission and Distribution Losses	Qualitative Work Plan--Not Quantified						21 / 0 / 0
Sector Total After Adjusting for Overlaps		**32**	**$1,006**	**$31**	**131**	**$1,060**	**$8**	
Recent State Actions [2]		**15**	**-$1,001 to $285**	**-$91 to 26**	**116**	**-$2,790 to $1,560**	**-$37 to $21**	
1	Act 129 of 2008 (HB 2200) (Already in Electricity Baseline Forecast)	4	-$258	-$65	40	-$1,409	-$35	NA
4a	Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard (No Price Suppression)	11	$285	$26	76	$1,560	$21	NA
4b	Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard (Moderate Price Suppression)	11	-$358	-$33	76	-$615	-$8	NA
4c	Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard (Full Price Suppression)	11	-$1,001	-$91	76	-$2,790	-$37	NA
Sector Total Plus Recent Actions		47	See Ranges above	See Ranges above	247	See Ranges above	See Ranges above	

[1] NA in this column means "not applicable." Electricity 1 and 4 are recent Commonwealth of Pennsylvania actions. For Electricity 8, the CCAC analyzed the potential impacts associated with joining the RGGI initiative only and, therefore, was not considered as a work plan recommendation.

[2] Totals are shown as a range reflecting the estimated GHG emission reductions and cost savings associated with Act 129 and the GHG emission reductions and range of costs / savings associated with the three Alternative Energy Portfolio Standard scenarios (i.e., without price suppression effects and with a moderate and high price suppression effects scenario)

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; RGGI = Regional Greenhouse Gas Initiative.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

The potential impacts associated with the seven quantified work plans were estimated and are incremental to the two recent actions. The results indicate that, if all seven work plans are fully implemented, they have the potential to reduce annual emissions in 2020 by 32 $MMtCO_2e$ at a cost over the next 11 years of about $1.1 billion on a net present value basis (NPV).[5]

- The weighted-average cost-effectiveness of the work plans combined is estimated to be a net cost of about $33 per ton of CO_2e reduced ($\$/tCO_2e$) in 2020.
- From 2009 through 2020, the work plans (if fully implemented) are estimated to reduce cumulative GHG emissions by 131 $MMtCO_2e$ with a potential net cost of about $1.86 billion on a NPV basis.
- The weighted-average cost-effectiveness of the work plans combined is estimated to be a net savings of about $\$14/tCO_2e$ for the 2009 through 2020 period.

Although not quantified, implementation of Electricity-11 and Electricity-12 have the potential to cost-effectively reduce emissions further if these recommendations are carefully, designed and implemented.

- Electricity Work Plan Nos. 2 and 3 (Electricity-2 and Electricity-3) include recommendations to increase demand-side energy efficiency in the state.
- Electricity-5 and Electricity-6 would affect coal-fired generation through higher efficiencies and carbon capture.
- Electricity-7 and Electricity-12 primarily affect transmission and distribution infrastructure.
- Electricity-9 incentivizes more combined heat-and-power.
- Electricity-10 would result in higher nuclear capacity in the state through uprates (increase in electrical power generation) at existing nuclear power plants and through the potential construction of a new nuclear power plant.
- Electricity-11 includes recommendations for DEP to conduct detailed technical and economic assessments potentially leading to a standard for new fossil-fuel generation units that would provide an equitable working environment for all sectors of Pennsylvania's economy.
- Regional Greenhouse Gas Initiative (RGGI) is a power plant generation standard. Electricity-8 is included for the purpose of evaluating the potential impacts associated with Pennsylvania joining the RGGI; however, the CCAC performed this analysis for informational/comparative purposes only and did not include this work plan among the CCAC's set of work plan recommendations.

[5] The net costs or cost savings, shown in constant 2007 dollars, are based on fuel expenditures, operations, maintenance, and administrative costs, and amortized, incremental equipment costs. All NPV analyses here use a 5 percent real discount rate.

The quantification results reported in Table 4-1 take into account overlaps in the expected emissions reduction and costs. Specific overlaps dealt with include work plan recommendations within the EGTD sector, as well as between work plan recommendations in the EGTD, RCI, and agricultural, forestry, and waste management sectors. Care was taken in the determination of emission reductions and costs (or cost savings) from each of the sectors to ensure that the combined calculated impact of the work plans would not “double count” impacts. Thus, overlapping impacts have been eliminated from the analysis in this chapter. Primary areas of overlaps are:

- Several interactions are possible within work plans in the ETGD sector. First, Electricity-3, Stabilized Load Growth, includes a requirement that some of the electricity demand in the state be met with energy efficiency measures and would overlap with the energy efficiency goals of Electricity-2, Reduced Load Growth. The reductions under Electricity-2 were eliminated as a result.

- In addition, a number of the RC work plans (RC-3, RC-4, RC-5, RC-6, RC-7 and RC-8) decrease overall electricity demand through specific measures. As Electricity-3 sets a goal for overall demand-side energy efficiency, the resulting saved energy associated with the overlaps with the RC work plans listed above were eliminated to avoid double-counting.

- An overlap between Electricity-3 and Industry Work Plan No. 2 (Industry-2) for industrial energy efficiency was addressed by reduced the combined estimated reductions from Electricity-3 to ensure consistency with 2025 of industrial efficiency potential from a report by the American Council for an Energy-Efficient Economy.

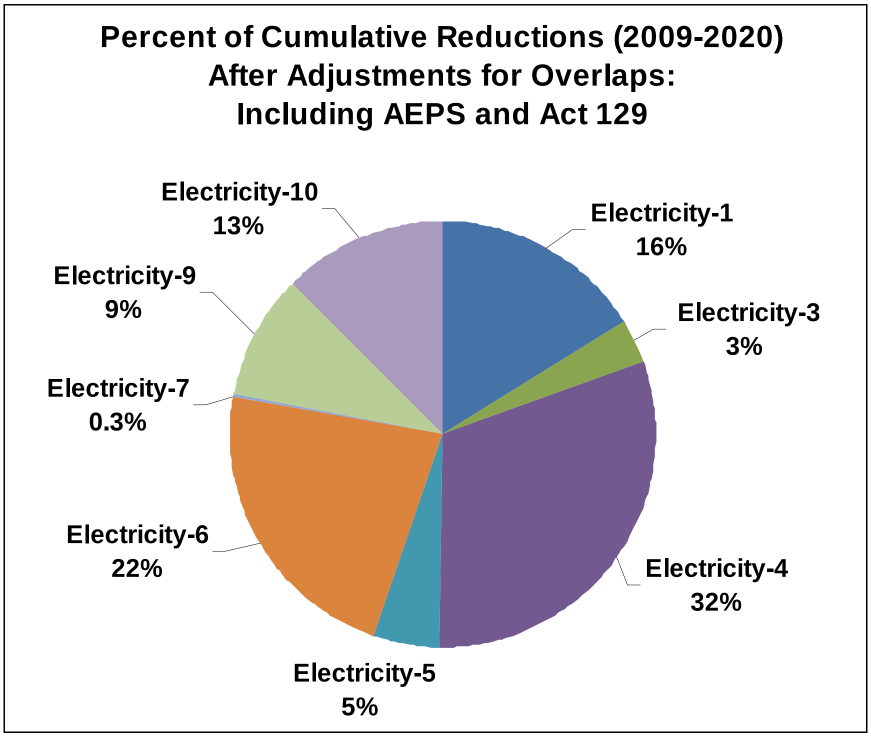
- See Appendix E, Electric Generation, Transmission and Distribution Work Plans, for additional description of overlaps among sectors and of analyses of the cumulative GHG reductions from the combined effects of the CCAC work plans that were quantified.

Description of Work Plan Recommendations

The EGTD sector has several opportunities for mitigating GHG emissions from electricity generation. These include all identifiable activities associated with the generation, transmission, and distribution of electricity. Taken into consideration is the combustion of fossil fuels, renewable energy sources in a centralized power station supplying the grid, and distributed generation facilities. The CCAC work plan recommendations are described briefly here and in more detail in Appendix E of this report.

After adjusting for overlaps, the work plans discussed below produce a cumulative (2009-2020) reduction of 131 $MMtCO_2e$. Figure 4-3 depicts the quantity of GHG reduction identified for each of the seven quantified work plans and reductions associated with the two recent state actions (after adjusting for overlaps) contributes to the total reductions associated with the seven quantified work plans and recent state actions combined. Note that the Electricity Work Plan numbers 11 and 12 were not quantified, (and Electricity 8 was not considered for recommendation as a work plan to DEP) so there are no GHG emissions reductions associated with these work plans.

Figure 4.3. Contribution by Each Work Plan and Each Recent State Action to Total Emission Reductions Associated with the Work Plans and Recent State Actions Combined for the Electricity Generation, Transmission, and Distribution Sector



The percent contribution by each work plan or recent action is calculated by dividing the cumulative reduction (2009-2020) for the work plan or recent state action by total cumulative reductions for all work plans and recent state actions combined (i.e., 247 $MMtCO_2e$). See Table 4-1 for numeric values used to calculate the percentages shown in this figure. The recent state actions include Act 129 (Electricity #1) and AEPS (Electricity #4).

Electricity 2. Reduced Load Growth

This work plan builds upon the electricity consumption requirements of Act 129 by requiring additional biennial reductions in electricity consumption equal to 1.5 percent per biennial period (0.75 percent/year), beginning in 2015 and carrying through 2020. The energy efficiency investments under this work plan reach 8.25 percent of load by the end of 2025 (11 years at 0.75 percent/year). These reductions are calculated from the previous year's estimated consumption. Note that this analysis does not include the very modest consumption and associated system losses from municipal electric utilities or for rural electric cooperatives.

Thirteen of the CCAC members approved and eight members disapproved of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan. One concern raised was an objection to any expansion of Act 129-style requirements until Act 129 was fully implemented and the state could gauge the effectiveness and cost to ratepayers of expanding the Act's requirements.

Electricity 3. Stabilized Load Growth

This work plan builds upon the electricity consumption requirements of Act 129 through additional reductions of 0.75 percent/year in the period 2015 through the end of 2017. This is followed by an assumption that consumption is static from 2018 through 2025. Historical annual load growth in Pennsylvania has been approximately 1.5 percent/year, which is what would be reduced in the 2018–2025 period. Therefore, the energy efficiency investments under this work plan affect 14.4 percent of load by the end of 2025 (2015–2017 at 0.75 percent/year, 2018 at 0.85 percent/year, and 2019–2025 at 1.6 percent/year). The annual reductions in 2018–2025 would be based on the previous year's consumption figures and would allow a subsequent one-year "true-up" for electricity distribution companies to achieve stabilized consumption levels. Note that this analysis does not include the very modest consumption and associated system losses from municipal electric utilities or for rural electric cooperatives.

Thirteen of the CCAC members approved and eight members disapproved of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan. One CCAC member objected to any expansion of Act 129-style requirements until Act 129 was fully implemented and the state could gauge the effectiveness and cost to ratepayers of expanding the Act's requirements.

Electricity 5. Carbon Capture and Sequestration in 2014

The work plan entails carbon capture retrofit to existing supercritical pulverized coal plants starting in 2015 through 2019. In addition, the work plan calls for installation of an integrated coal gasification combined-cycle (IGCC) plant in the state in 2020. Retrofits of existing supercritical pulverized coal plants entail amine scrubbing with a CO_2 capture rate of 90 percent and an increase in heat rate (a decrease in efficiency). The reduction in efficiency results because the amine-scrubbing system diverts steam for power generation or consumes additional power for CO_2 compression. IGCC power plants use coal to produce electricity. The technology is based around a gasifier that produces a mixture of hydrogen and carbon monoxide called syngas. This syngas is burned in a gas turbine that is used to drive a generator. IGCC technologies with CO_2 capture are equipped with three more processes than the conventional IGCC technology without capture. The first is a process of reacting syngas with steam to produce CO_2 and hydrogen through shift reactors. The second process separates the CO_2 from the remaining gas. The final process compresses and dries the CO_2. Adding CO_2 capture technology to IGCC plants significantly reduces overall plant efficiency.

Twenty of the 21 CCAC members approved and one member disapproved of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan.

Electricity 6. Improve Coal-Fired Power Plant Efficiency by 5 percent

This work plan would entail a 5 percent increase in energy efficiency at coal-fired power plants by 2025. Each facility would have the flexibility to meet this efficiency requirement at the least-cost method available. This measure is assumed to be implemented linearly in 2015 following scheduled outage in PJM queue. Work plan implementation methods would need to be designed so as not to trigger the "Major Modification" clause in the U.S. Environmental Protection Agency's (EPA) New Source Review (NSR) program for major stationary sources in attainment areas for the National Ambient Air Quality Standards. NSR requires plant owners to undergo review for environmental controls in case of major modifications beyond routine maintenance, repair, and replacements. Determination of what measures trigger NSR is made on a case-by-case basis, with numerous efforts by EPA to create broader guidelines to inform plant owners what measures trigger NSR.

Thirteen of the 21 CCAC members approved and eight members disapproved of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan. Several of the CCAC members disapproving of recommending this work plan noted that plant efficiency measures that trigger NSR could dramatically alter the "cost effectiveness" and economics of the work plan. Other CCAC members believe that such an efficiency requirement would not work for subcritical generation, which could not bear the capital costs. They also believe that such improvements would have already been made for supercritical facilities to the extent that they would not trigger New Source Review.

Electricity 7. Sulfur Hexafluoride (SF_6) Emission Reductions from the Electric Power Industry

This work plan uses a pollution prevention approach, including a best management practice (BMP) manual and recordkeeping and reporting requirements, to ensure that all SF_6 emission reductions are quantified and permanent. SF_6 is identified as the most potent non-CO_2 GHG, with the ability to trap heat in the atmosphere 23,900 times more effectively than CO_2. Approximately 80 percent of SF_6 gas produced is used by the electric power industry in high-voltage electrical equipment as an insulator or arc-quenching medium. Sulfur hexafluoride is emitted to the atmosphere during various stages of the equipment's life cycle. Leaks increase as equipment ages. The gas can also be accidentally released at the time of equipment installation and during servicing.

Twenty of the 21 CCAC members approved and one member disapproved of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan.

Electricity 8. Analysis to Evaluate Potential Impacts Associated with Joining RGGI

In response to comments during the CCAC's process for identifying work plans to analyze, the CCAC asked the EGTD Subcommittee to evaluate potential impacts associated with Pennsylvania joining the Regional Greenhouse Gas Initiative (RGGI). However, the CCAC agreed to not include this work plan with the set of work plans the CCAC considered recommending to DEP for inclusion in the state's Climate Action Plan. This work plan was not included with the set of work plan recommendations for several reasons, including the length of time required for the state to determine whether to join RGGI and the functional overlap between RGGI and the CCAC process. The CCAC, however, did recommend that the EGTD Subcommittee's evaluation of potential impacts associated with Pennsylvania joining RGGI be included as appendix or attachment in Appendix F of this report so as not to lose the data and analysis. Consequently, the CCAC did not vote on this work plan.

Electricity 9. Promote Combined Heat and Power (CHP)

This work plan encourages distributed Combined Heat and Power systems to reduce fossil fuel use and GHG emissions. Reductions are achieved through the improved efficiency of Combine Heat and Power systems, relative to separate heat and power technologies, and by avoiding the transmission and distribution losses associated with moving power from central generation stations to distant locations where electricity is used. CHP is a term used to describe scenarios in which waste heat from energy production is recovered for productive use. The theory of CHP is to maximize the energy use from fuel consumed and to avoid additional GHG's by the use of reclaimed thermal energy. The reclaimed thermal energy can be used by other nearby entities (e.g., within an industrial park or district steam loop) for productive purposes. Generating stations in urban areas may have existing opportunities or may require the co-location of new industry.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Electricity 10. Nuclear Capacity

This work plan examines the potential impact of capacity uprates at existing nuclear plants in the state, as well as a new plant build. This work plan incorporates both existing facility uprates, some of which are already in progress, as well as new nuclear capacity. To increase the power output of a reactor, typically a more highly enriched uranium fuel is added. This enables the reactor to produce more thermal energy and therefore more steam, driving a turbine generator to produce electricity. To accomplish this, such components as pipes, valves, pumps, heat exchangers, electrical transformers, and generators must be able to accommodate the conditions that would exist at the higher power level. In some instances, facilities will modify and/or replace components to accommodate a higher power level. Depending on the desired increase in power level and original equipment design, this can involve major and costly modifications to the plant, such as the replacement of main turbines. All of these factors must be analyzed by the facility as part of a request for a power uprate, which is accomplished by amending the plant's operating license. The analyses must demonstrate that the proposed new configuration remains safe and that measures continue to be in place to protect the health and safety of the public. Before a request for a power uprate is approved, the Nuclear Regulatory Commission must review these analyses.

The CCAC approved this work plan by a supermajority vote. Several members of the CCAC suggested that the work plan could be reviewed in three years as part of the periodic DEP review of its nascent action plan. The CCAC intends this work plan to serve as a study item, rather than a work plan with implementation steps for the state.

Electricity 11. Greenhouse Gas Performance Standard for New Power Plants

This work plan provides recommendations to ensure that newly added fossil fuel-fired electric generating capacity would be consistent with the efforts of the commonwealth to establish and maintain a climate change action plan. It would involve detailed technical and economic assessments potentially leading to a standard that would provide an equitable working environment for all sectors of Pennsylvania's economy, and that would balance the goal of reducing GHG emissions with the capability of meeting future energy demand within the commonwealth. Such a performance standard could conceivably set standards unachievable by existing or proposed coal-fired generation and only possible through carbon capture and sequestration. Carbon capture and sequestration is not currently commercially available at the scale required nor are there other technologies on the immediate horizon that could significantly reduce CO_2 emissions. Generators could possibly meet the overall GHG reduction standards through the purchase of an equivalent volume of Certified Emissions Reductions, but this would also involve a detailed analysis of the available market and how it could be structurally related to a performance standard.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Electricity 12. Transmission and Distribution Losses

This work plan examines potential increases in efficiency associated with new and existing transmission and distribution lines. It recommends that DEP look at potential increases in efficiency which reduces transmission and distribution losses. Because of the complexity, technical uncertainties and relation to national and state energy policy in this work plan, the CCAC elected to include it as a non-quantified work plan recommendation for further review by DEP.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Conclusion

The electricity generation, transmission, and distribution (EGTD) sector is the largest source of GHG emissions in the state. The proportion of the state's GHG emissions from EGTD is expected to increase through 2020. Coal-fired power generation accounts for nearly all of the state's GHG emissions from the EGTD sector. Significant opportunities to reduce GHG emissions from EGTD include: promotion and use of renewable energy sources to assist in fossil fuel combustion reduction; promotion and use of lower carbon fuels for electricity generation; retrofitting/replacement of less efficient coal-fired power plants; increase capacity at existing nuclear power plants; and investing in technology research and development including, but not limited to, carbon capture and sequestration technologies.

Next Steps – Pathways to Implementation

The department received comments from the PUC that through their authority under Act 129 they have contracted a statewide evaluator (SWE) that will conduct a market potential study to determine areas for additional incremental energy and load reductions and provide a report to the Commission by October 15, 2013. The contractor will also provide an Energy Efficiency and Conservation Program assessment report that will provide recommendations for improving the program as a whole. The report will also perform a cost-benefit analysis and recommend if additional reduction requirements should be imposed and what those reduction targets should be.

The department commented that they will work with DCNR on carbon capture and sequestration siting and permitting issues and work with EPA on determining what efficiency improvements can be made at power plants without triggering New Source Review (NSR) requirements. Combine Heat & Power (CHP) unit permit applications will be prioritized. DEP will encourage new legislation to establish GHG emissions standards for all new GHG emitting electricity generating units that will require offsetting an equal and maximum allowable level of GHG emissions. In all cases DEP will examine their existing regulatory authority with permit issuance to ensure that permits can be issued swiftly but without compromising the environment.

Chapter 5
Residential and Commercial Sector

Sector Overview

Overview of GHG Emissions

Building operations and occupancy contributes to a significant portion of Pennsylvania's greenhouse gas (GHG) emissions. GHG emissions associated with the combined Residential and Commercial (RC) sectors accounted for 35 percent of the total GHG emissions in 2000. These emissions are associated predominantly with energy use in homes and buildings, including institutional buildings, but also include other services such as street lighting, sewage and water treatment services. Therefore, the state's future GHG emissions will depend heavily on future trends in the consumption of electricity and other fuels in these sectors.

RC emissions can be separated into two categories – direct emissions that occur where fuels are used on-site and indirect emissions that occur at sites where electricity is produced to serve RC buildings and facilities. Direct emissions of GHGs from the RC sectors result principally from the on-site combustion of natural gas, oil, and coal. In 2000, Pennsylvania's direct emissions from the RC sectors accounted for 14 percent of total statewide gross GHG emissions on a consumption basis. On-site electric generation is a vanishingly small portion of RC emissions.

Considering only the direct emissions that occur within home and buildings, however, ignores the GHG emissions associated with electricity use in these facilities. Two thirds (67 percent) of electricity sold in Pennsylvania – or almost half of all electricity produced - is consumed as the result of activities in the RC sectors. Emissions associated with producing the electricity consumed in the RC sectors were responsible for approximately 21 percent of the State's total in 2000. Further details on GHG emissions from electricity generation, and options for reducing the GHG emissions from the supply-side, are provided in Chapter 4.

Figure 5-1 shows historical and projected GHG emissions from sources in the RC sectors. The projections indicate that GHG emissions from the RC sectors will grow by almost 23 percent from 2000 to 2020. All of the increased emissions will be due to growing electricity consumption (43 percent increase). In fact, GHG emissions from direct fuel use (coal, natural gas and heating oil) are projected to decrease by 5 percent over the same period. This projection is based on a trend already seen in Pennsylvania; as consumption of coal, natural gas and heating oil decreased between 2000 and 2005.

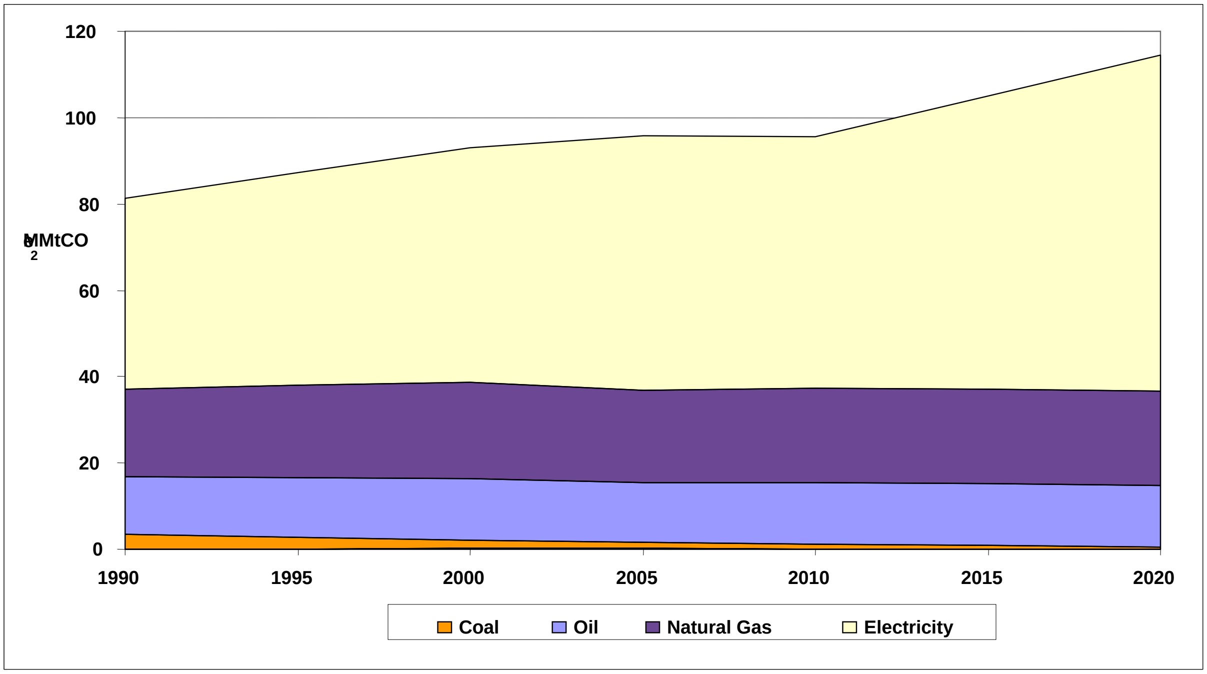
Key Challenges and Opportunities

Pennsylvania's GHG emissions from RC sectors are projected to increase by almost 23 percent between 2000 and 2020. In contrast, Pennsylvania's projected growth in population and the economy are relatively low. These two trends will be associated with limiting growth in GHG emissions. The U.S. Department of Commerce, Bureau of the Census projects Pennsylvania's population to grow by 2 percent between 2000 and 2020 and total housing units to grow by

6 percent in this time period.[1] Projected growth in electricity consumption for these sectors is 29 percent, significantly higher than population or housing growth. This indicates increased use of electricity per household, as some homes switch to more electricity heating and others add services such as air conditioning. Increased electricity consumption per household appears to drive much of the increase in GHG emissions between 2000 and 2020.

Overall, there are challenges to identifying effective options for reducing emissions below current levels. For example, much of Pennsylvania's building stock is older and was not designed to conserve energy. It will be a challenge to renovate this very large number of buildings and achieve high efficiencies. Pennsylvania also has a significant rural population that may face barriers associated with adopting programs focused on new technologies and practices. These barriers include a lack of readily available, high quality information sources – including a lack of well-distributed high speed internet service – and less easily accessed contractors with necessary skills in energy efficiency retrofits.

Figure 5-1. Recent and Projected GHG Emissions from the Residential and Commercial Sectors, Pennsylvania, 1990–2020



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Note: GHG emissions from wood combustion are less than 0.2 $MMtCO_2e$ and not visible on the chart. Emission estimates from wood combustion include only (N_2O) and methane (CH_4). Carbon dioxide emissions from biomass combustion are assumed to be "net zero," consistent with U.S. Environmental Protection Agency (EPA) and Intergovernmental Panel on Climate Change (IPCC) methodologies, and any net loss of carbon stocks due to biomass fuel use should be accounted for in the land-use and forestry analysis.

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[1] U.S. Department of Commerce, Bureau of the Census, 1990 Census of Population and Housing. Prepared by the Pennsylvania State Data Center.
http://pasdc.hbg.psu.edu/pasdc/PA_Stats/profiles_tables_and_charts/pennsylvania/pop_other/04XT1-16.html
http://www.census.gov/popest/housing/HU-EST2007.htm

There will be a number of opportunities to reduce emissions in the RC sectors in spite of current projections for increased emissions. A number of key GHG mitigation measures will be necessary to support homeowners and businesses as they seek to reduce emissions. Among opportunities to reduce GHG emissions, energy efficiency in new and existing buildings (including roofing and lighting technologies and ground-source heat pumps) is the most important. Other important measures include high efficiency appliances, improved efficiency of furnaces and other equipment using natural gas and heating oil, reducing water consumption, and use of renewable resources and other low-GHG energy sources (such as photovoltaics). It is also clear that successful expansion of these critical technologies will be far more effective if paired with education for the public and training for building professionals.

One important component of educating the public is to increase awareness of electricity losses from standby power, known as "vampire loads." Lawrence Berkeley National Laboratory notes that no one knows with certainty how much energy is consumed, in total, by household appliances in standby mode (the impacts on space heating and additional cooling loads need to also be considered), but 5 to 10 percent of residential electricity consumption is likely. In Pennsylvania, this amounts to 2,700 to 5,400 GWh at a cost of between 325 to 650 million dollars annually (at 0.121 dollars per kWh). The annual GHG emissions due to "vampire loads" are estimated to be 1.5 to 3.0 $MMtCO_2e$. The U.S. Department of Energy and the Energy Star program are likely to develop further information for public education to reduce standby power.

Overview of Work Plan Recommendations and Estimated Impacts

The CCAC Residential and Commercial Subcommittee membership includes Vivian Loftness (Chair), Robert Barkanic, Ronald Ramsey, Nathan Willcox and Laureen Boles. Drew Brown with City of Philadelphia Water Department contributed his expertise in water conservation. The CCAC has recommended 12 work plans for the RC sectors. The department agrees that these offer the potential for significant, cost-effective GHG emission reductions. Of these 12 work plans, eight were analyzed for their potential emission reduction and cost impacts and three are recommended as non-quantified work plans. In addition, the CCAC analyzed and has incorporated the effects of one recent federal action for appliance standards because the effects of the standards are not included in the baseline emissions forecast. Table 5-1 presents the analysis of the eight quantified work plans as well as the impacts associated with federal appliance standards. These impacts are presented on an annual basis for 2020 and on a cumulative basis for the 2009 to 2020 period. The last column of Table 5-1 summarizes the tally of votes among CCAC members on each work plan. The RC- 12 work plan titled "Demand Side Management – Electricity" was not recommended by CCAC because some members were unsure of what the plan recommended and there was also concern over the quantification of GHG emissions that could be achieved through the education and workforce training component.

The work plans not only result in significant emission reductions and overall cost savings, but offer the potential for several additional co-benefits as well. These co-benefits include health benefits from replacing old lighting containing PCBs. Manufacturing would increase for supplies of fixtures, blinds and ceilings and could also increase employment for engineers and union workers. Appliance standards are cost-effective ways for consumers to save energy due to long-term running costs being lowered. Green roofs have measurable benefits in reducing heat island effect. Water conservation is a co-benefit for the RC-13 work plan.

This analysis projects that full implementation of all plans will reduce annual emissions in 2020 by 32 $MMtCO_2e$. The projected cost savings for the plans is estimated at $538 million (after adjusting for overlaps) on a net present value basis (NPV).[2] The combined plans are expected to result in a net savings of about $17 per ton of CO_2e reduced ($/t$CO_2e$) in 2020. Over the period from 2009 through 2020, the work plans are estimated to reduce cumulative GHG emissions by 214 $MMtCO_2e$ with a potential NPV savings of about $3.67 billion.

The range of results reported in Table 5-1 is adjusted to take into account overlaps in the expected emissions reduction and costs (or cost savings) among the work plans recommended throughout the report. This was done to ensure that emission reductions, costs, and cost savings were not "double counted". In particular, the analysis for RC Work Plan No. 8 (Pennsylvania Buys Energy Efficient (EE) Appliances) was conducted exclusive of impacts of the federal appliance standards discussed below.

[2] The net costs or cost savings, shown in constant 2007 dollars, are based on fuel expenditures; operations, maintenance, and administrative costs; and amortized, incremental equipment costs. All net present value analyses here use a 5 percent real discount rate.

Table 5-1. Summary Results for Residential and Commercial Sector Work Plan Recommendations

Work Plan No.	Work Plan Name	Annual Results (2020) GHG Reduc-tions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $)	Annual Results (2020) Cost-Effectiveness ($\$/tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $)	Cumulative Results (2009-2020) Cost-Effectiveness ($\$/tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)
1-4	High-Performance Buildings (Total for RC-1 Through RC-4)	31.9	-$256.3	-$8.0	139.7	-$1,653	-$11.8	21 / 0 / 0
1	High-Performance State and Local Government Buildings	2.7			11.3			
2	High-Performance School Buildings	1.9			7.8			
3	High-Performance Commercial (Private) Buildings	9.0			37.4			
4	High-Performance Homes (Residential)	18.3			83.1			
5	Commissioning and Retrocommissioning PA Buildings	1.5	-$17	-$11.2	9.6	-$71	-$7.4	21 / 0 / 0
6	Re-Light Pennsylvania	12.9	-$823	-$64	103.2	-$4,020	-$39	20 / 0 / 1
	Residential	3.5	-$328	-$95	30.0	-$1,887	-$63	
	Commercial—lighting power density	5.3	-$367	-$69	30.7	-$806	-$26	
	Commercial—fixture performance	4.0	-$136	-$34	33.9	-$1,039	-$31	
	Commercial—daylighting	0.8	-$64	-$82	5.0	-$204	-$41	
	Commercial—controls	2.1	$108	$52	14.3	$511	$36	
	Commercial—parking lot lighting	1.1	-$117	-$103	10.5	-$613	-$58	
	Commercial—exit signs	0.0	-$1	-$64	0.1	-$6	-$44	
7	Re-Roof Pennsylvania	1.4	$472	$327	4.3	$1,064	$247	14 / 7 / 0
	Light-colored, insulated roofs	0.2	-$4	-$18	0.8	$13	$17	
	Green roofs	0.1	$77	$614	0.3	$147	$462	
	PV roof	1.1	$399	$359	3.2	$903	$282	
8	PA buys EE appliances	1.9	-$68	-$36	12.4	-$291	-$24	13 / 8 / 0
9	Geothermal Heating and Cooling	1.4	$224	$158	8.0	$879	$109	21 / 0 / 0
10	DSM - Natural Gas	7.3	-$51	-$7	40.5	-$357	-$9	21 / 0 / 0
11	Conservation and Fuel switching for Heating Oil	5.7	-$21	-$4	35.8	$140	$4	21 / 0 / 0
13	DSM - Water	0.1	-$255	-$1,944	0.8	-$1,011	-$1,285	21 / 0 / 0
14	Renew PA buildings PA Values Embodied Energy in Building Materials, Including Historic Structures	Not quantified						17 / 1 / 2
15	Sustainability Education Programs	Not quantified						17 / 1 / 2
16	Adaptive Building Reuse	Not quantified						17 / 1 / 2
Sector Total After Adjusting for Overlaps		32.25	-$538	-$17	214.5	-$3,668	-$17	
Reductions From Recent Federal		5.07	-$145	-$28	29.9	-$567	-$19.0	
Federal Appliance Standards - Electricity		4.77			28.7			
Federal Appliance Standards - Natural Gas		0.3			1.2			
Sector Total Plus Recent Actions		37.4	-$683	-$18	244.4	-$4,235	-$17	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.
Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.
The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

Description of Recent Federal Actions

The Energy Security and Independence Act, enacted by the federal government in December 2007, included energy efficiency standards for a number of appliances such as air-conditioners, dehumidifiers, motors, lamps, clothes washers, and boilers. These standards come into force between 2008 and 2014, depending on the type of product, and will results in electricity and natural gas savings in Pennsylvania based on sales of these products. Estimates of the impact of these appliance standards on GHG emissions and costs are reported in table 5-1.[3]

These new federal standards analyzed at the bottom of Table 5-1 are estimated to provide additional emission reductions and cost savings for Pennsylvania. These estimates show that annual emissions will be reduced by about 5 $MMtCO_2e$ in 2020. In addition, cumulative emissions will fall by about 30 $MMtCO_2e$ over the 2009-2020 period. Financial benefits are estimated at about $145 million in 2020 and a total cumulative savings of about $567 million from 2009 through 2020. These substantial benefits further demonstrate that addressing GHG emissions need not increase consumer costs.

Description of Work Plan Recommendations

The CCAC's work plan recommendations for the RC sectors are described in the following paragraphs and, in more detail in Appendix F. Figure 5-2 shows how each work plan plus the federal appliance standards contributes to the overall GHG reduction projected for the RC sector. Note that no GHG emissions reductions are associated with the unquantified RC Work Plan Numberss. 13, 14, and 15.

RC-1-4. High Performance Buildings

The High-Performance Buildings work plans are a set of energy performance goals for all buildings in Pennsylvania. These goals help to provide overall direction for future programs and policies that will be needed to meet the goals and subsequently reduce GHG emissions from these sectors. Work plans RC-1 through RC-4 recommend energy performance goals for new and existing government and commercial (private) buildings, school buildings, and residential homes - performance goals and timing differ slightly between public and private sectors. The performance goals for these work plans generally come from the Architecture 2030 Challenge building goals, with some revisions from the CCAC and the Residential Commercial

[3] Energy savings from 2007 federal appliance standards were estimated for Pennsylvania and reported in *Pennsylvania: Energy Efficiency, Demand Response and On-Site Solar Potential*. American Council for Energy Efficient Economy, Summit Blue Consulting, Vermont Energy Investment Corporation, ICF International and Synapse Energy Economics. 2009.

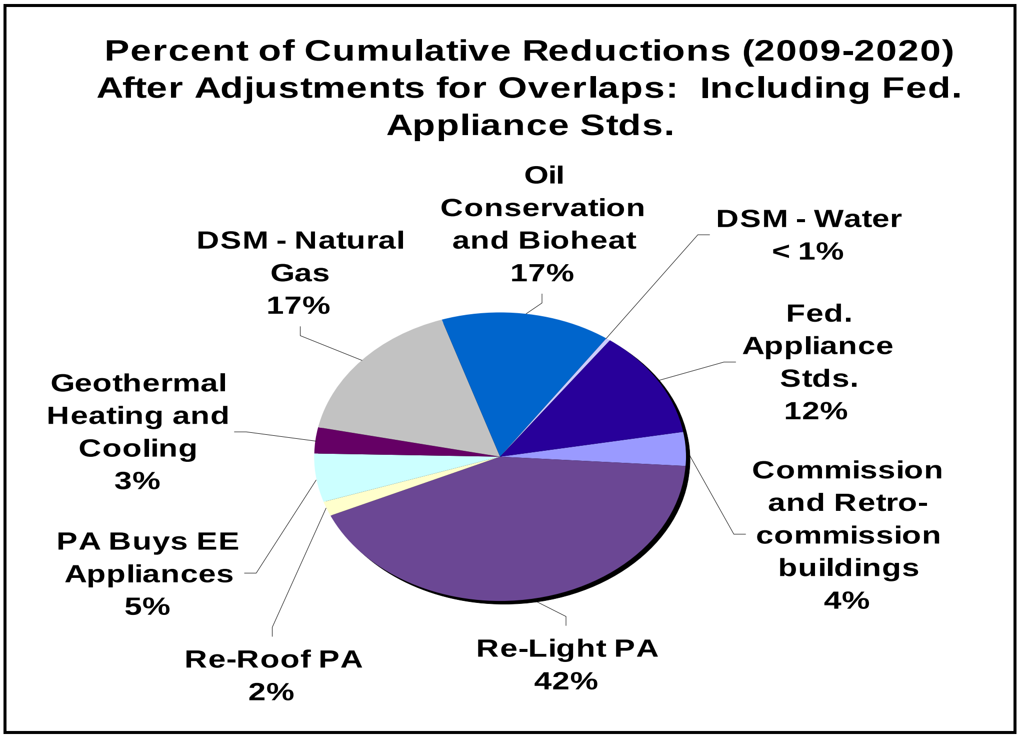
Subcommittee. Architecture 2030 Challenge goals have been adopted by numerous architecture and other organizations, including the U.S. Conference of Mayors.[4]

The work plans establish performance goals that could be met by a range of different actions, including improved design, orientation, size, insulation, renewable energy, and more efficient appliances. The quantification analysis of work plans for RC-1 through RC-4 uses the performance goals directly to determine the energy savings and associated GHG reductions. Since the actions that will be undertaken to achieve the energy savings will depend on building industry and future government policies, the specific costs are difficult to estimate. However, many of the most likely individual actions to meet the goals are covered in the work plans recommended for RC-5 through RC-12. Therefore, the costs for work plans RC-5 through RC-12 were combined to provide a general estimate of the costs and cost effectiveness of energy performance goals. Due to the large overlap of the work plans, the impacts associated with RC-1 through RC-4 are excluded from the cumulative impacts associated with all of the work plans combined to avoid double-counting of emission reductions and costs.

All 21 members of the CCAC recommended the inclusion of these work plan recommendations in Pennsylvania's Climate Action Plan. The CCAC endorses these goals and recommends RC-1 for new and existing commonwealth buildings and RC-2 for new schools as mandatory. The Committee recommends evaluating the viability of remaining goals by identifying funding sources to address implementation costs. CCAC further recommends a subcommittee be convened by DEP to provide this evaluation.

[4] Architecture 2030, a non-profit, non-partisan and independent organization, was established in response to the global-warming crisis by architect Edward Mazria in 2002. 2030's mission is to rapidly transform the US and global Building Sector from the major contributor of greenhouse gas emissions to a central part of the solution to the global-warming crisis. Our goal is straightforward: to achieve a dramatic reduction in the global-warming-causing greenhouse gas (GHG) emissions of the Building Sector by changing the way buildings and developments are planned, designed and constructed. http://www.architecture2030.org/.

Figure 5-2. Contribution by Each Work Plan and Each Recent State Action to Total Emission Reductions Associated with the Work Plans and Recent State Actions Combined for the Residential Commercial Sector



The percent contribution by each work plan or the federal action for appliances is calculated by dividing the cumulative reduction (2009-2020) for the work plan or recent state action by total cumulative reductions for all work plans and the federal action for appliances combined (i.e., 244 MMtCO_2e). See Table 5-1 for numeric values used to calculate the percentages shown in this figure.

RC-5. Commissioning and Retrocommissioning PA Buildings

Commissioning is a process of verifying through measurement and analysis that a building's heating, cooling and ventilation systems and construction are performing as designed. It ensures that the building owner got what they paid for when the building was constructed or renovated. Technically, "commissioning" is the term generally used for new construction while "retro-commissioning" describes the process when applied to renovation of existing buildings. For all buildings, but particularly for buildings designed to high efficiency standards, commissioning or retro-commissioning prevents quality problems and makes it possible for building owners and tenants to rely on expected energy costs.

The goals for this work plan are to (a) commission or retro-commission all non-commonwealth buildings greater than 25,000 square feet within 10 years of the implementation date and (b) commission or retro-commission all commonwealth buildings greater than 25,000 square feet within five years of the implementation date. This can be implemented through effective promotion of the process. For example, education and training can ensure that building project teams are familiar with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards. These standards promote building commissioning as good practice (Guideline 0-2005). Another approach is to make building certification standards apply universally. In addition, expanding training for building operators will make necessary skills and practices generally available. Finally, tax incentives can be used to provide an incentive to offset the costs of commissioning.

All 21 members of the CCAC recommended the inclusion of this work plan in Pennsylvania's Climate Action Plan.

RC-6. Re-Light Pennsylvania

This initiative is a critical building technology that accelerates replacement of less efficient outdoor and indoor lighting systems, including maximizing use of day lighting in indoor settings. This action plan applies to residential and commercial buildings, as well as parks, streetlights and parking facilities. The estimated GHG reduction from this work plan is 12.9 $MMtCO_2e$ in 2020. The estimated GHG reduction on a cumulative basis from 2009 to 2020 is 103.2 $MMtCO_2e$. The goals are to improve fixture performance by achieving minimum 70 percent lighting output ratio for all new construction and fixture replacements; improve lamp performance for all new lamp purchases by 2015; install occupancy sensors and individual lighting controls for new and existing construction by 2015. As part of the re-light plan, low or no cost education would promote the "Turn It Off" campaign to delamp where light levels are not needed, use daylight, and raise or tilt blinds.

Over 10 percent of Pennsylvania electricity is used for lighting. Fortunately, conservation in this area is technically straightforward and very cost-effective. This work plan recommends accelerating the replacement of less efficient outdoor and indoor lighting systems. Also included is a recommendation to maximize the use of day lighting. The replacement of incandescent lamps with higher performance compact fluorescent bulbs can save 50 percent of lighting costs. Office lighting levels can be lowered and occupancy sensors can be added to reduce electric consumption.

The quick expansion of this very cost-effective technology will create demand that spurs investment in manufacturing, sales, green collar jobs, and green building infrastructure. Projects will include relamping, replacement of fixtures, and upgrading lighting systems, windows, and control systems. Existing lighting is often too bright for computer work, too dim in areas of safety, and old enough to still contain magnetic ballasts that buzz and contain Polychlorinated biphenyls (PCBs), both health concerns. Thus, re-lighting will measurably improve productivity, safety and health.

Twenty of the 21 CCAC members voted to recommend this work plan for inclusion in the Action Plan.

RC-7. Re-Roof Pennsylvania

Roofs have a natural cycle of replacement and so provide an ongoing opportunity to reduce GHG through innovative and relatively low cost techniques and materials. This work plan presents three alternatives – light-colored highly insulated roofs; green roofs; and photovoltaic roofs. The goal of the work plan is to replace 75 percent of commercial building roofs by 2020 with more energy-efficient roofing at the time of replacement. Buildings have a natural cycle for re-roofing in the order of 20 to 25 years, meaning that 4 to 5 percent of roofs are in the process of selecting new roof materials.

Light-colored roofs, paired with high insulation value, offer an alternative that is effective and reasonably priced. A light-colored or white pigment on the roof deck reflects a substantial amount of the sunlight directly striking the surface. Adding substantial levels of insulation also prevents heat transfer from both the roof deck and the surrounding air while keeping cooler air from leaking from the home. The light color adds little additional cost and, if insulation is added at the time the roof is replaced, the total cost is very reasonable.

Green roofs integrate planted materials to absorb heat and insulate the building. The integration of living plant material adds the benefit of absorbing carbon and producing oxygen. The greatest benefit of green roofs is to insulate the building using a thick layer of dirt in which vegetation is planted. They can also provide aesthetic benefits by replacing typical roofing surfaces with growing plants. The drawback of green roofs is their relatively high cost as the roof structure must be strong enough to support tons of planting material and growing plants.

Finally, advances in design have created the opportunity to replace roofs with integral solar photovoltaic and solar domestic hot water systems. This approach takes advantage of the fact that typical solar photovoltaic installations are very darkly colored and thus accumulate a good deal of heat. Integrating solar hot water collectors in the solar electric collectors results in a highly efficient system for both electric and hot water production, potentially saving a substantial amount of the buildings energy requirement. Pennsylvania is taking a lead in this area and the existing PA Sunshine program already permits rebates for both technologies in one building. At a very minimum, well-insulated, highly reflective roofs could be mandated. Other roofing alternatives (green roofs and photovoltaic roofs) could be promoted with various incentives.

Fourteen of the 21 CCAC members voted to recommend and seven members disagreed with recommending this work plan to DEP. Some CCAC members objected to this work plan citing concerns that the measures should not be mandated.

RC-8. PA Buys Energy Efficient (EE) Appliances

This work plan recommends that Pennsylvania promote the adoption of the most energy-efficient appliances and equipment. The plan includes the proposal that Pennsylvania adopt its own efficiency standards for some products. Other states, including California, Maryland, New York and Rhode Island, have implemented efficiency standards for products not covered by federal appliance regulations. In most cases, these states have implemented a common standard. This was done to avoid the high costs that would result if manufacturers were required to meet a variety of different standards.

This work plan recommends that, in choosing products for state efficiency standards, Pennsylvania consider the following criteria proposed by the American Council of Energy Efficiency Engineers (ACEEE)[5]:

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[5] ACEEE (2006) Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards www.aceee.org/pubs/a062.htm

- The standard should achieve significant energy savings.
- The standard should be cost-effective for the purchaser.
- Products that meet the standard should be readily available.
- The state can implement the standard at low cost.
- Federal preemptions do not apply.

This work plan recommends setting state standards for the following appliances:

- Furnace fans
- Fluorescent lighting fixtures
- DVD players
- Compact audio equipment
- Portable electric spas
- Water dispensers
- Hot food holding cabinets
- TVs
- Portable lighting fixtures

In addition, the standard proposes that Pennsylvania encourage increased uptake of the most energy efficient appliance by requiring ENERGY STAR equipment in state-owned or state-funded buildings and by using incentives and funding to encourage local government and municipalities to adopt similar standards for their own buildings and for public by 2015. The plan also proposes the inclusion of ENERGY STAR qualified appliances in electric utility Act 129 plans and in their low-income programs.

Thirteen of the 21 CCAC members supported and eight members opposed recommending this work plan to DEP. Some of those in opposition expressed concerns with the "command and control" aspects of appliance standards while other members preferred standards be applied at national rather than state level.

RC-9. Geothermal Heating and Cooling

This work plan capitalizes on the efficiency of geothermal or ground source heat pumps (GSHPs). As with all technologies, more efficient use of energy for heating and cooling reduces GHG emissions. In addition, lower demand for peak generation and transmission can significantly reduce the wholesale price of electricity. Pennsylvania is already one of the top-tier states for experienced contractors and competitive installation prices in urban centers. This plan proposes to build on these strengths by expanding the network of trained drillers and installers throughout the state. To ensure that this strategy maximizes GHG reductions in Pennsylvania, the preferred approach to GSHPs uses electricity from renewable or low-GHG sources. This avoids increasing the demand for electricity from existing sources that produce large amounts of GHG.

This strategy advocates GSHP installations for individual buildings and in district systems. For example, Warren, Pennsylvania hosts one of the few district GSHP systems in the U.S. This strategy supports exactly this sort of application to capture energy and environmental benefits and promote economic revitalization. Implementation options for this work plan include requiring comprehensive life-cycle cost analysis for new buildings and building upgrades in the public sector. Likewise, the strategy advocates use of life-cycle cost analysis for all new and retrofit projects in the private sectors. It will be necessary to educate designers/contractors/consumers about geothermal heat pump efficiency ratings and to establish a mechanism for ensuring that drillers and installers have adequate skills.

Twenty of the 21 CCAC members supported this work plan.

RC-10. DSM - Natural Gas

Demand side management (DSM) typically refers to programs undertaken to encourage the efficient use of energy or water. DSM for natural gas appliances and equipment in RC buildings offers an excellent opportunity for GHG reduction and cost savings. Replacement of existing, older gas appliances and equipment have health benefits as well since older equipment is more likely to pose a risk to health in occupied spaces. Many homes will benefit from appropriately matched equipment sizing to the heating needs of the building. This ensures that the equipment is no larger than needed, thus avoiding unnecessary costs and GHG emissions. Ensuring that equipment is efficient and properly sized will tend to prevent consumer dissatisfaction that would result in replacement of gas with electric alternatives. Fuel switching from gas to electric heating would increase Pennsylvania electricity use and commensurate GHG emissions.

Natural gas DSM programs should focus on reducing the upfront cost of more efficient equipment. It may be necessary for natural gas utilities to directly support retrofits where the cost of new, efficient equipment is a disincentive.

Twenty of the 21 CCAC members approved (one member abstained) of recommending this work plan to DEP.

RC-11. Conservation and Fuel Switching for Heating Oil

This work plan includes two components – oil conservation and fuel-switching to biofuel. Twenty of the 21 CCAC members approved (one member abstained) of recommending this work plan to DEP.

Oil Conservation

This recommendation focuses on replacing or upgrading inefficient household appliances that use fuel oil with more energy-efficient models. Replacement of inefficient heating oil appliances and equipment may have health benefits since older equipment is more likely to pose a risk to health in occupied spaces. Many homes will benefit from appropriately matched equipment sizing to the heating needs of the building. This ensures that the equipment is no larger than needed, thus avoiding unnecessary costs and GHG emissions. Ensuring that equipment is efficient and properly sized will tend to prevent consumer dissatisfaction that would result in replacement of gas with electric alternatives. Fuel switching from fuel oil to electric heating would increase Pennsylvania electricity use and commensurate GHG emissions.

Fuel Switching to Biofuel

The work plan also recommends that all heating oil sold in Pennsylvania be blended with 5 percent biodiesel. "Bioheat" is the industry term for heating oil that is blended with biodiesel. Heating oil is essentially the same as diesel, with some difference in sulfur content and with a colorant added to deter tax evasion when it is used as a transportation fuel. Bioheat has proven to reduce maintenance requirements and it burns cleaner than conventional heating oil. Significant, positive experience utilizing bioheat exists. Numerous customers throughout Southcentral and Southeastern Pennsylvania have been using bioheat in their furnaces and boilers for the past few years. The Department of General Services, which procures fuels for state government use, also purchases bioheat.

Within the scope of bioheat there exist developing opportunities to further reduce heating oil related carbon emissions. Eleven Northeast and Mid-Atlantic States are exploring the development of a regional Low Carbon Fuel Standard (LCFS) program that would use a recently approved LCFS program in California for transportation fuels as a framework. A LCFS is a policy-neutral, carbon intensity-based standard that goes beyond a simple biofuels mandate by incorporating lifecycle GHG standards for assessing the indirect land-use impacts (land clearing; loss of stored carbon) on climate change and by encouraging of all types of fuels for consideration. Examples of lower carbon intensity fuels include natural gas, electricity and low-carbon biofuel blends. As the workgroup is still early in the development stages of this program and has not agreed on significant details of how such a program would be deployed in the region, a LCFS was not presented as a formal work plan component to the CCAC. For that reason, no reductions from this potential state action are included in reduction estimates for RC-11. Such a program could be presented once quantifiable benefits for Pennsylvania could be estimated.

RC-13. DSM - Water

Between 1950 and 2000, the U.S. population nearly doubled. However, in that same period, public demand for water more than tripled. America's public water treatment and distribution infrastrucutre consumes approximately 56 billion kilowatt-hours per year. If one out of every 100 American homes retrofitted with water-efficient fixtures, 100 million kilowatt-hours of electricity would be saved each year. (Source: EPA WaterSense Program - website accessed 06/10/09).

This work plan considers opportunities for water conservation state promotion of activities including rain capture for landscaping, dual flush toilets, low flow faucets and shower heads, and water efficient/ front loading washing machines. Water conservation could be encouraged through point of sale education and WaterSense Program (an existing program sponsored by the EPA to promote quality, water-efficient products), product performance standards; elimination of plumbing code barriers and water regulations that hinder reuse of stormwater; and utility managed programs that combine certified installers with favorable financing rates.

Twenty of the 21 CCAC members recommended this work plan to DEP.

RC-14. PA Values Embodied Energy in Building Materials, Including Historic Structures

The notion of supporting regional communities and economies is becoming widespread in "buy-local" campaigns. Included in that notion is the procurement of building product materials within one's own region. This practice supports local businesses and manufacturers by strengthening demand for local industries rather than relying on products shipped from other regions. Locally sourced building materials are also a major component of the LEED Rating System. Reducing the distance that materials are shipped reduces the amount of embodied energy in building materials and can thus reduce GHG emissions.

Included with the concept of embodied energy is the practice of reusing existing structures, such as historic buildings. The repurposing of buildings results in a very substantial reduction in GHGs and embodied energy that would result from new infrastructure, landfill waste, and the use of many materials typically consumed in new building construction. Many state and municipal governments already promote the use of regional materials within public buildings through legislation.

Due to resource limits, this work plan was not quantified as part of the CCAC process. Seventeen of the 21 CCAC members approved and one member disapproved (two members abstained) of recommending this work plan to DEP.

RC-15. Sustainability Education Programs

This work plan recommendation supports sustainability education programs in primary and secondary schools and post-secondary, college, and university programs.

- Introduce or augment environmental/energy curricula in schools.
- Introduce energy efficiency at community colleges and trade schools.
- Provide training and certification for builders, contractors and building code officials working in energy code enforcement.
- Provide continuing education for design professionals, including architects, engineers, developers, contractors, urban planners and realtors.
- Educate consumers with information programs on efficiency and conservation targeted to reduction and wise use of energy.
- Ensure municipalities coordinate and share resources.

Due to resource limits and challenges in quantifying impacts of education, this work plan was not quantified as part of the CCAC process. Seventeen of the 21 CCAC members approved and one member disapproved (two members abstained) of recommending this work plan to DEP.

RC-16. Adaptive Building Reuse

This work plan recommendation encourages adaptive building reuse and sourcing of regionally available building materials. By promoting the reuse of historic and existing buildings, the following reductions occur: GHG, landfill waste, new building materials, and new infrastructure. The sourcing of regionally available building materials results in similar reductions.

Due to resource limits, this work plan was not quantified as part of the CCAC process. Seventeen of the 21 CCAC members approved and one member disapproved (two members abstained) of recommending this work plan to DEP.

Conclusion

Greenhouse gas emissions from the residential and commercial sector are divided into two categories – direct and indirect. Direct emissions result from on-site fossil fuel combustion. Indirect emissions result from off-site electricity generation and are further detailed in the EGTD sector. Opportunities to reduce GHG emissions from the RC sector include: increasing energy efficiency in new and existing buildings (most important); use of higher efficiency appliances; use of higher efficiency fuel combustion equipment (e.g. furnaces); water consumption reduction; and use of renewable resources. Public education as well as training of building professionals and equipment installers/retrofitters would enhance these GHG emissions reduction opportunities.

Next Steps – Pathways to Implementation

DEP will continue to fund both photovoltaic (PV) roofs and encourage the purchase of energy efficient appliances through existing grant programs.

DCED has existing funding mechanisms through the Commonwealth Financing Authority to facilitate many of the RC action plans. These DCED programs include the High Performance Building (HPB) program, the Alternative and Clean Energy (ACE) program, the Renewable Energy program (REP) and the Solar Energy program (SEP). Both the HPB and ACE programs would need some revisions if high performance buildings were to be allowed to certify to a green standard other than LEED or ENERGY STAR.

Chapter 6
Land Use and Transportation Sector

Sector Overview

Overview of GHG Emissions

The Land Use and Transportation (LUT) sector includes light- and heavy-duty (on road) vehicles, aircraft, rail engines, and marine engines; causing GHG emissions when they burn gasoline or diesel fuel. In 2000, the LUT sector was the third largest source of GHG emissions in Pennsylvania (following the electricity generation and industrial sectors). Projections indicate, however, that by 2020 the LUT sector will become the state's second largest source of GHG emissions outpacing emissions associated with the industrial sector. Table 6-1 shows historical and projected LUT GHG emissions by fuel and source. Figure 6-1 graphically illustrates historical and projected emissions for 2000 through 2020.

In 2000, the LUT sector contributed about 69.5 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) emissions (about 25 percent) to Pennsylvania's total statewide gross GHG emissions (consumption basis). Within the LUT sector, onroad gasoline and diesel combustion contributed about 64 percent and 15 percent, respectively, to total LUT emissions. Therefore, the state's future GHG emissions will depend significantly on future trends in the consumption of gasoline and diesel fuel by onroad sources. The contribution of other sources to total LUT emissions include aviation (11 percent), marine (4 percent) and rail and other nonroad sources (5 percent).

From 2000 to 2020, total GHG emissions from transportation fuel are expected to remain fairly steady, decreasing slightly to about 68 $MMtCO_2e$ by 2020. The onroad gasoline sector shows a steady decrease in GHG emissions from 2000 to 2020, with onroad gasoline emissions declining by 12.6 percent from 2000 to 2020. This decrease occurs while gasoline vehicle miles traveled (VMT) increases by 32.5 percent. Over the same time period, the onroad diesel emissions show an increase of 34.6 percent, with a VMT increase of 38.1 percent. Under the reference case projections, the share of emissions from onroad gasoline vehicles decreases significantly from 2000 to 2020, to 57 percent of transportation emissions in 2020, while the share of emissions from onroad diesel vehicles increases to 21 percent of Pennsylvania's 2020 transportation emissions. All of the remaining sectors also show a slightly increased share of transportation emissions in 2020 compared to 2000.

Key Challenges and Opportunities

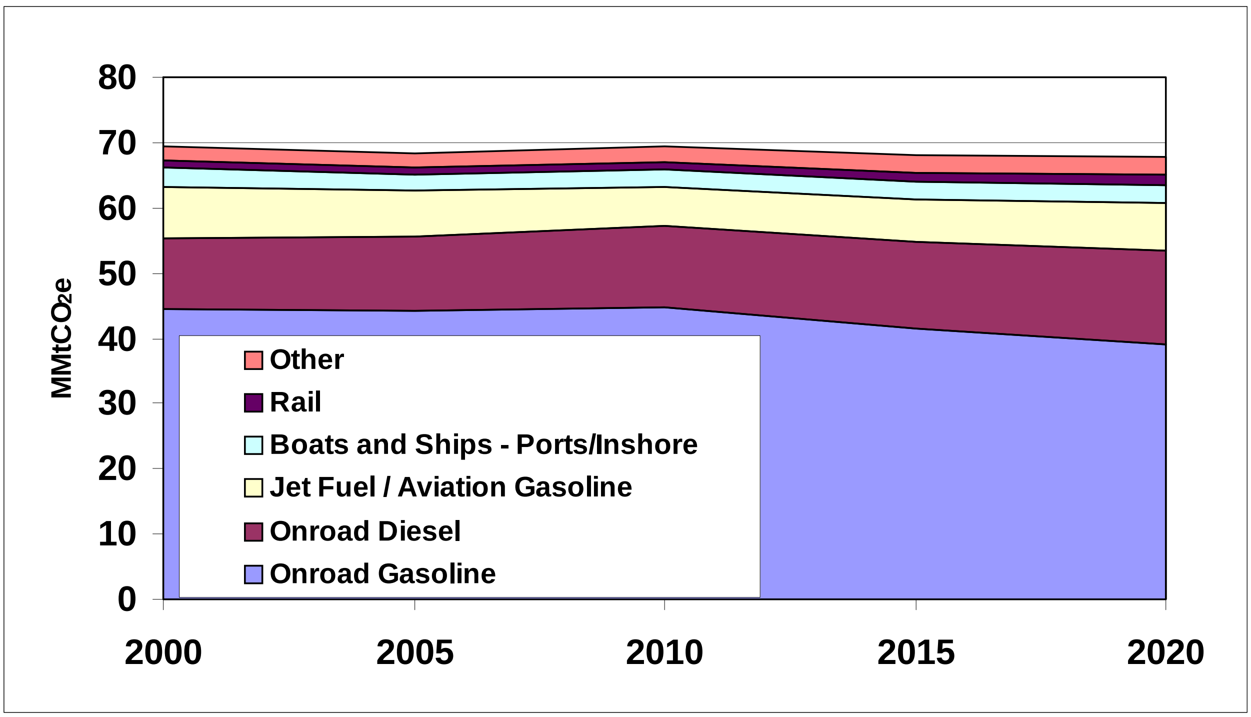
Pennsylvania has substantial opportunities to reduce transportation emissions. In the state, and in the nation as a whole, vehicle fuel efficiency improved little from the late 1980s to 2005, yet many studies have documented the potential for substantial increases consistent with maintaining vehicle size and performance. The Energy Independence and Security Act (EISA) of 2007 included increases in vehicle fuel economy, with further improvements expected with the President adopting the California GHG standards earlier this year. The use of fuels with lower GHG emissions is growing, and larger market penetrations will occur, in part due to provisions of EISA. Pennsylvania has taken steps to reduce GHG emissions from the transportation sector, as discussed below.

Table 6-1. Pennsylvania GHG Emissions from the Land Use and Transportation Sector ($MMtCO_2e$)

Source	1990	2000	2005	2010	2015	2020
Onroad Gasoline	N/A	44.58	44.30	44.75	41.40	38.98
Onroad Diesel	N/A	10.76	11.39	12.35	13.35	14.48
Jet Fuel / Aviation Gasoline	N/A	7.78	6.87	6.14	6.63	7.17
Boats and Ships - Ports/Inshore	N/A	3.00	2.65	2.64	2.68	2.71
Rail	N/A	1.15	1.07	1.20	1.41	1.61
Other	N/A	2.22	1.95	2.21	2.57	2.93
Total	**62.30**	**69.50**	**68.22**	**69.29**	**68.03**	**67.89**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent. N/A = not available.

Figure 6-1. Recent and Projected GHG Emissions from the Land Use and Transportation Sector, Pennsylvania, 2000–2020



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Description of Recent State and Federal Actions

Pennsylvania and the federal government have taken actions that will reduce GHG emissions between 2009 and 2020 that are accounted for in this report as recent actions. These actions include the Pennsylvania Clean Vehicles Program, Biofuel Development and In-State Production Incentive Act, the recent federal decisions about aligning the federal and California fuel economy and GHG emission standards, the federal Renewable Fuels Standard, and Pennsylvania's Diesel-Powered Motor Vehicle Idling Act (Act 124 of 2008). These recent actions are summarized below.

Transportation 1. Pennsylvania Clean Vehicles (PCV) Program, and Federal Vehicle GHG Emissions and CAFE Standards

Pennsylvania previously adopted the California low emission vehicle standards. The California Air Resources Board (CARB) recently added a GHG fleet average requirement to its existing low emission vehicles program beginning with model year 2009. The GHG fleet average will have to be met in California to obtain CARB certification. Now that EPA has granted California's waiver request, Pennsylvania will begin to realize the emission reductions associated with California's GHG-certified vehicles through the existing requirement that new vehicles have CARB certification. More importantly, the Obama administration's 2009 decision to promulgate national fuel efficiency standards that mirror the California low emission vehicle standards means that expected GHG emission reductions that would have occurred in Pennsylvania via the Pennsylvania Clean Vehicles Program will now be required by the federal government, in PA and nationwide.

Transportation 2. Biofuel Development and In-State Production Incentive Act

Transportation 2 analyzes the costs and GHG emission reductions associated with expanded use of biofuel in the transportation sector. The agricultural sector quantified the costs of producing biofuel to account for Pennsylvania's share (based on total fuel consumption) of the federal Renewable Fuels Standard. All of the costs and GHG emission reductions are accounted at the point of consumption, in the transportation sector. The analysis considers ethanol and biodiesel. The ethanol comes entirely from cellulosic feedstocks, whereas the biodiesel comes from soy and waste grease in the earlier years, and is replaced by algae biodiesel after 2016. The costs of additional transportation infrastructure (E85 pumps and flex-fueled vehicles) have also been considered in this analysis. Because all of the GHG emission reductions come as a result of state and federal policy, it is seen as a recent action rather than a potential work plan recommendation to implement.

Within the scope of transportation fuels using biofuels there exist developing opportunities to further reduce transportation fuel related carbon emissions. Eleven Northeast and Mid-Atlantic States are exploring the development of a regional Low Carbon Fuel Standard (LCFS) program that would use a recently approved LCFS program in California as a framework. A LCFS is a policy-neutral, carbon intensity-based standard that goes beyond a simple biofuels mandate by incorporating lifecycle GHG standards for assessing the indirect land-use impacts (land clearing; loss of stored carbon) on climate change and by encouraging of all types of fuels for consideration. In doing so, a LCFS is expected to stimulate growth in new technologies for vehicles, fuels and refueling infrastructure. Examples of lower carbon intensity fuels include natural gas, electricity and low-carbon biofuels. As the workgroup is still early in the development stages of this program and has not agreed on significant details of how such a program would be deployed in the region, a LCFS was not presented as a formal work plan component to the CCAC. For that reason no reductions from this potential state action are included in reduction estimates for Transportation 2. Such a program could be presented once quantifiable benefits for Pennsylvania could be estimated.

Transportation 4. Diesel Anti-Idling Program

The analysis for Pennsylvania's diesel anti-idling program evaluates the costs and GHG emission reductions of reduced heavy-duty truck and school bus idling in Pennsylvania. This work plan recommendation seeks to reduce idling emissions through two potential measures. The first is installing a smaller auxiliary engine to provide heating/cooling of the vehicle. The second is truck stop electrification, which can provide the climate services without running the engine at all. Costs come from installing the necessary equipment, and cost savings occur as a result of fuel savings. Act 124 of 2008, the Diesel-Powered Motor Vehicle Idling Act, establishes the goal of the analysis, and thus this is viewed as a recent state action, rather than a new recommendation.

Overview of Work Plan Recommendations and Estimated Impacts

The CCAC Land Use and Transportation Subcommittee membership includes Nathan Willcox (Chair), Ronald Ramsey, Vivian Loftness, Fred Harnack and Peter Alyanakian. The CCAC analyzed and is recommending eight work plans for the LUT sector that offer the potential for significant GHG emission reductions. All work plans were analyzed for their potential emission reduction and cost (or cost savings) impacts; however, two of the work plans (Transportation Work Plan Numbers. 10 and 11) were analyzed together. In addition, the CCAC analyzed three recent state actions (documented in the work plan format) and one recent federal action to estimate their potential emission reduction and cost impacts. Table 6-2 presents the analytical results for the work plans and four recent actions; impacts are presented on an annual basis for 2020 and on a cumulative basis for the 2009 to 2020 period. The last column of Table 6-2 summarizes the number of CCAC members that voted to approve, disapprove, or abstained from recommending that DEP include the work plans in the Pennsylvania Climate Action Plan.

The analysis of the recent actions show that Pennsylvania is already making significant progress in mitigating GHG emissions associated with the LUT sector. As shown at the bottom of Table 6-2, the recent actions together are estimated to reduce annual emissions in 2020 by about 15.7 $MMtCO_2e$, and cumulative emissions by 72 $MMtCO_2e$ over the 2009-2020 period. The recent actions together are estimated to yield a net annual cost savings of about $109 million in 2020 and a net cumulative cost savings of about $380 million for the 11-year period 2009 through 2020. The costs associated with the federal vehicle GHG emissions and CAFE standards (starting in 2012) were not estimated; however, this program is expected to result in a net cost savings overall.

The potential impacts associated with the eight work plans were estimated incremental to the recent state and federal actions. The results indicate that, if all of the work plans are fully implemented, they have the potential to reduce annual emissions in 2020 by about 6.6 $MMtCO_2e$ at a cost savings of about $494 million on a net present value basis (NPV).[1] The weighted-average cost-effectiveness of the work plans combined is estimated to be a net cost savings of about $75 per ton of CO_2e reduced ($/$tCO_2e$) in 2020. From 2009 through 2020, the work plans (if fully implemented) are estimated to reduce cumulative GHG emissions by about 60 $MMtCO_2e$ with a potential net cost of about $2.8 billion on a NPV basis. The weighted-

[1] The net costs or cost savings, shown in constant 2007 dollars, are based on fuel expenditures, operations, maintenance, and administrative costs, and amortized, incremental equipment costs. All NPV analyses here use a 5 percent real discount rate.

average cost-effectiveness of the work plans combined is estimated to be a net cost of about \$47/tCO_2e for the 2009 through 2020 period. The results indicate that for some of the work plans, cost savings are not realized until later in the analytical time frame (i.e., 2009-2020), and, therefore, overall a net cost savings is shown for 2020, but a net cumulative cost is shown for the cumulative results.

The work plans not only result in significant emission reductions and overall cost savings, but offer the potential for several additional co-benefits as well. These co-benefits include better fuel economy and quieter vehicles when low-rolling-resistance tires are used. The Clean Vehicles Program also lowers emissions of precursors of the formation of ground-level ozone, which are oxides of nitrogen and volatile organic compounds. Much of the argument in favor of lower speed limits concerns reducing highway fatalities. Feebates should result in reduced fuel consumption. In general, any measure that would reduce VMT would have commensurable reductions in criteria air pollutants. These reductions could help areas of Pennsylvania with impacted air quality to attain National Ambient Air Quality Standards.

The quantification results reported in Table 6-2 take into account overlaps in the expected emissions reduction and cost among some of the work plan recommendations within the LUT sector, as well as between work plan recommendations in the agricultural and waste management sectors. Care was taken in the determination of emission reductions and costs (or cost savings) from each of the sectors to ensure that the combined calculated impact of the work plans would not "double count" impacts.

Table 6-2. Summary Results for Land Use and Transportation Sector Work Plan Recommendations

Work Plan No.	Work Plan Name		Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)[1]
			GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/t$CO_2$e)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2$e)	
3	Low-Rolling-Resistance Tires		0.68	-$212	-$310	4.1	-$1,244	-$300	16 / 5 / 0
5	Eco-Driving	PAYD	0.43	-$277	-$651	1.76	-$1,065	-$605	13 / 8 / 0
		Feebates	0.41	-$133	-$320	2.74	-$810	-$296	13 / 8 / 0
		Driver Training	0.62	-$129	-$206	4.53	-$605	-$134	13 / 8 / 0
		Tire Inflation	0.09	-$27	-$282	0.58	-$137	-$238	13 / 8 / 0
		Speed Reduction	1.96	$185	$94	23.0	$4,153	$181	13 / 8 / 0
6	Utilizing Existing Public Transportation Systems		0.05	$300	$6,000	0.55	$3,000	$5,454	13 / 8 / 0
7	Increasing Participation in Efficient Passenger Transit		0.12	<$0	<$0	2.02	<$0	<$0	21 / 0 / 0
8	Cutting Emissions From Freight Transportation		0.99	-$293	-$295	6.67	-$1,495	-$224	15 / 6 / 0
9	Increasing Federal Support for Efficient Transit and Freight Transport in PA		1.17	$92	$78	12.87	$1,008[2]	$78	20 / 1 / 0
10	Enhanced Support for Existing Smart Growth/Transportation and Land-Use Policies		0.76-1.84	<$0	<$0	3.79-9.18	<$0	<$0	13 / 8 / 0

Work Plan No.	Work Plan Name	Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $)	Annual Results (2020) Cost-Effectiveness ($/t$CO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $)	Cumulative Results (2009-2020) Cost-Effectiveness ($/t$CO_2e$)	CCAC Voting Results (Yes / No / Abstained)[1]
11	Transit-Oriented Design, Smart Growth Communities, & Land-Use Solutions	Included in T-10	<$0	<$0	Included in T-10	<$0	<$0	13 / 8 / 0
Sector Total After Adjusting for Overlaps		6.6	-$494	-$75	60.1	$2,805	$47	
Reductions From Recent State and Federal Actions		15.7	-$109[3]	-$31[3]	72.0	-$380[3]	-$25[3]	
1	Pennsylvania Clean Vehicles (PCV) Program	0.095	0.0	0.0	1.27	0.0	0.0	NA
	Federal Vehicle GHG Emissions and CAFE Standards	12.2	NQ	NQ	57.3	NQ	NQ	NA
2	Biofuel Development and In-State Production Incentive Act	3.47	-$89	-$26	14.8	-$203	-$14	NA
4	Diesel Anti-Idling Program	0.07	-$20	-$273	0.7	-$177	-$238	NA
Sector Total Plus Recent Actions		22.3	-$603	-$27	132	$2,425	$18	

[1] NA in this column means "not applicable." Work plan numbers 1, 2, and 4 are recent state actions that are being implemented by the state; and the federal government will be implementing national vehicle GHG emissions and corporate average fuel economy (CAFÉ) standards starting in 2012.

[2] Because T-9 uses federal dollars exclusively, it should be noted that the cost figures for T-9 are calculations of how many federal dollars—not state dollars—would be required to implement the work plan.

[3] This cost per ton value excludes the emission reductions associated with the "Federal Vehicle GHG Emissions and CAFE Standards" since costs (savings) were not quantified for this recent federal action.

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/t$CO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; NQ = not quantified; PA = Pennsylvania; PAYD = Pay-As-You-Drive; CAFE = Corporate Average Fuel Economy.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

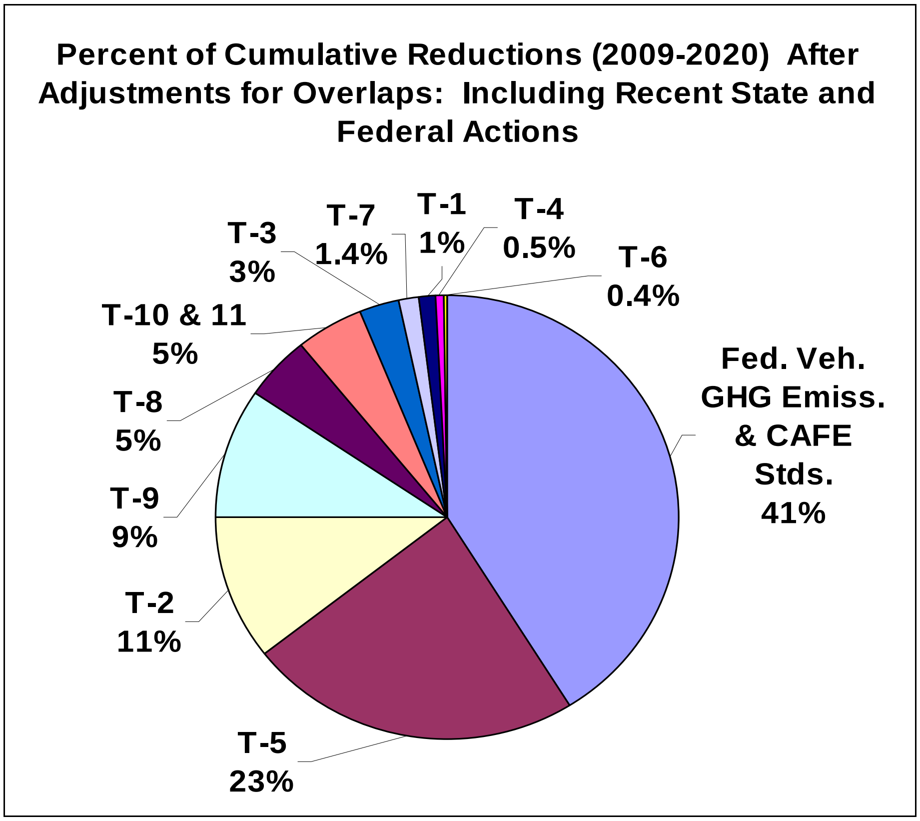
The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

Description of Work Plan Recommendations

The LUT sector has several opportunities for mitigating GHG emissions from the transportation sector. The eight work plans recommended for the LUT sector also provide a host of additional co-benefits, such as reduced local air pollution, more livable, healthier communities, and increased transportation choices.

The CCAC work plan recommendations are described briefly in the following paragraphs and in more detail in Appendix G of this report. Figure 6-2 shows the percentage of reductions that each of the eight work plans and each of the state and federal actions (after adjusting for overlaps) contributes to the total reductions associated with the eight work plans and recent state and federal actions combined.

Figure 6-2. Contribution by Each Work Plan and Each Recent Action to Total Emission Reductions Associated with the Work Plans and Recent Actions Combined for the Land Use and Transportation Sector



The percent contribution by each work plan or recent action is calculated by dividing the cumulative reduction (2009-2020) for the work plan or recent action by total cumulative reductions for all work plans and recent actions combined (i.e., 132 $MMtCO_2e$). See Table 6-2 for numeric values used to calculate the percentages shown in this figure.

Transportation 3. Low-Rolling-Resistance Tires

Low-rolling resistance tires (LRR) can improve fuel efficiency in all vehicles, typically at relatively low cost. This recommendation is to require that LRR tires be sold as replacement tires for vehicles that are normally equipped with LRR tires when new. For the analysis of this work plan, it was assumed that cars and trucks would achieve an efficiency improvement of 3 percent and 3.9 percent, respectively, and it was assumed that up to 35 percent of Pennsylvania vehicles would adopt these more fuel efficient tires.

Sixteen of the CCAC members approved and five members disapproved of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan. Committee members voting against recommending this work plan cited concerns about having a state requirement for LRR tires where they felt that a federal requirement would be more appropriate—to avoid having any situation where Pennsylvania residents would leave the state to purchase replacement tires.

Transportation 5. Eco-Driving

There were five elements of eco-driving that were included in this analysis: pay-as-you-drive insurance, feebates, eco-driver training, tire inflation and reduced speed limits. Thirteen of the CCAC members approved and eight members disapproved of recommending this work plan to DEP.

Pay-as-you-drive insurance seeks to convert the typically fixed cost of automobile insurance to a per-mile cost. Ideally, this would serve to provide an incentive for drivers to drive less (reducing VMT), at the same cost overall as traditional insurance. This would have benefits in terms of reduced traffic and reduced fuel consumption. Some CCAC members did not vote to recommend this work plan to DEP for including it in the state's Climate Action Plan because of concerns about pay-as-you-drive insurance. Their concern was primarily about possible disadvantages for residents of rural areas in Pennsylvania who are more likely to depend on their cars for mobility, and be unable to reduce their annual mileage.

Feebates provide an incentive to purchase more efficient vehicles. This is done by providing a monetary incentive for more fuel efficient vehicles, and a tax on less fuel efficient vehicles. Ideally, this program is operated such that it is revenue neutral, with the revenue from taxing less efficient vehicles counterbalancing the incentives toward more efficient ones.

Eco-driver training would provide direct training to drivers on methods to save fuel while on the road (accelerating more slowly, coasting into stops, etc). This can have significant fuel savings, at very minimal cost (driver training courses).

Proper tire inflation can improve vehicle fuel efficiency at virtually no cost. This work plan recommendation encourages drivers to be more aware of proper tire inflation guidelines, which provides fuel savings at minimal cost.

Speed limit reductions can help highway drivers operate their vehicles more efficiently. Because almost all vehicles get better gas mileage at 55 mph than 65 mph, reducing the speed limit should theoretically have significant GHG savings. Costs were calculated in this analysis based on the cost of lost time from the Federal Highway Administration's cost of highway delays, which were balanced against the cost savings of reduced fuel consumption.

Transportation 6. Utilizing Existing Public Transportation Systems

This work plan advocates taking steps to make the infrastructure investments needed to improve the commonwealth's public transportation systems without implementing any new policies or regulations. This strategic approach is expected to shift passenger mode choice towards increased transit ridership. Transit services affected include local, express, and commuter buses and trains, van/carpools, and intercity services. This recommendation signals the need for the commonwealth to make significant capital investments in transit in order to provide options to private vehicle travel, particularly where such options do not exist or are inadequate.

Thirteen of the 21 CCAC members approved and eight members disapproved of recommending this work plan to DEP. CCAC members voting against recommending this work plan were concerned about the high cost per ton value reported in the quantification.

Transportation 7. Increasing Participation in Efficient Passenger Transit

This work plan complements Transportation 6 and is designed to illustrate the importance of marketing and incentivizing the use of the transit options available to Pennsylvania citizens as another key component of increasing ridership. Possible new measures include work place incentives for public transit use, carpooling incentives, telecommuting, sales tax exemptions for e-Commerce, and urban and intercity tolls. These measures seek to increase transit ridership, decrease single occupant vehicle trips, and avoid motor vehicle trips altogether, where possible. Compared with Transportation 6, many of these measures would require passage of new regulations or policies.

All 21 members of the CCAC approved of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan.

Transportation 8. Cutting Emissions from Freight Transportation

This work plan acknowledges the potential GHG emissions savings from using the most energy efficient mode of freight transport to move goods. Options for reducing GHG emissions from the key freight transport modes: truck, rail and marine were identified for Pennsylvania. For trucks, fuel efficiency improvements were recommended based on concepts identified via EPA's SmartWay transport program like installing fairings to improve truck aerodynamics, and aluminum wheels for single-wide tires. This might be implemented via a loan program. Locomotive fuel efficiency options include auxiliary power units for switchyard locomotives and wheel flange lubrication systems for line haul trains. Ocean going vessel fuel efficiency improvements can be achieved via shore power and vessel speed reduction near ports.

Fifteen of the CCAC members approved and six members disapproved of recommending this work plan to DEP. CCAC members voting against recommending this work plan voiced concerns about whether the freight industry had an opportunity to fully consider the implications of the measures that were evaluated in the work plan.

Transportation 9. Increasing Federal Support for Efficient Transit and Freight Transport in PA

Transportation 9 examines the effects of a larger influx of federal support for public transit and freight transport operations in Pennsylvania. Many of the advancements needed in Pennsylvania's transit systems will not occur without a significant increase in federal funds. This initiative outlines several measures aimed at increasing federal support for efficient transit projects and freight transport in Pennsylvania, including public transit, car and van pooling, telecommuting, and other advancements that will cut transportation sector GHG emissions. Efficient transportation and freight systems reap many ancillary benefits, such as clean air, improved mobility, revitalized communities and local and regional economic benefits.

Twenty of the CCAC members approved and one member disapproved of recommending this work plan to DEP. The CCAC member voting against recommending this work plan voiced concerns about whether Pennsylvania would receive federal GHG reduction credits for this work plan.

Transportation 10. Enhanced Support for Existing Smart Growth/Transportation and Land-Use Policies

This work plan is designed to use existing policies and regulations to further promote smart growth and efficient transportation and land use. This work plan recommends accelerated adoption and implementation by localities and the state of existing transportation and land use policies and best practices that follow more sustainable smart growth principles. Smart growth seeks to create more compact communities, featuring increased density and a mix of land uses that generate less vehicle traffic, while being more supportive of auto trip reduction measures. Smart growth also sites commercial and industrial facilities and growth with ready access to an efficient, multi-modal freight transportation system.

Thirteen of the CCAC members approved and eight members disapproved of recommending this work plan to DEP (an explanation for objections to recommending this work plan is provided under Transportation 11).

Transportation 11. Transit-Oriented Design (TOD), Smart Growth Communities, & Land-Use Solutions

This work plan recommends new policies to promote smart growth communities and sustainable land use practices. TOD and smart growth communities have already been built, or proposed, in many locations within the commonwealth. This measure seeks to increase the number of TOD neighborhoods and smart growth communities, provide incentives for their development, and to extend the concept to all other areas, where appropriate. This measure also supports infill projects, which will increase density in support of transit services, and assist in reducing consumption of undeveloped land outside current urbanized areas—allowing for reforestation projects and farmland preservation. Denser developments require less infrastructure to support a given population/employment base, resulting in lower costs for water, sewer, and utility service.

Thirteen of the CCAC members approved and eight members disapproved of recommending this work plan to DEP. The CCAC members who voted against recommending this work plan and the work plan for Transportation 10 were concerned about the inherent uncertainties in the quantifications for these combined work plans. Recommendations were made that the DEP (and PennDOT) study the initiatives included in Transportation 10 and Transportation 11 more extensively in the near future.

Conclusion

Greenhouse gas emissions from the LUT sector result from the combustion of gasoline or fuel oil. Opportunities to reduce GHG emissions from the LUT sector include: increasing vehicle fuel efficiency; use of lower carbon fuels; and reduction in VMT per capita, both for light duty vehicles by individuals and all vehicle types by commercial entities.

Next Steps – Pathways to Implementation

PennDOT has existing authority to implement some of the transportation and land use plans considered by the CCAC; however, others will require state and/or federal legislation to either fund the initiatives or improve the existing authority to better implement those plans. Many also require local actions to implement existing best practices now allowed under existing state planning and transportation laws, regulations, and guidance.

Specifically PennDOT would require new legislation and/or budget authority to implement the following:

- Feebates in order to change the existing fee structure or to create a new fee;
- Significant public transportation expansions and new systems/lines (e.g. LUT6 and LUT7) would require additional funding in addition to working closely with MPOs and RPOs, and mass transit providers;
- Freight transport plans (e.g. LUT8 and LUT9) that are ultimately regulated at the federal level would need adequate federal transportation appropriations and state funding for incentives;
- Some land use planning and "smart growth" initiatives (e.g. LUT10 and LUT11) would be facilitated by state legislative changes to the Municipalities Planning Code (MPC) in order to give plans more weight in addition to incentives to encourage transit oriented design concepts. Other changes involve greater levels of voluntary participation by state agencies and local governments to implement smart growth concepts currently allowed under state law and regulations.

PennDOT has a variety of plans for increasing education and outreach on many of the action plans and will continue to address rail, mass transit and land use planning improvements through their existing strategic planning and Smart Transportation initiatives.

Regional transportation and metropolitan planning organizations echo many of the appropriations issues raised by PennDOT regarding funding for freight transportation, smart growth and transit oriented design initiatives (LUT8, LUT9 & LUT11). Similarly they provide ongoing education and outreach on smart growth and transportation and recognize the need to amend the MPC to increase local planning authority.

DCED has the authority to use Alternative and Clean Energy program (ACE) monies to fund biodiesel production facilities (LUT2). ACE funds may also be employed towards the development and enhancement of rail systems that deliver alternative fuels or use high efficiency locomotives (LUT8). Consistent with LUT10, Land Use Planning and Technical Assistance Program funding can help assist communities in the development of land use plans that incorporate smart growth principles while the Community Action Team (CAT) can assist in the coordination of state agency investment in local projects that meet smart growth criteria. DCED also identified that changes to the MPC would be needed to effectively implement elements of LUT11.

DEP continues to implement the existing PA Clean Vehicle Program and has oversight of the Act 124 Diesel Anti-Idling program. DEP participates in the statewide and regional transportation planning process through the general and transportation conformity requirements under the federal Clean Air Act (although these do not include greenhouse gases) and recognizes the need for additional federal and state funding for freight, mass transit and land use planning initiatives.

Chapter 7
Industry Sector

Sector Overview

Overview of GHG Emissions

Activities in the industrial sector produce GHG emissions when fuels are combusted to provide process heating and other applications, when natural gas is lost during transmission and at the point of use, and when methane is released from existing coal mines in the state. Figure 7-1 shows historical and projected GHG emissions from sources in the industrial sector (excluding those associated with generating electricity that is consumed by the industrial sector).

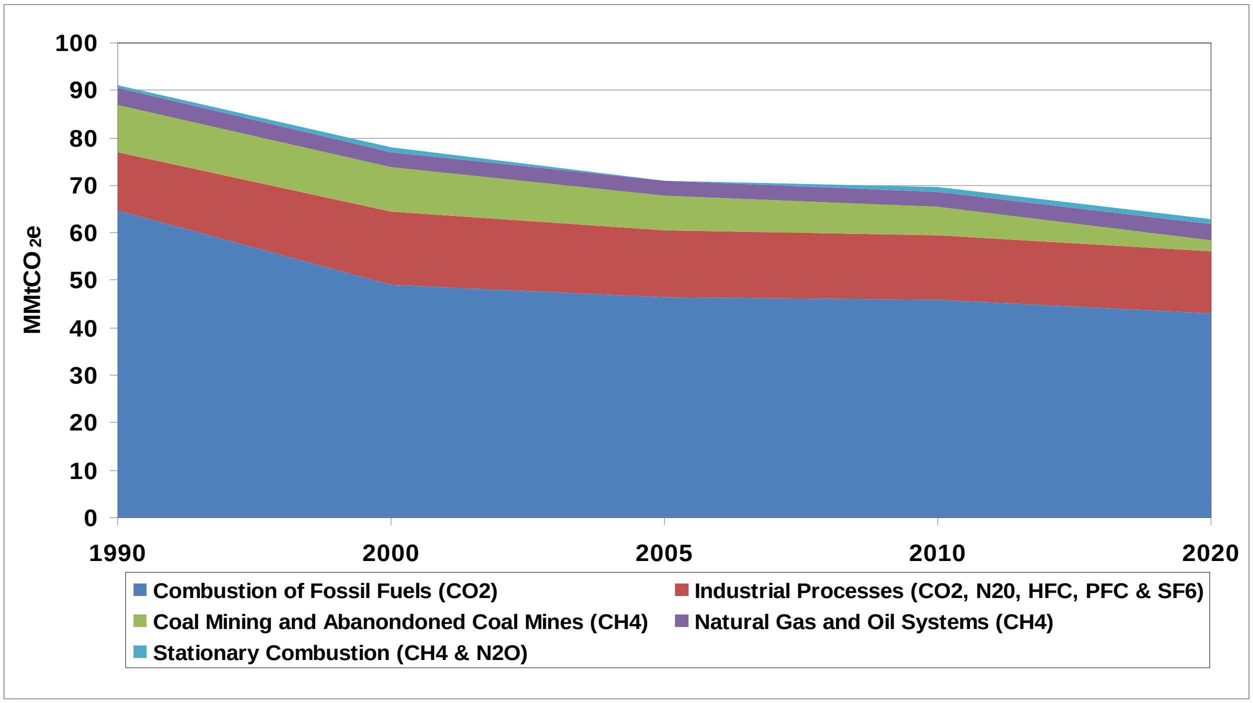
In 2000, the industrial sector contributed about 78 $MMtCO_2e$ emissions (about 28 percent) to Pennsylvania's total statewide gross GHG emissions (consumption basis) making it the second largest source of GHG emissions in the state. Within the industrial sector, the direct combustion of fossil fuels (i.e., oil, natural gas, coal) for energy use accounted for the largest source of emissions, representing 64 percent of total industrial emissions and 18 percent of total statewide gross GHG emissions in 2000. Therefore, the state's future GHG emissions will depend significantly on future trends in the consumption of electricity and other fuels in the industrial sector. The contribution of other industrial sources to total industrial emissions include industrial manufacturing processes associated with the processing of raw materials (20 percent), methane emissions associated with the coal mines (12 percent), and fugitive methane emissions from natural gas and oil transmission and distribution (4 percent).

Since 1990, industrial emissions have declined significantly in part due to improvements in combustion technologies and manufacturing processes, but also do to declines in economic activity for certain sources (e.g., steel manufacturing). Overall, emissions for the industrial sector are expected to decline by 19 percent from 2000 to 2020. In 2020, the proportional contribution of each industrial sector to total industrial source emissions is expected to change slightly relative to their contribution in 2000. In 2020, the direct combustion of fossil fuels by industrial sources is expected to account for about 70 percent of total industrial emissions, while industrial manufacturing processes are projected to contribute 21 percent, natural gas and oil transmission and distribution about 5 percent, and coal mines about 4 percent of total industrial emissions.

Key Challenges and Opportunities

The principal means to reduce industrial emissions include capturing coal mine methane, improving energy efficiency for both natural gas and electricity consumption, and reducing losses of natural gas from pipelines and associated delivery infrastructure as well as from end-use operations. Substituting electricity and natural gas with lower-emission energy resources (such as biomass and wind) will also reduce emissions associated with energy use at industrial facilities.

Figure 7-1. Recent and Projected GHG Emissions from the Industrial Sector, Pennsylvania, 1990–2020



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Pennsylvania has recently intensified statewide energy efficiency programs in response to concerns about energy costs. The state has an energy efficiency standard in place to secure cost-effective reductions in electricity consumption. The standard, Act 129, was signed into law on October 15, 2008. Emission reductions associated with the standard have already been included in the electricity forecast. The Act requires:

- A reduction in electricity consumption, by May 31, 2011, of 1 percent below consumption levels for the period June 1, 2009 through May 31, 2010;
- A reduction in electricity consumption, by May 31, 2013, of 3 percent below consumption levels for the period June 1, 2009, through May 31, 2010 (additional reduction of 2 percent from the June 2009 through May 2010 baseline for a net total reduction of 3 percent); and
- A reduction in peak demand, by May 31, 2013, of 4.5 percent of the highest 100 hours of demand.

By January 15, 2009, the state Public Utility Commission (PUC) must approve an energy efficiency and conservation program that requires each electric distribution company (EDC) to develop and implement cost-effective energy efficiency and conservation plans to reduce consumption and peak load within their service territories.

CCAC has identified significant opportunities for reducing future GHG emissions attributable to the state's industrial sector. These include capturing methane emissions associated with the state's many coal mines, expanding practices for demand-side management electricity and natural gas, and reducing natural gas losses in the state's gas delivery and end-use infrastructure.

The CCAC has also identified significant opportunities to reduce GHG emissions through policies addressing electricity production; these are detailed in Chapter 4.

Overview of Work Plan Recommendations and Estimated Impacts

The CCAC Industry and Waste Subcommittee membership includes Terry Bossert (Chair), Richard Allan, James Elliott (alternate for Al Magnotta), George Ellis, Jan Jarrett, Al Magnotta, Paul Opiyo and Ed Yancovich. The CCAC analyzed and is recommending three work plans for the industrial sector that offer the potential for significant, cost-effective GHG emission reductions within the state. Table 7-1 presents the analytical results for the three work plans; impacts are presented on an annual basis for 2020 and on a cumulative basis for the 2009 to 2020 period. The last column of Table 7-1 summarizes the number of CCAC members that voted to approve, disapprove, or abstained from recommending that DEP include the work plans in the Pennsylvania Climate Action Plan.

Table 7-1. Summary Results for Industry Work Plan Recommendations

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)	
1	Coal Mine Methane (CMM) Recovery	0.57	-$5.9	-$10.3	6.38	-$51.8	-$8.03	21 / 0 / 0
2	Industrial Natural Gas and Electricity Best Management Practices	5	-$348	-$68	25	-$972	-$38	18 / 3 / 0
3	Reduce Lost and Unaccounted for Natural Gas	0.1	-$11	-$84	1	-$48	-$55	21 / 0 / 0
Sector Total After Adjusting for Overlaps		**6**	**-$365**	**-$62**	**33**	**-$1,072**	**-$33**	
Reductions From Recent State and Federal Actions		0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Sector Total Plus Recent Actions		**6**	**-$365**	**-$62**	**33**	**-$1,072**	**-$33**	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

Analysis of the work plans indicate that the three work plans together (if fully implemented) have the potential to reduce annual emissions in 2020 by 6 $MMtCO_2e$ at a cost savings of $365 million on a net present value basis (NPV).[1] The weighted-average cost-effectiveness of the work plans combined is estimated to be a net savings of about $62 per ton of CO_2e reduced ($\$/tCO_2e$) in 2020. From 2009 through 2020, the work plans (if fully implemented) are

[1] The net cost savings, shown in constant 2007 dollars, are based on fuel expenditures; operations, maintenance, and administrative costs; and amortized, incremental equipment costs. All net present value analyses here use a 5 percent real discount rate.

estimated to reduce cumulative GHG emissions by 33 MMtCO_2e with a potential cost savings of $1 billion on a NPV basis. The weighted-average cost-effectiveness of the work plans combined is estimated to be a net savings of about $62/t$CO_2$e for the 2009 through 2020 period.

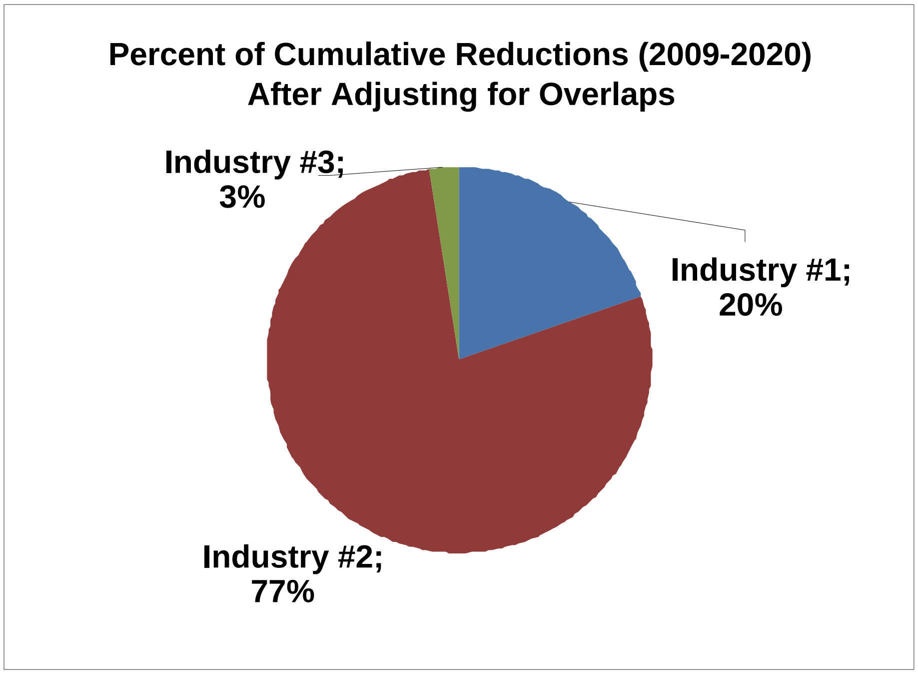
In brief, the work plans focus on the following:

- Industry-1 quantifies the reduction of coal mine methane that can be vented or recovered prior to, during, and after the coal mining process.
- Industry-2 implements best management practices (BMPs), as identified by the U.S. Department of Energy (U.S. DOE), for natural gas-fueled heating and steam systems to correspondingly improve energy efficiency between 5 percent and 25 percent.
- Industry-3 reduces lost and unaccounted for natural gas from retail operations by 15 percent through a variety of actions.

Description of Work Plan Recommendations

The industrial sector has several opportunities for mitigating GHG emissions from coal mine methane capture, increasing energy efficiency, and reducing natural gas losses from delivery and end-use infrastructure. The CCAC work plan recommendations are described briefly here and in more detail in Appendix H of this report. Figure 7-2 shows the percentage of reductions that each of the three work plans (after adjusting for overlaps) contributes to the total reductions associated with the three work plans.

Figure 7.2. Contribution by Each Work Plan to Total Emission Reductions Associated with the Work Plans Combined for the Industry Sector



The percent contribution by each work plan is calculated by dividing the cumulative reduction (2009-2020) for the work plan by total cumulative reductions for all work plans combined (i.e., 33 MMtCO_2e). See Table 7-1 for numeric values used to calculate the percentages shown in this figure.

There are two primary interactions between the industry and electricity sector work plans, both concerning the clean energy portfolio components in Electricity Work Plan Numbers 1 and 2 (load growth reduction and stabilization, respectively) and in Electricity Work Plan Number 4 (Alternative Energy Portfolio Standard). The Industry-2 work plan decreases overall electricity demand, which overlaps with the goals of Electricity-1 and Electricity-2. However, the Electricity Generation, Transmission, and Distribution (EGTD) Subcommittee eliminated the estimated overlaps between the two sectors from its work plans.

As the renewable energy portfolio requirements are based on meeting a percentage of consumption with specific resources, the costs and emissions reductions associated with Electricity-4 would be commensurately reduced by decreased energy consumption associated with the Industry-2 work plan. Also, an additional feedback effect is that certain electricity work plans (including Electricity-4) will have the effect of reducing GHG emissions associated with energy production, so that industrial work plans that target electricity use will have a correspondingly lower impact on overall emissions. However, this impact has not been reflected in the analysis.

The work plans not only result in significant emission reductions and overall cost savings, but offer the potential for several additional co-benefits as well. These co-benefits include savings to consumers and businesses on energy bills, which can have macroeconomic benefits; reduced peak demand, electricity system capital and operating costs, reduced risk of power shortages, energy price increases and price volatility; improved public health as a result of reduced pollutant and particulate matter emissions by power plants; reduced dependence on imported fuel sources and correspondingly greater energy security; and green collar employment expansion and economic development. The Coal Mine Methane Recovery work plan provides an additional energy source in Pennsylvania. Improved miners' safety is an important co-benefit that would result from removing significant amounts of methane from a coal formation before it is mined.

For the industry work plans recommended by the CCAC to yield the levels of estimated savings, they must be implemented in a timely, aggressive, and thorough manner. This means, for example, not only putting the work plans themselves in place, but also attending to the development of mechanisms that are needed to help make the recommended work plans effective. While the adoption of the recommended work plans can result in considerable benefits to Pennsylvania's environment and citizens, careful, comprehensive, and detailed planning and implementation, as well as consistent support, of these work plans will be required if these benefits are to be achieved.

Industry 1. Coal Mine Methane Recovery

This work plan quantifies the reduction of coal mine methane that can be vented or recovered prior to, during, and after the coal mining process. The release of methane gas to the atmosphere is a major component of GHG emissions. Methane gas is a fossil fuel and energy source, commonly known as natural gas, which occurs in various geologic formations in Pennsylvania, including coal formations. When coal is mined and processed for use, substantial amounts of methane gas are released. Coal bed methane (CBM) is methane contained within coal formations and may be extracted by gas exploration methods or released as part of coal mining operations. This work plan deals with coal mine methane (CMM), the methane within the coal that can be vented or recovered prior to mining the coal, during mining, and immediately after mining as some gas escapes to the surface through post-mining vents or boreholes. Methane gas that remains sequestered within an abandoned underground coal mine does not contribute to GHG emissions, but could be and sometimes is recovered by subsequent gas exploration operations.

Currently and in recent years approximately 85 percent of the methane gas released during the mining of coal in Pennsylvania occurs from mining in longwall underground mines. The five large longwall underground coal mines now operating in Pennsylvania extract approximately 60 percent of the 68 million short tons of coal mined each year within Pennsylvania. The high amounts of longwall mine production and the fact that the longwall mines recover coal from greater depths than other mines make longwall mining the predominant current source of coal mine methane release and an important contributor to GHG emissions. In recent years, several mining companies have begun to capture and use methane gas within longwall underground mines, resulting in a reduction of methane GHG emissions.

This Coal Mine Methane Recovery work plan encourages owners/operators of current longwall mines, and of any new gassy underground coal mines that are mined by any method, to capture 10 percent of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations. This could be accomplished by pre-mining gas exploration into the coal formation to be mined, capturing methane from pre-mining vertical degas holes, capturing methane by horizontal drilling within active underground mines, or possibly capturing methane from post-mining areas of underground mines, where for a brief period of time gas is still making its way to the surface through existing boreholes.

Potential ancillary benefits associated with the work plan may include the following:

- Provides an additional energy source from within Pennsylvania.
- Construction of local and regional gathering pipeline line infrastructure could be used to help or encourage natural gas exploration from other local or regional non-coal or unmineable coal reservoir formations containing natural gas.
- Profits realized from sale of coal mine methane and/or sale of carbon credits could help offset additional costs for mine companies in developing still deeper coal formations, and thus insure future exploitation of this valuable energy source and future jobs.
- Helps to improve safety within future underground coal mines by removing significant amounts of methane from a coal formation before it is mined. All methane in active mines must be vented for miners' safety. Several years of pre-mining capture would help reduce the amount of gas which must be vented during mining.

All 21 members of the CCAC approved of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan.

Industry 2. Industrial Natural Gas and Electricity Best Management Practices

This work plan recommends the implementation of BMPs, as identified by the U.S. Department of Energy, for natural gas-fueled heating and steam systems to correspondingly improve energy efficiency between 5 percent and 25 percent. Programs are assumed to begin in January 2012. Implementation of energy efficiency is assumed to occur at a rate of 1 percent of sales per year for both natural gas and electricity measures.

Industrial gas and electricity consumption in Pennsylvania are expected to increase by 1.2 percent and 0.9 percent per year, respectively.[2] This change in consumption is also influenced by the growth and decline in particular industries over the planning period. Industries that show an increase in electricity and natural gas consumption between 2008 and 2025 are chemical manufacturing and petroleum and coal products manufacturing. The largest declines are expected in primary metal manufacturing.

Implementation could include conducting workshops for industrial energy users to advance implementation of BMPs for process heating and steam systems, advancing the use of process heating and steam system analysis tools, assessing and benchmarking all process heating and steam systems using state and federal assessment resources, reviewing and (when cost-effective) implementing BMPs for all large natural gas systems, curtailing service to any large un-assessed process heating or steam system in an emergency, and partnering with utilities to develop energy use reduction programs for large energy users. Implementation of this work plan would result in energy conservation and direct fuel reductions of natural gas, fuel oil, and coal. Reduced fossil fuel combustion contributes to improvements in air quality and public health.

Eighteen of the 21 CCAC members approved and three members disapproved of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan. The committee amended language in the implementation steps to replace certain requirements with encouragements, and one member did not approve the work plan because of this substantive change.

Industry 3. Reduce Lost and Unaccounted for Natural Gas

This work plan would reduce lost and unaccounted for natural gas from transmission and distribution of natural gas for retail operations by 15 percent through a variety of actions. Natural gas is released to the atmosphere through fugitive and vented emissions. Fugitive emissions are methane leaks often through pipeline and system components (such as compressor seals, pump seals, and valve packing). Vented emissions are methane leaks from a variety of equipment and operational practices directly attributed to an organization's actions (e.g., purge and blow down activities from operation) or accidental line breaks/thefts.

However, reported "lost and unaccounted for" values for natural gas are not accurately covering gas companies' individual contributions to fugitive or vented emissions for reasons such as end-use consumer meters (likely to be residential sector meters) not accurately accounting for temperature and pressure sensibilities, natural gas companies using a portion of their product in

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[2] Source: ACEEE et al. (2009). Energy Efficiency, Demand Response, and Onsite Solar Energy Potential in Pennsylvania. April. Pp. 9-10. http://www.aceee.org/pubs/e093.htm

various stages of transmission without separate quantification, and the lack of standardized calculation and reporting procedures for lost and unaccounted for natural gas.

Implementation steps could include encouraging utilities to regularly perform self-assessments and report (to the PUC) operation and maintenance practices that have resulted in environmental savings, requiring improved and standardized reporting to the PUC on lost and unaccounted for natural gas, so that atmospheric system losses can be better understood and separated from non-atmospheric losses, investigating the savings from increased enforcement of the Pennsylvania One Call system, and phasing out older metering devices with more accurate “pressure and temperature compensated” metering. Implementation of this work plan would results in energy conservation and fuel savings of natural gas.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Conclusion

Greenhouse gas emissions from the industry sector primarily result from on-site (direct) fossil fuel combustion for energy use. Other GHG emission sources include: industrial manufacturing processes associated with raw materials processing; methane emissions associated with coal mines; and fugitive methane emissions associated with natural gas and oil transmission and distribution. Opportunities to reduce GHG emissions from the industry sector include: coal mine methane (CMM) recovery; implementation of BMP to improve energy efficiency for natural gas and electricity consumption; and loss reduction from the natural gas and oil transmission/ distribution/end-use infrastructure.

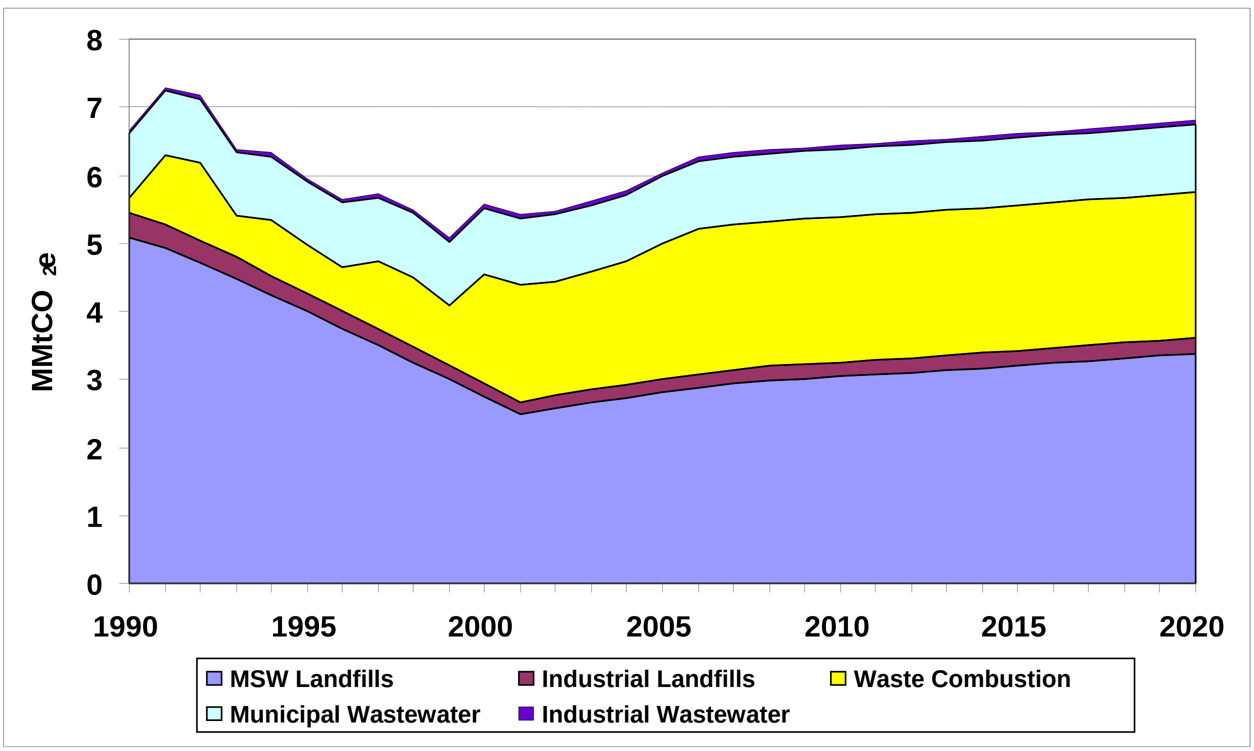
Chapter 8
Waste Sector

Sector Overview

Overview of GHG Emissions

Relative to other sectors in Pennsylvania, the waste sector produces a moderately low amount of GHG emissions. Figure 8-1 shows historical and projected GHG emissions from sources in the waste sector. Emissions from waste management consist largely of methane (CH_4) emitted from landfills, while emissions from wastewater treatment include both methane and nitrous oxide (N_2O). Emissions are also included for municipal solid waste (MSW) combustion. Overall, in 2000 the waste management sector accounted for about 3.8 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) of GHG emissions; about 1.3 percent of Pennsylvania's total gross emissions on a consumption basis. In 2020, gross GHG emissions for the sector are estimated to increase to about 4.4 $MMtCO_2e$ (or by 0.64 $MMtCO_2e$ from 2000 levels) accounting for about 1.5 percent of the state's total gross GHG emissions on a consumption basis. Based on information provided by the Industry and Waste Subcommittee of the CCAC, the collection of landfill gas (LFG) will continue to increase during the forecast period thus mitigating the overall growth in emissions for the sector.

Figure 8-1. Recent and Projected GHG Emissions from the Waste Sector, Pennsylvania, 1990–2020



Source: PA DEP and CCS Calculations.

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; MSW = municipal solid waste.

Key Challenges and Opportunities

Pennsylvania's waste sector is very advanced in terms of capturing and utilizing landfill methane emissions. Several opportunities remain, however, for the Pennsylvania waste sector to reduce GHG emissions. Most of the GHG benefit from this sector would be indirect, in the form of offseting fossil fuel-generated electricity production, as well as reduced production of packaging and products from raw materials. These GHG reductions may or may not be realized within Pennsylvania’s borders. The principal means to reduce emissions in the waste sector are:

- Improving methods for managing MSW, including additional recycling and composting;
- Utilizing a larger portion of collected LFG to generate energy and/or provide an alternative source of natural gas with a high energy content (i.e., British thermal units [Btu]);
- Exploring the use of technologies such as anaerobic digestion to reduce methane emissions from wastewater treatment plants and decomposition of organic MSW and produce biogas that can be used to generate energy (electricity or direct heat) on-site or delivered to market as a natural gas substitute; and
- Continuing to develop clean MSW combustion waste-to-energy (WTE) technology to reduce the amount of waste transported to landfills and generating electricity to offset fossil fuel-based electricity.

The largest challenges facing the implementation of programs that would take advantage of the above opportunities are financing for necessary capital expenditures, availability of mechanisms and incentives to encourage MSW diversion (to recycling or composting facilities), and overcoming public perception of digestion or WTE facilities.

Overview of Work Plan Recommendations and Estimated Impacts

The CCAC Industry and Waste Subcommittee membership includes Terry Bossert (Chair), Richard Allan, George Ellis, Jan Jarrett, Al Magnotta, Paul Opiyo and Ed Yancovich. James Elliott (alternate for Al Magnotta), David Vollero and Mark Hammond contributed to the development of the work plans. The CCAC analyzed six work plans and is recommending five work plans for the waste sector that offer the potential for significant, cost-effective GHG emission reductions. The five recommendations address a diverse array of activities capturing emission reductions both within and outside of Pennsylvania’s borders. Table 8-1 presents the analytical results for the five work plans; impacts are presented on an annual basis for 2020 and on a cumulative basis for the 2009 to 2020 period. The last column of Table 8-1 summarizes the number of CCAC members that voted to approve, disapprove, or abstained from recommending that DEP include the work plans in the Pennsylvania Climate Action Plan. The Waste 3 work plan titled Reduced Transportation of Waste was not recommended by CCAC and the Subcommittee because the original work plan was modified to move parts to other work plans and there was not adequate data to quantify.

Analysis of the work plans indicate that if the five work plans are fully implemented they have the potential to reduce annual emissions in 2020 by 5.9 $MMtCO_2e$ at a cost savings of $365 million on a net present value basis (NPV).[1] The weighted-average cost-effectiveness of the

[1] The net costs or cost savings, shown in constant 2007 dollars, are based on fuel expenditures; operations, maintenance, and administrative costs; and amortized, incremental equipment costs. All net present value analyses here use a 5 percent real discount rate.

work plans combined is estimated to be a net savings of about $62 per ton of CO_2e reduced ($/t$CO_2$e) in 2020. From 2009 through 2020, the work plans (if fully implemented) are estimated to reduce cumulative GHG emissions by 37 MMtCO_2e with a potential cost savings of about $300 million on a NPV basis. The weighted-average cost-effectiveness of the work plans combined is estimated to be a net savings of about $8/t$CO_2$e for the 2009 through 2020 period. To yield the levels of GHG savings described here, the recommended work plans need to be implemented in a timely, aggressive, and thorough manner.

Table 8-1. Summary Results for Waste Sector Work Plan Recommendations

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
		GHG Reductions (MMtCO_2e)	Costs (Million $)	Cost-Effectiveness ($/t$CO_2$e)	GHG Reductions (MMtCO_2e)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2$e)	
1	Landfill Methane Displacement of Fossil Fuels	0.1	-$0.1	-$0.8	0.56	-$11	-$19	21 / 0 / 0
2	Statewide Recycling Initiative	5.44	-$41	-$8	34.4	-$246	-$7	21 / 0 / 0
4	Improved Efficiency at Wastewater Treatment Facilities	3.8×10^{-3}	-$0.5	-$126	0.023	-$3.2	-$143	21 / 0 / 0
5	Waste-to-Energy Digesters	0.1	$0.1	$1.0	0.60	$0.7	$1.2	21 / 0 / 0
6	Waste-to-Energy MSW	0.24	-$8.1	-$34	1.42	-$40	-$28	19 / 1 / 1
Sector Total After Adjusting for Overlaps		5.9	-$50	-$8	37	-$299	-$8	
Reductions From Recent State and Federal Actions		0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Reductions From Recent State and Federal Actions		5.9	-$50	-$8	37	-$299	-$8	

GHG = greenhouse gas; MMtCO_2e = million metric tons of carbon dioxide equivalent; $/t$CO_2$e = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; NQ = not quantified; MSW = municipal solid waste.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

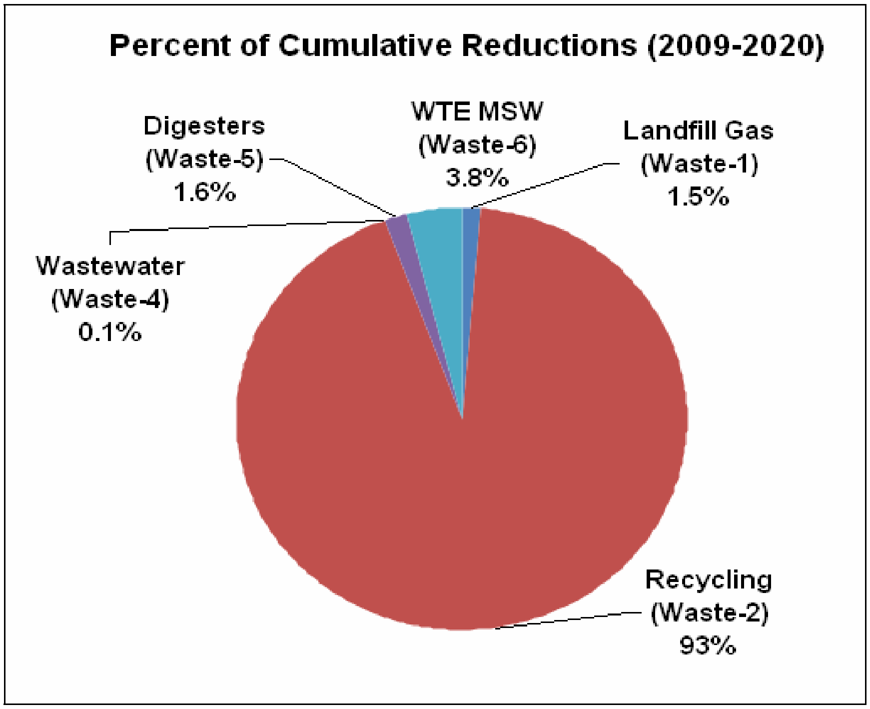
The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

Description of Work Plan Recommendations

The waste sector has several opportunities for mitigating GHG emissions from reduced methane generation at landfills, generating energy (electricity and direct heat) to offset fossil fuel-based energy production, reducing methane generation from wastewater treatment and organic MSW management, and reducing energy embedded in products and packaging produced from raw materials. The CCAC work plan recommendations are described briefly here and in more detail in Appendix I of this report.

Figure 8-2 displays the percentage of reductions that each work plan contributes to the total reductions associated with all five work plans combined. The recycling work plan contributes the largest reduction, at 93 percent. Note that the wastewater work plan contributes a slight amount to total reductions, but it is too small to be seen in the figure.

Figure 8-2. Contribution by Each Work Plan to Total Emission Reductions Associated with the Work Plans Combined for the Waste Sector



The percent contribution by each work plan is calculated by dividing the cumulative reduction (2009-2020) for the work plan by total cumulative reductions for all work plans combined (i.e., 37 $MMtCO_2e$). See Table 8-1 for numeric values used to calculate the percentages shown in this figure.

Waste 1. Landfill Methane Displacement of Fossil Fuels

Recovery and beneficial use of methane from landfills increased sharply in the U.S. between 1990 and 2001, with the result that estimated emissions of methane from landfills fell 38 percent from 258 $MMtCO_2e$ to 161 $MMtCO_2e$ in that period.[2] Pennsylvania has moved aggressively to require large landfills to collect and control LFG emissions, and it is believed that results at Pennsylvania landfills between 1990 and 2001 were even better than the national average. This work plan recommends increased utilization of collected LFG for energy generation, specifically direct heat. The CCAC recommends a target that would increase the percentage of collected LFG utilized for energy generation from 69 percent to 80 percent by 2025.

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[2] Emissions of Greenhouse Gases in the United States 2007, U.S. Department of Energy, Office of Integrated Analysis and Forecasting, Energy Information Administration (DOE/EIA-0573(2007), December 2008), page 28, Table 19.

Key implementation steps that could be taken to achieve this target are: providing tax credits for LFG utilization projects, prioritization of rights-of-way for LFG projects, and the provision of assistance for potential project operators to identify the nearest economical end uses. The full implementation of work plans 2, 5, and 6 would slightly reduce the GHG reductions from this work plan, due to the reduction in the amount of waste deposited in landfills (and the corresponding LFG produced by that waste). This change in GHG reductions, however, would be slight, as waste that is already in place will generate the most LFG over the life of the projects that would meet the target of this work plan. The principal ancillary benefit associated with this recommendation is fossil fuel conservation/savings because energy generated from landfill methane displaces energy generated from traditional sources of fossil fuels.

All 21 members of the CCAC approved of recommending this work plan to DEP for including it Pennsylvania's Climate Action Plan.

Waste 2. Statewide Recycling Initiative

Based on data analyzed by the Northeast Recycling Council's (NERC's) Environmental Benefits Calculator, Pennsylvania saved 2.5 million metric tons (MMt) of Carbon equivalent, or 9 $MMtCO_2e$ of emissions, as a result of recycling approximately 4.9 MMt of materials in 2005. Energy conserved from manufacturing products using recycled feedstock rather than virgin raw materials, or non-renewable resources, resulted in the savings of 98 *trillion* Btu of energy in 2005, enough to power over 941,000 Pennsylvania homes for one year or the equivalent of conserving 786 million gallons (MMgal) of gasoline. DEP could target recycling programs to specifically begin or increase collecting those materials that provide the maximum GHG reductions. To further stimulate recycling opportunities, DEP could ultimately ban those materials from disposal or processing. Aluminum, steel, cardboard, and paper should be initially targeted, as these materials will yield the greatest GHG reductions. Act 101, the Municipal Waste, Planning Recycling and Waste Act Reduction of 1988, provides the foundation for recycling that has resulted in comprehensive environmental and economic benefits for Pennsylvania. The CCAC recommends a target that would increase the current MSW recycling rate of 28.2 percent to the target diversion rate of 42.4 percent by 2020. This rate represents the total mass of MSW diverted (recycled or composted) divided by the total MSW generated in Pennsylvania.

Implementation of this work plan requires cooperation between many levels of government, including the DEP and municipalities. Act 101 could serve as a framework that would be built upon to provide funding for local recycling activities and establish access to recycling for many Pennsylvanians living in less densely populated areas. Additional attention will be paid to establishing and expanding markets for recyclable materials. For example, the work plan includes recommendations to amend Act 101 to:

- Require recycling programs for smaller populations and densities to capture more recycled materials from rural areas;
- Increase public recycling availability for public areas in which waste receptacles are placed (e.g., airports, parks, and retail outlets). Appropriate language can be incorporated into the Act 101 amendments; and

- Develop a legislative package to address changes needed to achieve increased recycling at the source of generation, encourage market development and limit disposal of recyclable materials at landfills and other disposal facilities. Certain materials, such as plastic bottles and aluminum cans, have well-established markets and processing facilities to handle increased recycling. A disposal ban would require diversion of certain recyclable materials from the waste stream at the source of generation, e.g. businesses and homes, by encouraging additional drop-off centers, recyclable hauling contracts and other implementation options.

Increasing recycling of waste materials has intrinsic benefits beyond reducing GHG emissions. Diverting recycled materials from disposal will ultimately reduce the amount of land needed for landfills. Recycling materials displaces virgin resources in manufacturing which saves nonrenewable resources (e.g. fossil fuels) as well as reduces the need for consumption of those resources which are renewable. This lowered consumption translates to more standing forest and less mineral extraction. A lessened reliance on natural resource extraction to produce goods also yields less pollution. Most importantly, maximizing recycling has benefits of a qualitative nature whose values aren't often recognized. The first step to a truly sustainable society is not depleting the resources which sustain it. Recycling is an important means to accomplish this goal.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Waste 4. Improved Efficiency at Wastewater Treatment Facilities

Wastewater treatment plants typically are the largest consumer of electricity on most municipal bills, often consuming more than one-third of the energy consumed for all municipal services. In many instances, opportunities exist to reduce energy consumption at these facilities. The savings realized by energy-efficient measures could be used to fund improved water quality. In fact, in cases where a facility starts using denitrification for the beneficial uptake of nitric acid, there would be a recovery of 60 percent of the cost of nitrification and improved water quality at the same time. Cost savings are certain, and the savings could escalate as energy costs continue to rise. The CCAC recommends assisting three to four additional treatment plants per year from 2010 through 2020 to improve energy efficiency, reducing both GHG emissions and operation costs.

The implementation of a program to meet this target would be largely the responsibility of DEP. The CCAC recommends that DEP increase personnel assigned to the Outreach Assistance Provider Program wastewater treatment plant outreach by 50 percent, provide grant funding for wastewater plant upgrades, and improve ease of permitting for wastewater plant upgrades.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Waste 5. Waste-to-Energy Digesters

This work plan includes recommendations for incentives to encourage an expansion of regional digesters that can offer larger-scale and higher technology treatment. Regional digesters would accept manure from smaller farms, as well as food and green waste from nearby municipalities that otherwise would not be able to provide enough feedstock for a digester.

Thermophilic anaerobic digestion is the preferred strategy for future digestion facility planning, rather than the common mesophilic technologies that predominate on U.S. farms and wastewater treatment plants. Technologies common in Europe provide for mixed feedstocks, yield more gas, and are more efficient than manure-only digesters. The effluent (digestate) is closely monitored and can yield precision-agriculture soil amendment with a guaranteed nitrogen-phosphorus-potassium analysis for fertilizer application. Depending on the exact technology/vendor selected for these digesters, about 50 percent of the input is manure, and the remainder is some combination of food residues, crop residues, yard wastes, organic fraction of MSW, or sewage sludge. The European model for centralized digestion relies on processes that digest waste that has a moisture content of less than 25 percent. Utilizing drier feedstock creates a higher biogas yield and allows for a more stable digestion process that requires less mixing and disposal of wastewater.

Based on data provided by DEP on residual waste availability, it appears that York and Adams counties are potential locations for digestion facilities. These data, in addition to the availability of manure and organic MSW in Pennsylvania, suggest that there would be ample feedstock to support four additional anaerobic digesters, each requiring 25,000 tons of waste feedstock per year. For a digester project to reach its full environmental and economic potential, a constant feedstock supply is required. The target recommended for this work plan is to establish between one and four new regional anaerobic digesters by 2025, beyond those that are currently in the permitting or planning phases. For the purposes of the analysis of this option, it was assumed that one new digester would be built in 2012, one in 2014, one in 2016, and one in 2028.

The ancillary benefits associated with this work plan include some reduction in landfill use, reduced energy use from fewer vehicle miles traveled to other disposal locations, and improved soil structure for agricultural purposes through the land application of organic matter resulting from the digesters.

All 21 members of the CCAC approved of recommending this work plan to DEP. The CCAC recommends that the following implementation steps be considered in order to achieve the targets noted above:

- Allowance of renewable energy credits for carbon offset trading.
- Provision of renewable energy grants and loans from federal, state, and municipal funds.
- Purchasing agreements with utilities for electricity and direct heat provided by digestion facilities.
- Streamlining of the permitting process to allow location within 30 miles of a reliable feedstock source.

Waste 6. Waste-to-Energy MSW

In 2006, Pennsylvania saved approximately 2.3 $MMtCO_2e$ as a result of recovering energy from 2.92 million tons of municipal and residual waste.[3] The commonwealth can reduce additional emissions by recovering energy from additional Pennsylvania municipal and residual wastes.[4]

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[3] As presented by Brian Bahor, Covanta Energy at the May 10, 2007 Solid Waste Advisory Committee Meeting; meeting materials can be found at http://www.dep.state.pa.us//dep/subject/advcoun/solidwst/swac2007.htm under the link "Waste as an Alternative Fuel"

[4] http://www.depweb.state.pa.us/landrecwaste/cwp/view.asp?A=1216&Q=488974

The burning of solid waste reduces GHGs from avoided landfill emissions and the displacement of traditional fossil fuel energy sources, despite the fact that the operation of WTE facilities and the burning of waste also produce GHG emissions. The CCAC recommends an increase in WTE derived from MSW by 20 percent by 2020 and 40 percent by 2030 at existing facilities.

Implementation of this target would require incentives for WTE MSW, including making it easier to divert waste to privately-owned WTE facilities and the inclusion of WTE in the state renewable energy standards. Long-term implementation actions include regulatory changes to further reduce obstacles to the use of waste as an energy source.

Nineteen of the 21 CCAC members approved and one member disapproved of recommending this work plan to DEP, while one member abstained from voting on the work plan recommendation. One concern raised was recommending this work plan on the basis that moving forward with WTE using current technology is not as beneficial as utilizing new technology such as atmospheric incineration or plasma gasification. The work plan, as recommended by the remaining members of the CCAC, emphasizes the expansion of WTE potential at current facilities.

Conclusion

GHG emissions from the waste sector primarily result from landfills (methane). Other GHG emission sources include MSW combustion and wastewater treatment plants. Opportunities to reduce GHG emissions from the waste sector include: using a larger fraction of collected landfill gas to generate energy as well as being a fuel source for direct heat, thus resulting in fossil fuel combustion reduction; expansion of regional waste-to-energy anaerobic digesters and MSW combustors; and expansion of recycling initiatives.

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link is at “2006 Residual Waste Biennial Report Data” (Excel spreadsheet – 2006_rw.xls).
5.3 million tons is probably combustible portion of the total 19.4 million tons of residual waste (“2006 PA RW” tab of spreadsheet). Additional 4.1 $MMTCO_2$-e is 0.788 times 5.2 million tons residual waste (same multiplier as that used by Covanta).

Chapter 9
Agriculture Sector

Sector Overview

Overview of GHG Emissions

Agricultural sector GHG emissions include non-energy methane (CH_4) emissions from livestock (i.e., enteric (intestinal) fermentation), [1] CH_4 and nitrous oxide (N_2O) emissions from the storage and treatment of livestock manure (e.g., in compost piles or anaerobic treatment lagoons),[2] N_2O emissions and net fluxes of CO_2 associated with the management of agriculture soils,[3] and CH_4 and N_2O emissions associated with agriculture residue burning. Figure 9-1 shows Pennsylvania's historical and projected GHG emissions from sources in the agriculture sector for 1990 through 2020.

Relative to other sectors, Pennsylvania's agriculture sector contributes relatively low amounts of GHG emissions to total statewide emissions. In 2000, the agriculture sector contributed about 8.4 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) emissions (about 3 percent) to Pennsylvania's total statewide gross GHG emissions (consumption basis). Within the agriculture sector, agricultural soil management accounted for the largest source of emissions, representing 46 percent of total agricultural emissions and 1.4 percent of total statewide gross GHG emissions in 2000. The contribution of other agricultural sources to total agricultural emissions include livestock enteric fermentation (36 percent), manure management (18 percent), and burning of agricultural crop waste (0.1 percent).

Since 2000, agricultural sector emissions have remained fairly constant through 2009, and are expected to following a similar trend through 2020. Overall, emissions for the agricultural sector are expected to increase slightly by about 0.6 $MMtCO_2e$ (approximately 7.3 percent) from

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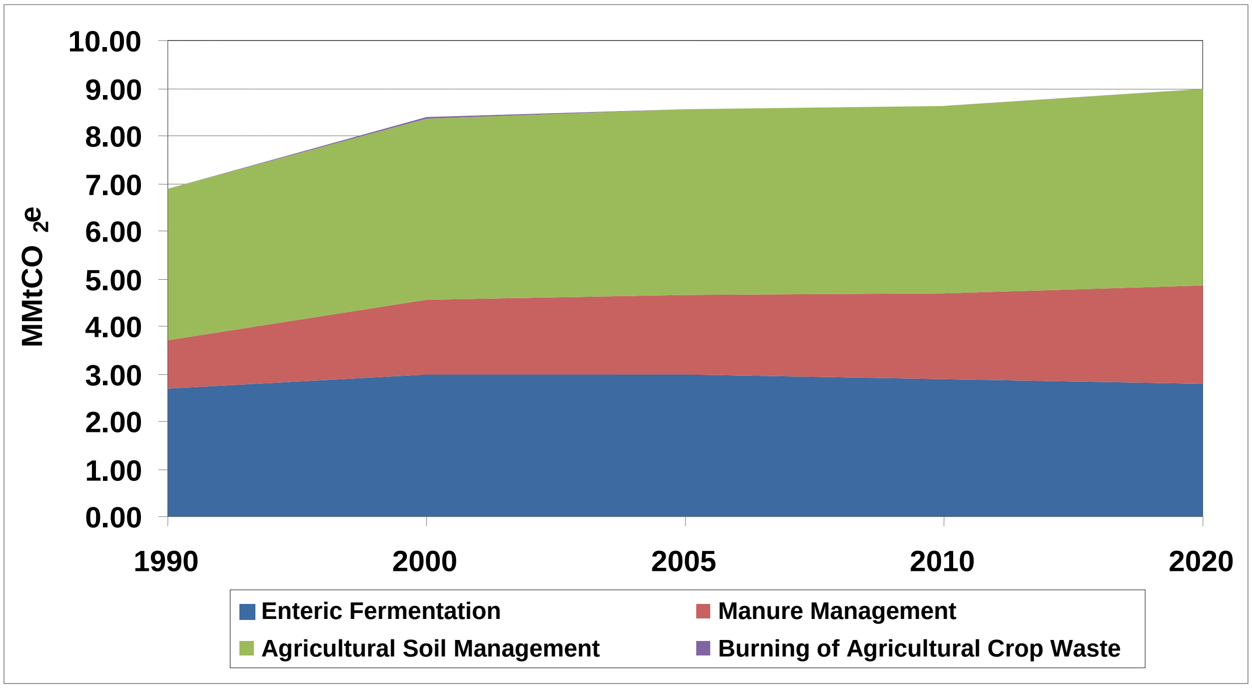
[1] Methane emissions from enteric fermentation are the result of normal digestive processes in ruminant and non-ruminant livestock. Microbes in the animal digestive system breakdown food and emit CH_4 as a by-product. More CH_4 is produced in ruminant livestock because of digestive activity in the large fore-stomach.

[2] Methane and N_2O emissions from the storage and treatment of livestock manure (e.g., in compost piles or anaerobic treatment lagoons) occur as a result of manure decomposition. The environmental conditions of decomposition drive the relative magnitude of emissions. In general, the more anaerobic the conditions are, the more CH_4 is produced because decomposition is aided by CH_4 producing bacteria that thrive in oxygen-limited aerobic conditions. Under aerobic conditions, N_2O emissions are dominant. Emissions estimates from manure management are based on manure that is stored and treated on livestock operations. Emissions from manure that is applied to agricultural soils as an amendment or deposited directly to pasture and grazing land by grazing animals are accounted for in the agricultural soils emissions.

[3] The management of agricultural soils can result in N_2O emissions and net fluxes of CO_2 causing emissions or sinks. In general, soil amendments that add nitrogen to soils can also result in N_2O emissions. Nitrogen additions drive underlying soil nitrification and de-nitrification cycles, which produce N_2O as a by-product. Agricultural soils emissions also account for decomposition of crop residues, synthetic and organic fertilizer application, manure application, sewage sludge, nitrogen fixation, and histosols (high organic soils, such as wetlands or peatlands) cultivation. Both direct and indirect emissions of N_2O occur from the application of manure, fertilizer, and sewage sludge to agricultural soils. Direct emissions occur at the site of application and indirect emissions occur when nitrogen leaches to groundwater or in surface runoff and is transported off-site before entering the nitrification/denitrification cycle.

2000 to 2020. In 2020, the proportional contribution of each agricultural sector to total agricultural source emissions is expected to change slightly relative to their contribution in 2000. In 2020, agricultural soil management is expected to remain at 2000 levels accounting for 46 percent of total agricultural emissions, while livestock enteric fermentation is projected to contribute 31 percent, manure management about 23 percent, and burning of agricultural crop waste about 0.1 percent of total industrial emissions.

Figure 9-1. Recent and Projected GHG Emissions from the Agriculture Sector, Pennsylvania, 1990–2020



Source: Pennsylvania DEP; emissions associated with the burning of agricultural crop waste are too small to be seen in this figure.

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Key Challenges and Opportunities

Opportunities for GHG mitigation in the agriculture sector include measures that can reduce emissions within this sector and measures that can reduce emissions in other sectors. Within the agricultural sector, changes in crop cultivation can reduce GHG emissions by building soil carbon (indirectly sequestering carbon from the atmosphere) or through more efficient nutrient application (reducing both direct N_2O emissions and embedded GHG emissions within those nutrients). The implementation of improved farming and harvesting techniques, as well as utilization of biomass for bio-based products, has the potential to reduce future emissions relative to current emissions from this sector and other sectors such as electricity and transportation. On-farm energy expenses can also be reduced at the same time. In addition to the potential cost savings and GHG benefit from the work plan recommendations discussed in the following section, the implementation of these measures may serve to sustain the viability of farming in Pennsylvania by preserving the quality of the land.

The foremost challenge facing the implementation of these measures in the agriculture sector is breaking any economic barriers that may exist which are preventing (or not properly incentivizing) farmers in Pennsylvania from undertaking these measures.

Overview of Work Plan Recommendations and Estimated Impacts

The CCAC Agriculture and Forestry Subcommittee membership includes John Quigley (former Chair), Paul Roth (Chair), Ronald Ramsey, Sarah Hetznecker and David Cannon. The CCAC analyzed and is recommending five work plans for the agricultural sector that offer the potential for cost-effective GHG emission reductions and carbon sequestration opportunities within the state. Table 9-1 presents the analytical results for the five work plans; impacts are presented on an annual basis for 2020 and on a cumulative basis for the 2009 to 2020 period. The last column of Table 9-1 summarizes the number of CCAC members that voted to approve, disapprove, or abstained from recommending that DEP include the work plans in the Pennsylvania Climate Action Plan.

Impacts were estimated for four of the five work plans; for Agriculture-1, the CCAC is recommending that DEP conduct studies to collect data needed to define and implement foodshed development strategies. Agriculture-2 provides recommendations to generate biofuel supplies for use in the transportation and residential fuel use sectors; therefore, the emission reductions and costs for this work plan are credited to the biofuel use work plans that the CCAC recommends for the transportation and residential sectors to avoid double counting of impacts.

The work plans not only result in significant emission reductions and overall cost savings, but offer the potential for several additional co-benefits as well. The Foodshed Development Strategy encourages locally produced commodities. A co-benefit includes lowered cost of delivering goods because products are consumed close to where produced. Increased use of biofuel reduces air pollutants of concern and also increases jobs by creating infrastructure within Pennsylvania to produce locally owned fuel sources. Co-benefits for Management Intensive Grazing are reduced fuel consumption by farmers and watershed benefits through nutrient load reduction in local water. Manure digesters are a revenue stream for farmers. Another co-benefit is reduced fuel consumption by offsetting use of propane.

Analysis of the work plans indicate that the if they are all fully implemented, they have the potential to reduce annual emissions in 2020 by about 1.4 MMtCO_2e at a cost savings of $62 million on a net present value basis (NPV).[4] The weighted-average cost-effectiveness of the work plans combined is estimated to be a net savings of about $44 per ton of CO_2e reduced ($/t$CO_2$e) in 2020. From 2009 through 2020, the work plans (if fully implemented) are estimated to reduce cumulative GHG emissions by about 10 MMtCO_2e with a potential cost savings of $380 million on a NPV basis. The weighted-average cost-effectiveness of the work plans combined is estimated to be a net savings of about $37/t$CO_2$e for the 2009 through 2020 period.

[4] The net costs or cost savings, shown in constant 2007 dollars, are based on fuel expenditures; operations, maintenance, and administrative costs; and amortized, incremental equipment costs. All net present value analyses here use a 5 percent real discount rate.

The five work plan recommendations for the agriculture sector address a diverse array of activities capturing emission reductions both within and outside of Pennsylvania's borders. The estimated impacts of the individual work plans are shown in Table 9-1. To yield the levels of savings described here, the recommended work plans would need to be implemented in a timely, aggressive, and thorough manner.

Table 9-1. Summary Results for Agriculture Sector Work Plan Recommendations

Work Plan No.	Work Plan Name		Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
			GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)	
1	Foodshed Development Strategy		Not Quantified[1]						21 / 0 / 0
2	Next-Generation Biofuels		Costs and GHG savings from biofuels are considered in Transportation-2 and Residential-11 Work Plans						21 / 0 / 0
3	Management-Intensive Grazing		0.62	-$59	-$95	5.50	-$369	-$67	21 / 0 / 0
4	Manure Digester Implementation Support	Dairy	0.26	-$0.3	-$1	1.46	$2	$1	21 / 0 / 0
		Swine	0.04	$0.1	$4	0.23	$1	$4	21 / 0 / 0
5	Regenerative Farming Practices		0.059	$2.1	$36	0.30	$17	$56	21 / 0 / 0
	Soil Sequestration from Continuous No-Till Agronomic Systems		0.44	-$5	-$11	2.7	-$31	-$12	21 / 0 / 0
Sector Total After Adjusting for Overlaps			1.42	-$62	-$44	10.2	-$380	-$37	
Reductions From Recent State and Federal Actions			0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Sector Total Plus Recent Actions			1.42	-$62	-$44	10.2	-$380	-$37	

[1] The CCAC recommends that this be a research and analysis work plan.

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

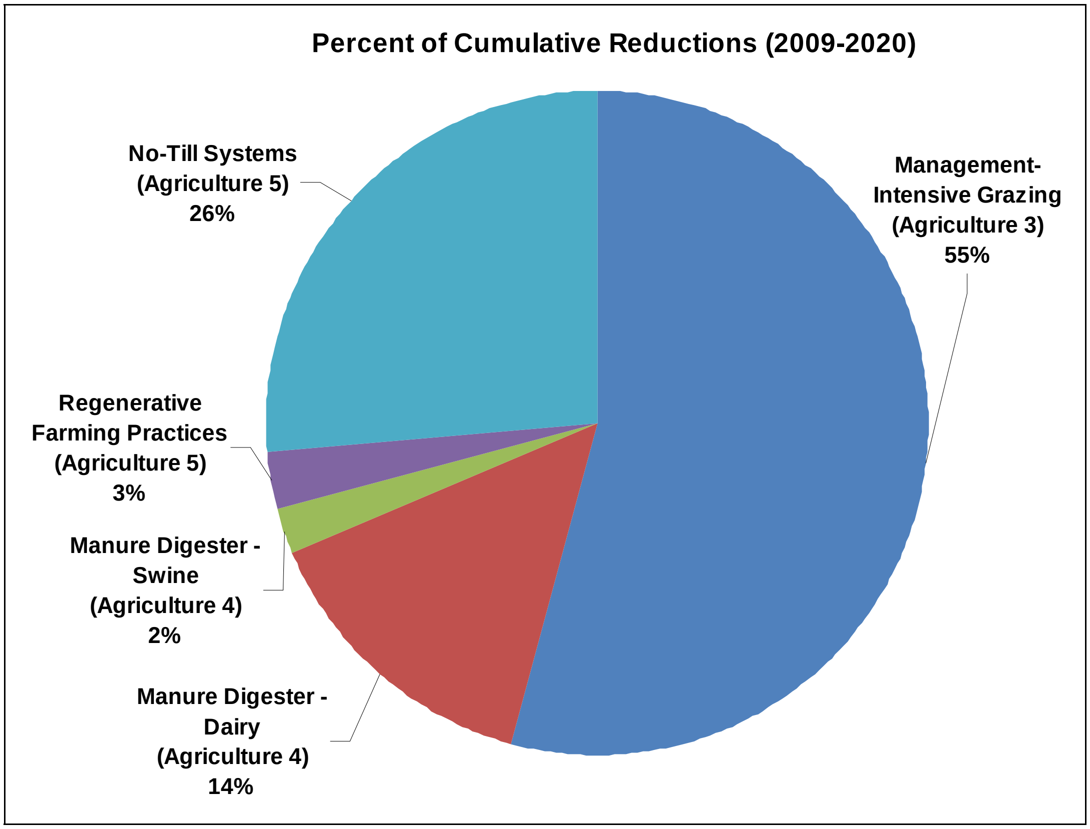
The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

Description of Work Plan Recommendations

The agriculture sector has several opportunities for mitigating GHG emissions from the generation of renewable energy, protecting and enhancing agricultural carbon sinks, controlling agricultural N_2O emissions, reducing CH_4 emissions from manure management, and producing renewable liquid fuels. The CCAC work plan recommendations are described briefly here and in more detail in Appendix J of this report.

Figure 9-2 shows the percentage of reductions that each work plan contributes to the total reductions associated with the three quantified work plans combined. The manure – intensive grazing work plan contributes the largest portion, at 54 percent. Note that the Foodshed Development Strategy was not quantified so there are no GHG emissions reductions associated with this workplan. Additionally, the GHG emissions savings from Next-Generation Biofuels were accounted for in the sector where the biofuels are used (such as transportation) so no GHG emissions reductions are included for this work plan in the agriculture sector.

Figure 9-2. Contribution by Each Work Plan to Total Emission Reductions Associated with the Work Plans Combined for the Agriculture Sector



The percent contribution by each work plan is calculated by dividing the cumulative reduction (2009-2020) for the work plan by total cumulative reductions for all work plans combined (i.e., 10.2 $MMtCO_2e$). See Table 9-1 for numeric values used to calculate the percentages shown in this figure.

Agriculture 1. Foodshed Development Strategy

This work plan recommendation would start with an economic, demographic, and land-use analysis of all of Pennsylvania to determine a limited number of "foodsheds," where the utilization of locally produced and processed foods would be maximized, and where the use of fossil fuels in the procurement and delivery of the food would be minimized. To quantify GHG reductions due to the use of local food, more data are needed on what food is being imported from where into the various regions of Pennsylvania. Packaged and processed foods are especially difficult to define, as they may use ingredients or elements from different states or countries. The goals of this non-quantified work plan include the completion of a foodshed analysis, formation of foodshed policy teams, development of strategic plans, fund development, granting and implementation programs, and creation of market-based, local investment opportunities.

After analysis of food origination is complete, the next implementation steps would include:

- Granting authority to specialized "food policy teams" in each foodshed to work in conjunction with county governments to develop and implement "foodshed strategic plans" within a specified time.
- Providing funds from the state and other sources in the form of grants to farmers, market venues, and municipalities wishing to participate. In addition, each team could maintain its own development function to raise funds through local foundations, businesses, and individuals to supplement state funds.
- Establishing backyard gardens (e.g., victory gardens), urban farming initiatives, farmers' markets, community-supported agriculture (CSA) projects, cooperatives and on-farm or community-based processing facilities (e.g., meatpacking, creameries, packaging and storage of fruits and vegetables, etc.), and plans for consolidating transportation and distribution.

Agriculture 2. Next-Generation Biofuels

The purpose of this work plan recommendation is to prompt production of advanced biofuels including cellulosic ethanol, soy/grease biodiesel, and algae biodiesel. The analysis of the work plan focused on quantifying costs associated with the cultivation of feedstocks (i.e., cellulose, soy, and algae) and the production costs of fuels. The GHG reductions and costs or cost savings associated with using the fuels are not addressed here but rather are addressed in the sectors where the fuels would actually be used such as transportation for vehicle fuels (see Work Plan No. 2 in Chapter 6), and residential for home-heating (see Work Plan No. 11 in Chapter 5).

GHG reductions are achieved when petroleum-based fuels are replaced with advanced biofuels. This work plan focuses on in-state production of the biofuels. The production of biofuels was quantified at two levels: first, the amount of biofuel necessary to meet Pennsylvania's share of the federal Renewable Fuels Standard (RFS), which is 3.63 percent, and second, the technical potential of biofuel production based on using all available feedstocks (not including those that are already being used for food, fuel, or fiber). The production of advanced biofuels necessary to meet Pennsylvania's share of the RFS is 545 million gallons (MMgal) by 2020. The technical potential is 1,375 MMgal by 2020. The GHG reductions from using the advanced biofuels are considered in the transportation and residential and commercial sectors.

This agricultural sector initiative suggests the following implementation steps:

- The production of feedstocks for biofuel, including winter crops;
- Incentivizing biofuel producers to utilize these crops as a feedstock; and
- The establishment of coordinated systems for biofuel production with economic incentives to agricultural producers to ensure the sufficient commitment of production of corn, soybean, and plant materials for biofuel use.

Any public investments or other incentives for biofuel production should include specific requirements and conditions to assure that the harvesting and processing of feedstocks are accomplished in an ecologically sustainable manner. It is extremely important to ensure that biomass feedstocks for cellulosic bioenergy use in Pennsylvania are produced in an ecologically sustainable manner. As Pennsylvania continues its efforts to step up production of second-generation biofuels, it can look to the work of initiatives such as the Council on Sustainable Biomass Production, which is working on a set of voluntary biomass-to-biofuel sustainability principles and standards for cellulosic feedstocks. When available, these standards should help guide and inform future work on this plan and the related biofuel plans in the Transportation and Residential sectors.

Agriculture 3. Management-Intensive Grazing

This work plan recommendation would create incentives and provide support for farmers wishing to transition their livestock operations from grain-intensive practices (which usually requires importing of grain/nutrients into the state) to continuous Manure-Intensive Grazing (MiG), which by contrast takes advantage of more local resources and increases sequestered carbon in pasturelands. The target recommended by the CCAC is to double the number of acres in Pennsylvania under MiG by 2020.

In addition to the implementation of MiG on farms, the initiative would help in marketing Pennsylvania-grown, pasture-based products to Pennsylvanians. It would emphasize the need for consumers to choose products that help to maintain the bucolic pasturelands for which Pennsylvania is famous, while also improving their own nutrition and the health of the planet by sequestering more carbon through intensive grass production. The establishment of financial incentives for farmers, grazers, and/or ranchers to transition to MiG would further facilitate achievement of the 2020 target.

Agriculture 4. Manure Digester Implementation Support

Pennsylvania has been and will continue to support and encourage installation of manure digesters and other energy-saving and -production implements on farms. DEP's Energy Harvest Grant continues to support such improvements, in addition to the Pennsylvania Grows program, which helps farmers put together finance packages for such projects. Pennsylvania will also take advantage of $2.4 billion of the federal stimulus package that is allocated for carbon capture and sequestration, and the $165 million to be provided via the Pennsylvania Alternative Energy Investment Act, which reserves some of its funds for alternative energy production.

Anaerobic digestion is a biological treatment process that reduces manure odor, produces biogas which can be converted to heat or electrical energy and improves the storage and handling characteristics of manure. Currently, there are 31 manure digesters in Pennsylvania. At least 14 of them have been funded through the Energy Harvest Grant program. Also, 16,600 dairy cows are on farms with digesters out of over 561,000 dairy cows in Pennsylvania.[5] The CCAC recommends a target by which 50 percent of animals living in large or medium-sized farms (more than 100 head for cattle and more than 1,000 head for swine) will have advanced manure management technologies installed to reduce GHG emissions by 2020. This target would be

[5] Penn State University, College of Agricultural Sciences, "Anaerobic Digestion on the Farm" pamphlet. 2006.

achieved through continuation of grants and funding assistance through the Pennsylvania Grows program and Energy Harvest Grant.

Agriculture 5. Regenerative Farming Practices/Soil Sequestration from Continuous No-Till Agronomic Systems

This two-park work plan includes targets for both regenerative farming and no-till agronomic systems that would serve to increase the soil sequestration. The target for regenerative farming is as follows: Increase the net carbon sequestration capacity of Pennsylvania agriculture by increasing the acres of farmland managed with regenerative cropping practices that improve the rate of biological sequestration of atmospheric carbon as soil organic matter; and decreasing practices, and the use of products that release carbon into the atmosphere. The no-till target would increase no-till acres to 1.5 million acres by 2020.

The Regenerative Farming Practices Initiative (RFPI) will encourage and guide farmers to convert to cropping practices that generate a net increase in the amount of carbon sequestered through a crop cycle. Husbandry, mechanical, and biological practices will be rated on their estimated positive or negative GHG contribution, expressed as carbon equivalent (kg Ce/ha) to allow assessment of a range of climate change impacts.

For the purposes of this work plan, it is assumed that conservation practices include conservation till (no-till and strip-till), and other conservation farming practices that provide enhanced ground cover, or other crop management practices that achieve similar soil carbon benefits. Common definitions of conservation tillage are systems that leave 50 percent or more of the soil covered with residue.

The implantation of regenerative farming and no-till farming programs would be aided by the provision of funding, including carbon credits, federal grants, and state-level programs that provide assistance to farmers undertaking alternative farming methods that will increase the soil carbon sequestration.

Conclusion

GHG emissions from the agriculture sector result almost exclusively from agricultural soil management, livestock enteric fermentation and manure management. Opportunities to reduce GHG emissions from the agricultural sector include: biofuel production to assist in fossil fuel combustion reduction in the residential and commercial sector and land use and transportation sector; manure management improvements including anaerobic digestion; and agricultural carbon sink protection and enhancement via crop cultivation changes and more efficient nutrient application.

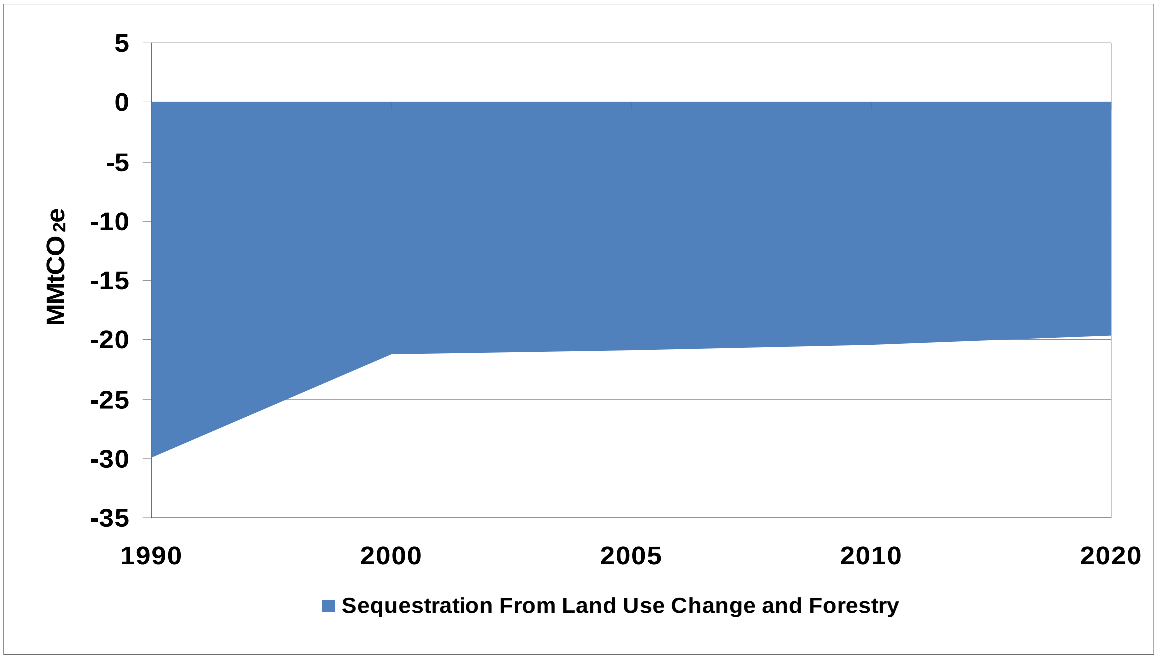
Chapter 10
Forestry Sector

Sector Overview

Overview of GHG Emissions

Pennsylvania's forestry sector is responsible for sequestering moderate amounts of carbon. In 2000, the sequestration in Pennsylvania from land use change and forestry was about 21 million metric tons carbon dioxide equivalent (MMtCO_2e). The number of metric tons sequestered from forestry is equivalent to approximately 7.5 percent of the state's gross GHG emissions (consumption basis) from all sectors. Figure 10-1 shows historical and projected GHG emissions from sources in the forestry sector. The sector is expected to remain a net carbon sink through 2020. However, from 2000 to 2020, the amount of net carbon sequestered by forest lands in Pennsylvania is projected to decline to about 19.6 MMtCO_2e, or by about 8 percent relative to 2000 levels, due primarily to increased conversion of forest land to developed uses. The forest itself, if able to maintain its current land cover status, would continue to sequester 2000 levels and beyond through 2020.

Figure 10-1. Recent and Projected GHG Emissions from the Forestry Sector, Pennsylvania, 1990–2020



Source: PA DEP Inventory and Forecast

MMtCO_2e = million metric tons of carbon dioxide equivalent.

Key Challenges and Opportunities

Pennsylvania has significant opportunity for increased carbon sequestration in the forestry sector. The principal means to reduce emissions in these areas are:

- Protecting forestland through easements, acquisitions, or other programs;
- Promoting management practices to increase carbon sequestration in forestlands;
- Planting new forests; and
- Utilizing wood for durable products and energy.

Enhanced management of the state's forests can lead to higher levels of carbon sequestration. These enhancements can be achieved through afforestation projects and enhanced stocking in existing forests. Conversion of land to development results in a loss of current and future carbon sequestration potential. Slowing land conversion will provide opportunities for meaningful, additional carbon sequestration.

Actions taken within the forestry sector can also lead to GHG reductions in other sectors. For example, urban forestry projects can reduce energy consumption within buildings through shading and wind protection. The establishment of woody crops for producing biomass energy feedstocks can replace fossil fuel consumption, including transportation fuels and fuels used to produce electricity or steam in the energy supply sector.

The commonwealth faces several key challenges in the forestry sector. One challenge includes balancing the implementation of forest protection and promotion strategies with development and economic growth in the commonwealth. Another challenge is providing incentives to utilize durable wood products and wood energy sources. A continuing challenge in the commonwealth - as in most states - is ensuring funding for new forestry programs.

Overview of Work Plan Recommendations and Estimated Impacts

The CCAC Agriculture and Forestry Subcommittee membership includes John Quigley (former Chair), Paul Roth (Chair), Ronald Ramsey and David Cannon. The CCAC analyzed and is recommending nine work plans for the forestry sector that offer the potential for significant, cost-effective GHG emission reductions within the state. The nine work plan recommendations address a diverse array of activities that sequester carbon and capture emission reductions within Pennsylvania's borders. The recommendations not only result in significant emission reductions, but also offer a host of additional co-benefits, including improved water quality and habitat protection. Forest protection measures provide watershed protection, including reduced erosion and sedimentation. Additional outdoor recreation opportunities and increased tourism are important outcomes of forest protection. Durable wood products support the preservation and may increase wood product jobs, which is estimated at 78,000 in 2006. Another co-benefit is expansion of commonwealth revenue from timber sales and providing a market for those among the 500,000 private forestland owners who manage their wood as working forest. Urban forestry provides many co-benefits. For example, air pollution heat island effect and noise pollution are reduced; water quality is improved by mitigation of storm water run-off. To yield the levels of savings described here, the work plan recommendations would need to be implemented in a timely, aggressive, and thorough manner.

Table 10-1 presents the analytical results for the nine work plans; impacts are presented on an annual basis for 2020 and on a cumulative basis for the 2009 to 2020 period. The last column of Table 10-1 summarizes the number of CCAC members that voted to approve or disapprove, or who abstained from the vote recommending that DEP include the work plans in the Pennsylvania Climate Action Plan. Analysis of the work plans indicate that the nine work plans (if all are fully implemented) have the potential to reduce annual emissions in 2020 by about 11.3 $MMtCO_2e$ at a cost savings of $1.376 billion on a net present value basis (NPV).[1] The weighted-average cost-effectiveness of the work plans combined is estimated to be a net savings of about $121 per ton of CO_2e reduced ($/$tCO_2e$) in 2020 after adjusting for overlaps with other sectors. From 2009 through 2020, the work plans (if all are fully implemented) are estimated to reduce cumulative GHG emissions by about 98 $MMtCO_2e$ with a potential cost savings of $10 billion on a NPV basis over the full 11-year period after adjusting for overlaps with other sectors. The weighted-average cost-effectiveness of the work plans combined is estimated to be a net savings of about $104/$tCO_2e$ for the 2009 through 2020 period. The 2020 annual and 2009-2020 cumulative weighted-average cost-effectiveness estimates associated with work plan recommendations have both much lower and much higher likely costs per ton.

Table 10-1. Summary Results for Forestry Sector Work Plan Recommendations

Work Plan No.	Work Plan Name		Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
			GHG Reductions ($MMtCO_2e$)	Costs (Million $2007)	Cost-Effectiveness ($/$tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $2007)	Cost-Effectiveness ($/$tCO_2e$)	
Forest Growth and Protection/Avoided Conversion									
1*	Forest Protection Initiative -- Easement		0.178	$0	$0	12.22	$67.5	$5.53	21 / 0 / 0
3*	Forestland Protection and Avoided Conversion -- Acquisition								21 / 0 / 0
Option	Total acreage protected	Develop-ment threat							
A	80,000	100%	0.178	$0	$0	14.60	$236.4	$16.19	
A	80,000	50%	0.178	$0	$0	8.23	$236.4	$28.71	
A	80,000	20%	0.178	$0	$0	4.41	$236.4	$53.58	
A	80,000	10%	0.178	$0	$0	3.14	$236.4	$75.33	
A	240,000	100%	3.72	$37.1	$9.99	41.68	$590.9	$14.18	
A*	240,000	50%	2.13	$37.1	$17.47	22.57	$590.9	$26.18	
A	240,000	20%	1.17	$37.1	$31.74	11.11	$590.9	$53.20	
A	240,000	10%	0.85	$37.1	$43.62	7.28	$590.9	$81.12	
A	400,000	100%	7.26	$72.2	$10.23	68.76	$945.3	$13.75	
A	400,000	50%	4.07	$72.2	$18.23	36.91	$945.3	$25.61	
A	400,000	20%	2.16	$72.2	$34.35	17.80	$945.3	$53.11	
A	400,000	10%	1.52	$72.2	$48.70	11.43	$945.3	$82.71	
B	64,745	100%	1.7	$18.50	$10.69	10.98	$226.6	$13.22	

[1] The net costs and cost savings, shown in constant 2007 dollars, are based on fuel expenditures; operations, maintenance, and administrative costs; and amortized, incremental equipment costs. All net present value analyses here use a 5% real discount rate.

Work Plan No.	Work Plan Name		Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $2007)	Annual Results (2020) Cost-Effectiveness ($/$tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $2007)	Cumulative Results (2009-2020) Cost-Effectiveness ($/$tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)
B	129,556	100%	3.5	$36.99	$10.69	21.97	$453.4	$13.22	
B	259,046	100%	6.9	$73.99	$10.69	43.94	$906.7	$13.22	
B	129,556	20%	0.9	$36.99	$40.11	5.47	$453.4	$53.14	
B	129,556	10%	0.6	$36.99	$61.16	3.40	$453.4	$85.35	
Increased Utilization of Durable Wood Products									
2	Woodnet		*Qualitative work plan*						14 / 6 / 1
6*	Durable Wood Products								21 / 0 / 0
	1.12 Bbf/year (2006 PA harvest)*		0.73	NQ	NQ	8.77	NQ	NQ	
	1.5 Bbf/year		0.98	NQ	NQ	11.74	NQ	NQ	
	80 Mbf/year (2006 State Forest harvest)		0.04	NQ	NQ	0.46	NQ	NQ	
Reforestation, Afforestation, Regeneration									
4	Reforestation, Afforestation, Regeneration		3.98	$41.9	$10.52	25.89	$568.7	$21.97	21 / 0 / 0
5	Improved Forest Management								21 / 0 / 0
Scenario	Shift to uneven-aged management								
2	Shift 20% of even-aged management to uneven-aged		0.26	NQ	NQ	0.82	NQ	NQ	
3	Shift 50% of even-aged management to uneven-aged		0.65	NQ	NQ	2.04	NQ	NQ	
4	Shift 75% of even-aged management to uneven-aged		0.97	NQ	NQ	3.07	NQ	NQ	
Scenario	Restock understocked forestland**								
1	Restock 100% of poorly stocked forest		(5.1)	$66.8	$13.08	(75.1)	$1,063	$14.15	
2	Restock 100% of poorly stocked forest and 50% of moderately stocked forest		(26.3)	$264.4	$10.04	(359.1)	$4,209	$11.72	
3	Restock 100% of poorly stocked forest and 100% of moderately stocked forest		(47.6)	$462.1	$9.71	(643.1)	$7,355	$11.44	
Urban Forestry									
7*	Urban Forestry								21 / 0 / 0
	Increment existing urban forest by 10%		1.20	-$560	-$468.15	7.78	-$4,399	-$565.74	
	Increment existing urban forest by 25%*		2.99	-$1,400	-$468.15	19.44	-$10,997	-$565.74	
	Increment existing urban forest by 50%		5.98	-$2,800	-$468.15	38.88	-$21,994	-$565.74	
Wood-based Energy									
8*	Wood to Electricity		0.26	$0.18	$0.67	1.71	$2.8	$3.14	21 / 0 / 0

Work Plan No.	Work Plan Name	Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million \$2007)	Annual Results (2020) Cost-Effectiveness ($\$/tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million \$2007)	Cumulative Results (2009-2020) Cost-Effectiveness ($\$/tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)
9*	Biomass Thermal Energy Initiatives							21 / 0 / 0
	Combined heat and power*	0.47	-$21.1	-$45.30	3.03	-$151.5	-$50.03	
	Fuels for Schools*	0.61	-$33.9	-$55.23	3.99	-$258.8	-$64.78	
Sector Total After Adjusting for Overlaps*		11.3	-$1,376	-$121	98	-$10,177	-$104	
Reductions From Recent State and Federal Actions		0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Sector Total Plus Recent Actions		11.3	-$1,376	-$121	98	-$10,177	-$104	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; Mbf = thousand board feet; Bbf = billion board feet; NQ = Not Quantified.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

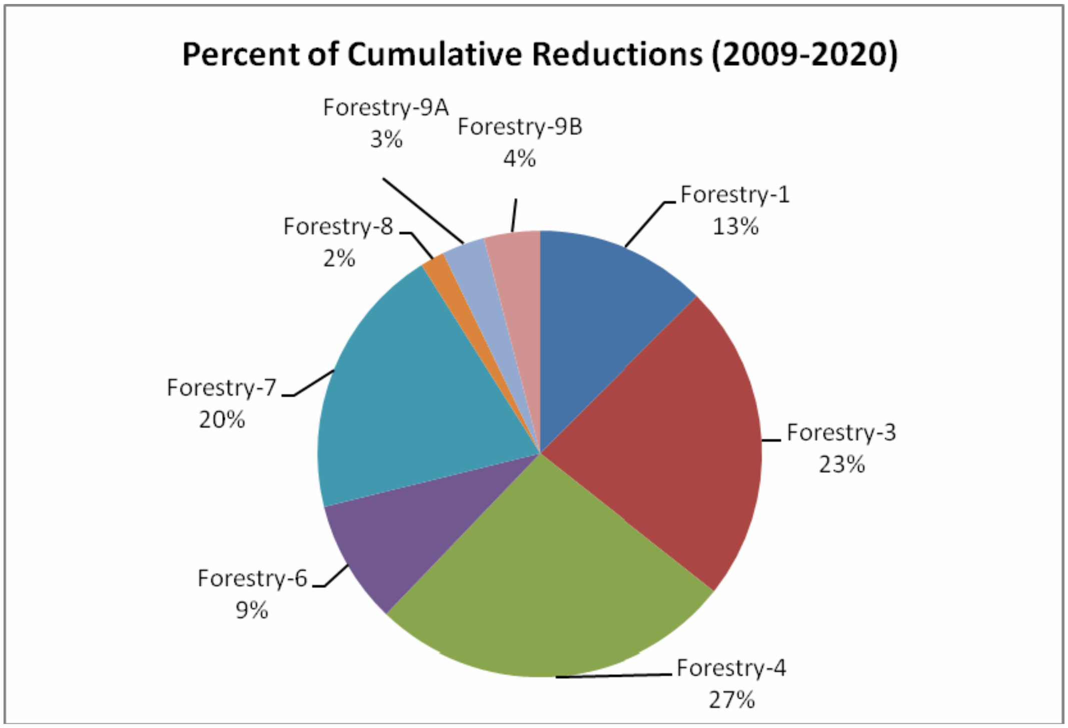
The numbering used to denote the above draft work plans is for reference purposes only; it does not reflect prioritization among these important draft work plans.

* An asterisk identifies the work plan number and name included in the "Sector Total After Adjusting for Overlaps."
** For the F-5 scenario (i.e., restocking of understocked forestlands), the analysis estimates an emissions increase relative to baseline conditions associated with site preparation and planting, and these increases are recorded in parenthesis.

Description of Work Plan Recommendations

The forestry sector has several opportunities for mitigating GHG emissions including: improved forest management, protecting forests, planting new forests, increasing the use of durable wood products, and using wood to replace fossil fuels as an energy source. The CCAC work plan recommendations are described briefly here and in more detail in Appendix K of this report. Figure 10-2 shows the percentage of reductions that each of the nine work plans (after adjusting for overlaps) contributes to the total reductions associated with the nine work plans.

Figure 10-2. Contribution by Each Work Plan to Total Emission Reductions Associated with the Work Plans Combined for the Forestry Sector



The percent contribution by each work plan is calculated by dividing the cumulative reduction (2009-2020) for the work plan by total cumulative reductions for all work plans combined (i.e., 98 $MMtCO_2e$). See Table 10-1 for numeric values used to calculate the percentages shown in this figure.

Forestry-2 was a non-quantified work plan and is not included in the total.

Forestry 1. Forest Protection Initiative -- Easement

The goal of this work plan recommendation is to augment the carbon-sequestering benefits of Pennsylvania's forests by preserving the existing forest base and conserving additional forestland. This will be accomplished in two ways:

- Assisting local partners in acquiring open space, such as parks, greenways, river and stream corridors, trails, and natural areas.
- Acquiring voluntary conservation easements with private landowners.

Carbon savings from this work plan include the amount of carbon that would be lost as a result of forest conversion to developed uses (i.e., "avoided emissions"), and the amount of annual carbon sequestration potential that is maintained by protecting the forest area. Many of the gains from forest protection will be realized after the 2020 time horizon considered by the CCAC. Forest measures have the potential to achieve substantial long-term GHG reductions.

All 21 members of the CCAC approved of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan.

Forestry 2. Woodnet

This work plan recommendation promotes the utilization of locally and sustainably produced wood products to extend the forest carbon storage cycle and reduce emissions from the utilization of alternative products. This work plan was not quantified. For quantification of recommendations related to durable wood products see Forestry-6 Durable Wood Products. The goals of this Forestry-2 work plan include:

- Expanding the state's current green building efforts beyond the current LEED standards to include a mandate for greater utilization of local wood products;
- Utilizing local wood as a substitute material for government procurement; and
- Providing access to state financial assistance to logger and wood product companies for equipment resulting in improved efficiencies and reduced carbon emissions.

Durable products made from wood prolong the length of time forest carbon is stored and not emitted to the atmosphere. Wood products disposed of in landfills may store carbon for long periods under conditions that minimize decomposition and when methane gas is captured from landfills (carbon originally stored in wood products becomes methane during decomposition). Maintaining a sustainable harvest rate and converting it into a durable wood products pool increases carbon sequestration from forests. This can be achieved through improvements in production efficiency, product substitution, expanded product lifetimes, and other practices.

Increased production and utilization of wood products includes many secondary benefits. A vibrant forest products industry is essential to the success of any biomass-based energy initiatives, as mill and forestry residuals are an important source of biomass energy stock. The demand for traditional wood products also supports the local forest products community and makes it more economically viable to harvest forest biomass for energy initiatives.

Fourteen of the 21 CCAC members approved and six members disapproved (one member abstained) of recommending this work plan to DEP for including it in Pennsylvania's Climate Action Plan. Some of the CCAC members objected to recommending the work plan because it did not contain information explaining how the work plan would be implemented.

Forestry 3. Forestland Protection and Avoided Conversion -- Acquisition

This work plan recommendation seeks to examine the carbon benefits from various land conservation scenarios. Conservation might be accomplished via incentives that seek create easement protection on privately owned land, thereby reducing the rate of conversion. The GHG benefit is twofold: avoided carbon emissions that might otherwise have taken place on converted acreage, and carbon storage on cumulative protected acreage. Note that Forestry-1 assumes easement purchase for forest protection, while Forestry-3 assumes direct fee-simple land acquisition as the implementation mechanism.

Two implementation scenarios are considered in this work plan. The first considers protection of private forestland through direct acquisition or through various Pennsylvania Department of Conservation and Natural Resources' (DCNR) programs for open-space preservation. The second focuses on providing incentives to forest landowners to reduce the likelihood of forestland conversion, rather than by direct purchase of easements. In both cases the benefits include avoided emissions from not converting the land, and the sequestration benefits that forests provide each year they remain in forested use.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Forestry 4. Reforestation, Afforestation, Regeneration

This work plan seeks to increase carbon stored in vegetation and soils through expanding the land base associated with terrestrial carbon sequestration. Establishing new forests (“afforestation”) increases the amount of carbon in biomass and soils compared to preexisting conditions. Planting and afforestation can take place on land not currently experiencing other uses, such as abandoned mine lands (AMLs), brownfields, oil and gas well sites, marginal agricultural land, and riparian areas. In addition to planting forest cover, this work plan includes consideration of planting short-rotation woody crops and warm-season grasses on a variety of underutilized land-cover types. Afforestation provides additional benefits of improved water and habitat protection.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Forestry 5. Improved Forest Management

This work plan addresses the potential for increasing carbon stocks in forests through forest practices that increase tree density, enhance forest growth rates, alter rotation lengths, or decrease the chances of biomass loss from fires, pests, and disease. Increasing the transfer of biomass to long-term storage in wood products can also enhance net carbon sequestration. Managed forests can sequester more carbon than unmanaged forests for a number of reasons. Practices may include management of rotation length, density, and ecosystem health, and sustainable use of wood products. In addition, encouraging regeneration of existing forests through stocking/planting and restoration practices (soil preparation, erosion control, etc.) can increase carbon stocks above baseline levels and ensure conditions that support forest growth, particularly after intense disturbances. Land participating in a certified management program may be eligible to generate offset credits. Additionally, this work plan recommends the promotion of restocking of under-stocked forests.

This work plan analyzed the potential carbon benefits of shifting management practices to a greater level of “uneven-aged management, and restocking poorly stocked forestland. Both of these alternative approaches result in short-term emissions increases due solely to the relatively brief period of analysis, through 2020, as compared to the long-term emissions that will ultimately be sequestered during the trees average lifespan (80 to 120 years or greater). Trees and the forest systems they inhabit are long lived, with some species of trees living many hundreds of years. To fully appreciate the role forests play in the natural carbon cycle of the planet, analysis such as a “life cycle assessment” are necessary, which looks at the carbon input and outputs in a “cradle to grave” fashion. In terms of the forest communities in Pennsylvania, for commercially desirable species, a life cycle would range from 80-100 years. In terms of ecological and recreational interests, this may range upwards to hundreds of years.

Forests in Pennsylvania are primarily “regenerated” naturally, which implies that the next forest seed source is generated by trees on site prior to harvesting. Under-plantings of understocked mature forests is not widely employed, nor is “artificial” regeneration, a practice widely employed in the Southeast and Northwest regions of the United States, or the mechanical/man made planting of the next forest, often with genetically improved stock. As indicated in the work plan, from United States Department of Agriculture (USDA) US Forest Service data, there are thousands of acres of understocked forests in PA, generally a result of weather or pest generated disturbances. When these acres are treated, most often, the remaining trees are harvested to regenerate the future stand to a more fully stocked condition. The methodology employed in this work plan did not account for: the harvested wood entering either a durable wood products stream (Forestry-6) or bio-energy feedstock stream (Forestry-8 and Forestry-9), and, therefore are quantified as carbon emissions to the atmosphere. Exacerbating this circumstance is the 11 year period of analysis for this project. In the work plan scenario, when these acres are harvested and regenerated, it will take two to three decades (still a young forest) to surpass the “carbon emissions” incurred at harvest with total carbon volume on-site from in-growth for a “given acre.” However, and this is critically important, the long term productivity and carbon sequestration capability of the “given acre” is much higher, and will continue to sequester additional carbon throughout its life cycle, perhaps another 80-120 years or longer. The forest stand will then eventually reach a late successional ecological stage where growth and mortality are generally equal and the carbon budget remains relatively constant.

Forests provide additional significant values, such as watershed protection, wildlife habitat, biodiversity conservation, aesthetics, and recreation which need to be evaluated with the carbon sequestration opportunities associated with each site.

It is important to note that there are existing carbon offset protocols that acknowledge this activity. Specifically, the Climate Action Reserve (CAR), as well as the Chicago Climate Exchange (CCX) has a protocol accepting projects that engage in “improved forest management” and “managed forest projects.” There are specific requirements and rule sets for projects to be eligible to generate offset credits. It will be important to evaluate these project protocols and encourage pilot projects within Pennsylvania to more fully understand these opportunities. Furthermore, it has a direct relationship with the costs associated with this option; as such potential revenues for entering into such projects will positively impact the cost effectiveness.

Based upon the recommendations of the CCAC, DEP has endorsed the Climate Action Reserve, the Voluntary Carbon Standard, and the Gold Standard as offset registries. This recommendation for a suite of registries will meet Pennsylvania’s needs by creating a wide range of offset protocols and accommodating multinational businesses located within the commonwealth.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Forestry 6. Durable Wood Products

This work plan recommendation seeks to enhance the use and lifetime of durable wood products. This can be achieved by enhancing management activities and timber sales to provide a reliable supply of timber for durable wood products. Durable products made from wood prolong the length of time forest carbon is stored and not emitted to the atmosphere. Substituting products made from wood for products with higher embodied energy in building materials can reduce life-cycle GHG emissions from other products. This can be achieved through improvements in production efficiency, product substitution, expanded product lifetimes, and other practices. Increasing the efficiency of the manufacturing life cycle for wood products will also enhance GHG benefits. This work plan is similar in its goals to Forestry-2 Woodnet, which was not quantified.

All 21members of the CCAC approved of recommending this work plan to DEP.

Forestry 7. Urban Forestry

This work plan seeks to increase carbon stored in urban forests, and thereby to reduce residential, commercial, and institutional energy use for heating and cooling. Carbon stocks in trees and soils in urban land uses—such as in parks, along roadways, and in residential settings—can be enhanced in a number of ways, including planting additional trees, reducing the mortality and increasing the growth of existing trees, and avoiding tree removal (or deforestation). Forest canopy cover, properly designed, can also reduce energy demand by reducing building heating and cooling needs. GHG benefits are twofold: direct carbon sequestered in newly-planted trees and avoided GHG emissions from strategic tree planting to reduce energy demand due to heating and cooling. Side benefits include reduced local air pollution and improved habitat for birds and other animals.

Forestry-7 includes the suggested implementation steps:

- Leverage/expand TreeVitalize program.
- Consider a comprehensive approach to school tree planting.
- Provide incentives for private landowners to plant trees in residential areas.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Forestry 8. Wood to Electricity

This work plan promotes the use of wood as a fuel for electricity production. GHG emissions reductions are realized when wood replaces other fossil fuels in electricity generation.

Market and policy forces are driving the expanding use of forest biomass energy. Biomass can be used to generate renewable energy in the form of liquid fuels (such as cellulosic ethanol, which is close to being market-ready), or through direct combustion to generate electricity, heat, or steam. Carbon in forest biomass is considered biogenic under sustainable systems; CO_2 emissions from biomass energy combustion are replaced by future carbon sequestration. Expanded use of biomass energy in place of fossil fuels results in net emissions reduction by shifting from high- to low-carbon fuels (when sustainably managed), provided the full life cycle of energy requirements for producing fuels does not exceed the energy content of the renewable resource. Expanded use of biomass energy can be promoted through increasing the amount of biomass produced and used for renewable energy, and providing incentives for the production and use of renewable energy supplies.

Biomass can be co-fired with coal under certain circumstances, so a larger proportion of the Pennsylvania electricity demand would likely be met if wood is also used as a secondary fuel. A large group of locally financed small projects spread widely across the commonwealth could capture the value of replacing high-cost fuel imports and gain carbon benefits, while limiting the transportation costs of the feedstock. This model has been shown to allow displacement of significant quantities of current or projected fossil carbon release from a broad range of users—including industry, public institutions, commercial offices, and multi-family buildings—through reduced electrically driven cooling and distributed generation of electricity through combined heat and power facilities.

There was extensive discussion within the Subcommittee regarding the importance of assuring ecological sustainability when implementing Forestry-8 and Forestry-9 recommendations. We need to ensure that the harvesting of wood biomass for F-8 and F-9 is done in an ecologically sustainable manner, and that we account for availability of timber resources for other purposes, both of which are addressed through the discounts applied to the total availability figure. Any public investments or other incentives for biomass electricity/thermal projects should include specific requirements and conditions to assure that the harvesting and processing of feedstocks are accomplished in an ecologically sustainable manner. We suggest the use of biomass harvesting guidelines, such as those developed by DCNR, to protect forest health and assure availability of multiple forest values and uses.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Forestry 9. Biomass Thermal Energy Initiatives

This work plan promotes community-based and district-scale energy initiatives that reduce net carbon emissions through the utilization of forested woody biomass and other clean wood source material. Suggested implementation steps are:

- Provide state leadership to encourage these facilities as part of an energy independence strategy;
- Provide technical assistance to communities on project design and development and biomass procurement;
- Provide access to capital financing for the development of such projects;
- Address issues needed to ensure adequate and affordable procurement of biomass material for these projects; and
- Maximize, within the limits of resource sustainability, local, highly efficient installations for the utilization of biomass to displace fossil sourced heat, cooling, and electricity.

There are two types of GHG benefits from this work plan recommendation: the first is offsetting electricity and the second is offsetting other fossil fuels that would have otherwise been used for heating and/or steam (e.g., natural gas or oil). Ecological sustainability should be considered when producing wood for thermal energy, as well as safeguarding the timber market.

All 21 members of the CCAC approved of recommending this work plan to DEP.

Conclusion

The forestry sector is a net carbon sink and sequesters an equivalent of 7.5 percent of the state’s gross GHG emissions on a consumption basis from all of the aforementioned sectors. Opportunities to further reduce GHG emissions from the forestry sector include: forest protection; forest management improvements; planting new forests; increase durable wood product usage; and wood usage as an energy source to assist in fossil fuel combustion reduction.

Next Steps – Pathways to Implementation

DCED has Alternative and Clean Energy (ACE) and High Performance Building (HPB) funding available for forestry biomass initiatives and LEED buildings that use Forest Stewardship Council (FSC) certified wood products. Future actions could include attempts to allow LEED certification credits for use of low-carbon intensity wood products in construction. Biomass thermal energy initiatives (F9) can be funded under ACE program monies as long as the system is an alternative energy production system as defined under the Alternative Energy Portfolio Standards (AEPS) act.

In order to facilitate the increase in existing "urban forestry" plans (F7), the Municipalities Planning Code (MPC) Act should be amended to allow for tree cover preservation as a part of new land development.

Chapter 11
Macroeconomic Assessment of Action Plan

Introduction

There is a strongly positive overall economic impact from the group of recommendations presented in this report. Specifically, the net present value (NPV) impact on total gross state product (GSP) for the period 2009-2020 is about $5.13 billion dollars and by year 2020 the impact from the 42 quantified work plans is expected to result in the creation of 54,000 new jobs. This chapter discusses the impact of the 42 quantified work plans on the whole of Pennsylvania's economy by analyzing the summation of each work plan separately and further by analyzing the totality of the impact of the work plans implemented simultaneously which reflects the benefit of interaction between the various elements.

The Action Plan has endeavored to identify the least costly mitigation work plans, and, in fact, has identified several that result in net cost savings. For example, many electricity demand-side management practices translate into less electricity needed to produce a given outcome, such as running an assembly line or cooling a home. When this is accomplished at no cost at all or at a net cost-savings on an electricity bill, this is referred to as an energy efficiency improvement.[1] In other cases, as when new equipment must be purchased, the additional expense may exceed this cost savings in reducing GHGs.

All of the cost estimates of mitigation work plans in the Action Plan apply to the site of their application, or what are termed local economic impacts. It was beyond the scope of the Subcommittees' analysis to evaluate broader economic impacts, which are often referred to as regional and national macroeconomic impacts. The mitigation work plans include the ripple effects of decreased or increased spending on mitigation, and the interaction of demand and supply in various markets. For example, reduction in consumer demand for electricity reduces the demand for generation by all sources, including both fossil energy and renewables. It therefore reduces the demand for fuel inputs such as coal and natural gas. Moreover, the investment in new equipment may partially or totally offset expenditures on ordinary plant operations and equipment, depending in part on whether investment is attracted from outside the state. At the same time, businesses and households whose electricity bills have decreased have more money to spend on other goods and services. If the households purchase more food or clothing, this stimulates the production of these goods, at least in part, within the state. Food processing and clothing manufacturers in turn purchase more raw materials and hire more employees. Then more raw material suppliers in turn purchase more of the inputs they need, and the additional employees of all these firms in the supply chain purchase more goods and service from their wages and salaries. The sum total of these "indirect" impacts is some multiple of the original direct on site impact; hence this is often referred to as the multiplier effect, a key aspect of macroeconomic impacts. It applies to both increases and decreases in economic activity. It can be further stimulated by price decreases and muted by price increases.

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[1] This definition is widely used by economists and employed here; however the *Climate Action Plan* may also include some positive cost demand-side management measures within the meaning of "energy efficiency."

The extent of the many types of linkages in the economy and macroeconomic impacts is extensive and cannot be traced by a simple set of calculations. It requires the use of a sophisticated model that reflects the major structural features of an economy, the workings of its markets, and all of the interactions between them. In this study, we used the Regional Economic Models, Inc. (REMI) PI+[2] modeling software to be discussed below (REMI, 2009). This is the most widely used state level economic modeling software package in the U.S. and heavily peer reviewed. The REMI Model is used extensively to measure proposed legislative and other program and policy economic impacts across the private and public sectors by government agencies in nearly every state of the U.S. In addition, it is often the tool of choice to measure these impacts by a number of university researchers and private research groups that evaluate economic impacts across a state and nation. The Pennsylvania version of the REMI Model was applied to the estimation of the macroeconomic impacts of the major GHG mitigation work plans on output, income, employment, and prices in the state for years 2009-2020 (i.e., 12 years).

Our results indicate that the net macroeconomic impacts on the Pennsylvania economy will be positive. While many mitigation activities incur costs, as when electricity production is reduced or the cost of production is increased by the need to purchase new equipment that does not pay for itself with cost savings, these are more than offset by shifts in spending out of energy savings and by the stimulus of business in the state that produce the necessary equipment.

The analysis below is based on the best estimation of the cost of various mitigation work plans.[3] However, these costs and some conditions relating to the implementation of these work plans are not known with full certainty. Examples include the net cost or cost savings of the work plans themselves, which are highly dependent on assumptions regarding fuel prices, and the extent to which investment in new equipment will simply displace investment in other equipment in the state or will attract new capital from elsewhere. Accordingly, we performed sensitivity analyses to investigate these alternative conditions.

This chapter is divided into 4 sections. Section 2 presents an overview of how we translate the analysis of the CCAC subcommittees' mitigation work plans into REMI simulation policy variables, as well as how the data are further refined and linked to key structural and policy variables in the Model. Section 3 presents the simulation results, including a sensitivity analysis and interpretation of results. Section 4 provides a summary and some policy implications.

Input Data

Linking the Pennsylvania Work Plans to the REMI Model Input

In total, the 42 quantified work plans that are going to be analyzed in this chapter can generate $11.7 billion net cost savings (2007 NPV) and reduce 583.0 million tons of carbon dioxide-equivalent (CO_2e) GHG emissions during the 2009-2020 period.

[2] PI stands for "Policy Insight".
[3] Data used for REMI inputs were provided by Electricity Generation, Transmission & Distribution Subcommittee, Residential & Commercial Subcommittee, Land Use & Transportation Subcommittee, Industry Subcommittee, Waste Subcommittee, Agriculture Subcommittee, and Forestry Subcommittee, July 2009.

The quantification analysis of the costs/savings undertaken by the CCAC was limited to the direct effects of implementing the work plans. For example, the direct costs of an energy efficiency work plan include the ratepayers' payment for the program and the energy customers' expenditure on energy efficiency equipments and devices. The direct benefits of this work plan include the savings on energy bills of the customers.

All the analyses of the CCAC pertain to the direct (microeconomic or partial equilibrium) effects of work plan implementation. It was beyond the scope of the Subcommittees to perform broader economic impacts analyses, which are often referred to as macroeconomic and general equilibrium impacts. To supplement the microeconomic analysis of the Subcommittees, the REMI PI+ Model was selected to evaluate macroeconomic impacts (such as gross state output, employment, and personal income) of various GHG emissions reduction strategies. In this study, the Pennsylvania REMI Model is based on Pennsylvania historical data through 2006. For a discussion of the workings of the REMI Model and the steps involved in linking work plans to model variables, see Appendix L.

Modeling Assumptions

The major data sources of the analysis are the Subcommittees' quantification results or their best estimation of the cost/savings of various recommended work plans. However, we supplement these with some additional data and assumptions in the REMI analysis in cases where these costs and some conditions relating to the implementation of the work plans are not specified by the Subcommittees or are not known with certainty. Below is the list of major assumptions we adopted in the analysis:

1. Capital investment in power generation is split 60:40 between sectors that provide generating equipment and the construction sector for large power plants (such as coal-fired power plants), and 80:20 for smaller installations (mainly renewables).
2. In all the applicable analyses, we simulated a stimulus from only 50 percent of the capital investment requirements. This is based on the assumption that 50 percent of the investment in new equipment will simply displace other investment in the state and that 50 percent will be additive, stemming from a combination of attracting private investment funds from outside the state and from federal subsidies.
3. We assume that any increase in household spending on energy-efficient appliances will reduce the household spending on other commodity categories by the same dollar amount. Similarly, any energy bill savings will enable households to increase their spending on other commodities and services by the same dollar amount.
4. For some Electricity and Res/Com work plans, the energy consumers' participant costs of energy efficiency programs are computed for the residential, commercial, and/or industrial sectors by the Subcommittees. For the commercial and industrial sectors, the Subcommittees' analyses only provide the total costs for the entire commercial sector and the entire industrial sector. In the REMI analysis, we distributed the total costs for the commercial and industrial sectors among the REMI 169 individual sectors based on the

Pennsylvania Input-Output data provided in the REMI model in relation to the delivery of utility services to individual sectors.[4]

5. For the forestry work plans that include land acquisition, it is assumed that the program funding comes from the state government budget. It is also assumed that increasing the government spending in these forestry programs will be offset by a decrease in the same amount of government spending on other goods and services.
6. For Forestry 7 (Urban Forestry), the non-energy benefits, such as aesthetic/other, stormwater, and air quality benefits are not included in the REMI macroeconomic impacts analysis.
7. For Forestry 7 (Urban Forestry), it is assumed that one-third of the program funding comes from the state government budget. The other two-thirds will be borne by the commercial sector and residential sector.
8. For Transportation 6 (Utilizing Existing Public Transportation Systems) and Transportation 9 (Increasing Federal Support for Efficient Transit and Freight Transport in PA), potential fuel savings were not counted in the quantification analysis of the work plans. Therefore, the macroeconomic stimulus from energy savings associated with these two work plans are not included in the macro study.
9. For Forestry 8 (Wood to Electricity), benefits from avoided fossil fuel use were not analyzed in the quantification of the work plans, since wood-to-electricity was likely to offset very little of the fossil fuel when used for electricity. Therefore, the macroeconomic impacts from the avoided fossil fuel are not included in the REMI analysis.

Presentation of the Results

Basic Results

A summary of the basic results of the application of the REMI Model to determining the state-wide macroeconomic impacts of individual *Pennsylvania Climate Action Plan* mitigation work plans is presented in Tables 1 and 2. Table 1 includes the GSP impacts for each work plan for three selected years, as well as a net present value (NPV) calculation for the entire period of 2009 to 2020. Table 2 presents analogous results for employment impacts statewide, though, for reasons noted below, an NPV calculation of employment impacts is not appropriate. The reader is referred to Section E in the Appendix for detailed results for each year, as well as the impacts on other economic indicators, such as gross regional product and prices, for a representative set of work plans. Individual sectoral results are presented in Section F in the Appendix. Please note different from the results presented in the microeconomic analysis tables, a positive number in tables in this chapter represents a positive stimulus to the economy (i.e., an increase in Gross State Product or a creation of jobs). A negative number, on the contrary, means negative impacts to the state economy (i.e., a decrease in the Gross State Product or a decline in total employment in PA).

The NPV total GSP impact for the period 2009-2020 is about $5.09 billion (constant 2007) dollars with the impacts being negative in 2010 and increasing steadily over the years to an

[4] PA chose the larger 169-sector REMI model over the 70-sector model to undertake the macroeconomic analysis. The standard 70-sector REMI model is not as adequate as the 169-sector model to evaluate the impacts of the PA Climate Action Plan because the former combines electricity, gas and water into a single Utilities sector, while the latter separates the three activities into individual sectors.

annual high of $2.22 billion in 2020. In that year, the impacts represent an increase of 0.32 percent in GSP in the State.

The last row of Table 1 and Table 2 present the simulation results of the GSP and employment impacts for the simultaneous run, in which we assume that all the work plans are implemented concurrently. When we implement the simultaneous run in the REMI model, we "shock" the model by including all the variable changes in the individual runs together.

Table 1 highlights several important points:

- The macroeconomic impacts of 27 of the 42 work plans are positive, which means implementing these work plans will bring about a positive stimulus to the Pennsylvania state economy by increasing the Gross State Product and creating more jobs.
- Work plans Res/Com-5 (Commission Buildings) and Industry-2 (Industrial Natural Gas and Electricity Best Management Practices) yield the highest positive impacts on the economy—an NPV of $4.94 billion; work plan Electricity-9 (Combined Heat and Power) results in the highest negative impacts to the economy—an NPV of -$3.24 billion.
- Mitigation work plans from the Residential and Commercial sector and the Industrial Sector would yield the highest positive impacts on the economy, followed by the work plans from the Agriculture sector and Waste Management sector.

Table 1. Gross State Product Impacts of the Pennsylvania Climate Action Plan

(Billions of Fixed 2007$)					
Scenario		**2010**	**2015**	**2020**	**Net Present Value**
	E3	$0.00	$0.00	$0.02	$0.01
	E5	$0.00	-$0.03	-$0.12	-$0.21
	E6	$0.04	$0.10	$0.13	$0.71
	E7	$0.00	$0.00	$0.00	$0.00
	E9	-$0.03	-$0.41	-$0.94	-$3.24
	E10	$0.00	-$0.01	-$0.11	-$0.10
Subtotal - Electricity		$0.00	-$0.35	-$1.02	-$2.84
	I1	$0.01	$0.01	$0.01	$0.06
	I2	$0.00	$0.25	$1.06	$2.47
	I3	$0.00	$0.02	$0.04	$0.12
Subtotal - Industrial		$0.01	$0.28	$1.11	$2.66
	RC5	$0.03	$0.31	$0.75	$2.47
	RC6	-$0.04	$0.28	$0.95	$1.98
	RC7	$0.00	-$0.04	-$0.31	-$0.57
	RC8	$0.00	-$0.02	-$0.02	-$0.10
	RC9	$0.01	$0.07	$0.18	$0.54
	RC10	$0.05	$0.28	$0.35	$1.85
	RC11	$0.13	$0.13	$0.09	$0.98
	RC13	$0.01	$0.05	$0.08	$0.35
Subtotal - Res/Com		$0.17	$1.06	$2.07	$7.50
	F1	-$0.02	$0.00	$0.00	-$0.07
	F3	-$0.01	-$0.02	-$0.03	-$0.16
	F4	-$0.08	-$0.10	-$0.12	-$0.86
	F7	$0.00	-$0.02	-$0.06	-$0.16

(Billions of Fixed 2007$)					
Scenario		2010	2015	2020	Net Present Value
	F8	$0.00	$0.00	$0.00	$0.00
	F9a	$0.02	$0.12	$0.25	$0.92
	F9b	$0.00	$0.00	-$0.01	-$0.03
Subtotal - Forestry		-$0.10	-$0.02	$0.03	-$0.37
	Ag3	$0.00	$0.04	$0.07	$0.27
	Ag4b	$0.00	$0.00	$0.00	$0.00
	Ag5a	$0.00	$0.00	$0.00	-$0.01
	Ag5b	$0.00	$0.00	$0.00	$0.02
Subtotal - Ag		$0.00	$0.04	$0.07	$0.27
	W1	$0.00	$0.03	$0.06	$0.22
	W2	$0.00	$0.02	$0.02	$0.13
	W4	$0.00	$0.00	$0.00	$0.00
	W5	$0.00	$0.00	$0.00	$0.01
	W6	$0.00	$0.00	$0.01	$0.02
Subtotal - Waste		$0.01	$0.06	$0.09	$0.39
	T3	$0.00	$0.06	$0.13	$0.43
	T5a	-$0.01	-$0.06	-$0.34	-$0.84
	T5b	-$0.01	$0.00	$0.01	$0.01
	T5c	-$0.10	-$0.10	-$0.09	-$0.77
	T5d	$0.00	$0.00	$0.01	$0.00
	T5e	-$0.58	-$0.11	-$0.11	-$1.91
	T6	-$0.11	-$0.12	-$0.13	-$0.93
	T8	$0.00	$0.07	$0.27	$0.65
	T9	$0.10	$0.11	$0.11	$0.84
Subtotal - TLU		-$0.72	-$0.14	-$0.14	-$2.52
Summation Total		**-$0.62**	**$0.92**	**$2.22**	**$5.09**
Simultaneous Total		**-$0.82**	**$0.69**	**$3.41**	**$5.13**

Note: A positive number in this table means a positive stimulus to the state economy, or an increase in the Gross State Product; a negative number in this table means negative impacts to the state economy, or a decrease in the Gross State Product.

Most of the work plans that generate positive impacts do so because they result in cost-savings, and thus lower production costs in their own operation and that of their customers. This raises business profits and the purchasing power of consumers in Pennsylvania, thus stimulating the economy. The cost-savings emanate both from direct reductions in lower fuel/electricity costs, by simply using existing resources more prudently, or through the payback on initial investment in more efficient technologies. Those work plans that result in negative macroeconomic impacts do so because, while they do reduce GHG's, the payback on investment from a purely economic perspective is negative, i.e., they don't pay for themselves in a narrow economic sense. This also raises the cost for production inputs or consumer goods to which they are related.[5]

[5] The results for Electricity-9 (cogeneration), for example, can be decomposed into negative and positive stimuli, with the net effects being negative. The negative economic stimuli of this work plan include the increased cost (including annualized capital costs, operating and maintenance costs, and fuel costs) to the commercial and industrial sectors due to the installation of the CHP systems; reduced final demand from the conventional electricity generation (which equals the sum of electricity output from the CHP plus avoided electricity use in boilers/space

Table 2. Employment Impacts of the Pennsylvania Climate Action Plan

(Thousands)				
Scenario		**2010**	**2015**	**2020**
	E3	0.0	0.1	0.8
	E5	0.0	-0.2	-0.9
	E6	0.4	0.9	1.0
	E7	0.0	0.0	0.0
	E9	-0.3	-3.8	-7.1
	E10	0.0	-0.1	-0.4
Subtotal - Electricity		0.1	-3.1	-6.5
	I1	0.1	0.1	0.1
	I2	0.0	2.8	9.5
	I3	0.0	0.2	0.3
Subtotal - Industrial		0.1	3.1	9.9
	RC5	0.4	3.9	7.8
	RC6	0.6	8.5	13.3
	RC7	0.0	-0.2	-1.7
	RC8	0.1	0.3	0.4
	RC9	0.0	0.2	0.7
	RC10	0.7	3.1	3.1
	RC11	1.9	1.6	1.0
	RC13	0.2	0.7	1.0
Subtotal - Res/Com		3.8	18.0	25.6
	F1	-0.3	0.0	0.0
	F3	-0.3	-0.3	-0.4
	F4	-1.2	-1.4	-1.6
	F7	3.0	9.8	15.5
	F8	0.0	0.0	0.0
	F9a	0.3	1.4	2.4
	F9b	0.0	-0.1	-0.1
Subtotal - Forestry		1.4	9.5	15.8
	Ag3	0.0	0.5	0.8
	Ag4b	0.0	0.0	0.0
	Ag5a	0.0	0.0	0.0
	Ag5b	0.0	0.0	0.1
Subtotal - Ag		0.0	0.5	0.9
	W1	0.0	0.3	0.5
	W2	0.1	0.4	0.4
	W4	0.0	0.0	0.0
	W5	0.0	0.0	0.0
	W6	0.0	0.1	0.2
Subtotal - Waste		0.1	0.8	1.2
	T3	0.1	0.6	1.2

heaters/water heaters). The positive stimuli include various fuel cost savings (e.g., electricity, natural gas, oil, and other fuel cost savings) to the commercial and industrial sectors from displaced heating fuels for all kinds of CHP systems; increase in final demand to the Construction and Engine, Turbine, and Power Transmission Equipment Manufacturing sectors; and increase in final demand in Farm (biomass) and Natural Gas Distribution sectors due to the increased demand of fuels and feedstocks to supply the CHP facilities.

(Thousands)				
Scenario		**2010**	**2015**	**2020**
	T5a	-0.2	-1.0	-5.0
	T5b	-0.2	0.0	0.2
	T5c	-1.7	-1.4	-1.2
	T5d	-0.1	0.0	0.1
	T5e	-8.4	-4.2	-5.9
	T6	0.5	0.3	0.3
	T8	0.0	0.7	2.1
	T9	1.9	1.8	1.7
Subtotal - TLU		-8.1	-3.2	-6.6
Summation Total		**-2.5**	**25.5**	**40.2**
Simultaneous Total		**-5.1**	**24.6**	**54.4**

Note: A positive number in this table means job creation in Pennsylvania; a negative number in this table means a reduction in the total employment of Pennsylvania.

The employment impacts are summarized in Table 2 and are qualitatively similar to those in Table 1. In this case, 28 of 42 work plans yield positive employment impacts. By the year 2020, for the simple summation results, these new jobs accumulate to the level of about 40 thousand full-time equivalent jobs generated directly and indirectly in the Pennsylvania economy by the Climate Action Plan. This represents an increase over baseline projections of 0.54 percent. For the simultaneous simulation case, the job gains are projected to be 54,000 full time equivalent jobs in Pennsylvania, or an increase of 0.73 percent. The employment impacts in the REMI model are presented in terms of annual differences from the baseline scenario and as such cannot be summed across years to obtain cumulative results. For example, a new business opens its doors in 2009 and creates 100 new jobs. As long as the business is open, that area will have 100 more jobs than it would have had without the business. In other words, it will have 100 more jobs in 2009, 2010, 2011, etc. We cannot say that the total number of jobs created is 100 + 100 + 100 +… Every year it is the *same* 100 jobs that persist over time not an additional 100 jobs.

The simulation results indicate that work plans in the Residential and Commercial, Forestry, and Industrial sectors would create more jobs than the mitigation work plans in other sectors.

The work plans in the Action Plan have the ability to lower the Pennsylvania Price Index by 0.29 percent from baseline by the Year 2020. This price decrease, of course, has a positive stimulus on GSP and employment.

The simultaneous simulation indicates a GSP impact in NPV terms of $5.13 billion for the period 2009-2020, with the impacts being negative in 2010 and then increasing steadily over the years to an annual high of $3.41 billion in 2020. This increase represents 0.49 percent of GSP in the State in that year. The cumulative new job creation in 2020 is about 54 thousand full-time equivalent jobs, an increase of about 0.73 percent from the baseline level.

A comparison between the simultaneous simulation and the summation of simulations of individual work plans shows that the former yields higher positive impacts to the economy—the GSP NPV is 0.9 percent higher and the job increase in 2020 is 35.5 percent higher. The overlaps between work plans have been accounted for in the microeconomic analysis and have been eliminated before performing the macroeconomic analysis. The difference between the simultaneous simulation and the ordinary sum can be explained by the non-linearity in the REMI model and synergies in economic actions it captures. In other words, the relationship between the model inputs and the results of REMI is not one of constant proportions. The higher positive impact from the simultaneous simulation is due to non-linearities and synergies in the model that reflect real world considerations. In actuality, few phenomenon scale-up in a purely proportional manner. For example, in REMI, labor market responses are highly non-linear, and a much larger scale stimulus sets off a significant shift from capital to labor. Given that the simulation results are magnitude-dependent and are not calculated through fixed multipliers, it is not surprising that when we model all the mitigation work plans together, the increased magnitude of the total stimulus to the economy causes wage, price, cost, and population adjustments to occur differently than if each work plan is run by itself.

Table L6 and Table L7 in the Appendix present the impacts on GSP and employment of each individual economic sector for the simultaneous simulation. The impacts of the various mitigation work plans vary significantly by sector of the Pennsylvania Economy. One would expect producers of energy efficient equipment to benefit from increased demand for their products, as will most consumer goods and trade sectors because of increased demand stemming from increased purchasing power. The top five positively impacted sectors in terms of the NPV of GSP are, in descending order, Real Estate, Transit and Ground Passenger Transportation, Waste Collection; Waste Treatment and Disposal and Waste Management, Offices of Health Practitioners[6], and Monetary Authorities, Credit Intermediation.

One would expect Electric Utilities related to fossil fuels, including gas pipelines to witness a decline. In fact, the Electric Power Generation, Transmission, and Distribution sector is expected to have the largest negative impact by far -- $7.38 billion (NPV). Other negatively affected sectors in descending order of impacts are Petroleum and Coal Products Manufacturing, Natural Gas Distribution, Coal Mining, Water, Sewage, and Other Systems, and Pipeline Transportation. However, none of these sectors is expected to have a decline of more than $0.4 billion.

Sensitivity Analysis and Sensitivity Tests

a. Sensitivity Analysis

In the sensitivity analysis, we simulate the macroeconomic impacts of two recent state actions of the electricity sector. The first recent state action is Electricity-1 Act 129 of 2008, which aims to reduce carbon emissions associated with the reduction of electricity consumption and peak load. The second recent state action plan is Electricity-4 Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard, which requires that all electricity consumed in PA by 2021 be generated at least from 0.5 percent solar PV technology and 8 percent other renewable resources.

Act 129 of 2008 was signed into law on October 15, 2008. The Pennsylvania REMI model did not take this legislation into account in the model baseline condition. From personal contact with

[6] The increased activity in this sector stems not from any increase in healthcare needs but rather from the fact that consumer disposable income has increased.

the REMI modelers, we also learned that, although the Alternative Energy Portfolio Standard was signed in November 24, 2004, since most of its effects would take place 10 or so years from its inception, REMI did not explicitly take the implications of this legislation into account in the Pennsylvania baseline forecast as well.

Table 3 shows the impacts on GSP and employment of these two recent state actions.

Table 3. GSP and Employment Impacts of Electricity-1 and Electricity-4

	2010	2015	2020	NPV
Electricity-1 (Act 129)				
GSP (Billions of Fixed 20002007$)	$0.00	$0.03	$0.13	$0.29
Employment (Thousands)	0.2	1.4	2.1	n.a.
Electricity-4 (AEPS)				
GSP (Billions of Fixed 2007$)	$0.06	$0.39	$1.00	$3.21
Employment (Thousands)	0.4	3.9	8.9	n.a.

b. Sensitivity Tests

We performed sensitivity tests on two parameters of the analysis for some of the work plans with large economic impacts. For example, for Electricity-9 (cogeneration) these parameters are: fuel prices and costs. In the simulations we assumed:

1. The fuel prices are 50 percent lower or 50 percent higher than the levels used in the base case analysis. These would first affect the fuel cost savings to all the commercial and industrial sectors (which are the product of the physical amount of displaced fuel use and the price of fuels). Meanwhile, change of fuel prices will also affect the gross fuel costs for the CHP systems, which are part of the increased production cost to the commercial and industrial sectors. Moreover, these would also affect the "exogenous final demand" for the outputs of the Natural Gas Distribution sector and Farm sector (in value terms).

2. The costs of the CHP systems are 50 percent lower or 50 percent higher than the levels used in the current analysis. The costs of the CHP systems include three parts: annualized capital costs, fuel costs, and O&M costs. The sensitivity of the fuel costs is analyzed in #1. The O&M costs are very small compared with the capital cost. Thus, we confine the sensitivity analysis to the capital cost. This translates into the demand for production for the Construction, Engine, Turbine, and Power Transmission Equipment Manufacturing sectors. Note also that this sensitivity test can implicitly also refer to whether the investment funds come from within the State, and thus displace other investment, or whether they flow into the State from the outside and therefore do not have a displacement effect.

We combined these two sensitivities into two cases:

Upper-Bound case--the two variations that result in the highest estimate[7]

[7] Please note since the overall impacts of this work plan are negative, the highest estimate here means highest negative impacts.

Lower-Bound case--the two variations that result in the lowest estimate

The Upper-Bound case involves fuel costs that are 50 percent higher (the fuel cost savings (including electricity savings) of this work plan cannot offset the gross fuel costs increase for the CHP systems) plus CHP investment costs that are 50 percent higher. The Lower-Bound case includes the opposite combination. The sensitivity tests indicated that our results are relatively robust, i.e., varying the parameters does not change them in a major way.

In the base case simulation, we simulated a stimulus from only 50 percent of the capital investment and only a 50 percent change in the capital cost requirement in the utility sector or production sectors. The assumption is that 50 percent of the investment in new equipment will simply displace other investment in the state and that 50 percent will be additive, stemming from a combination of attracting private investment funds and from federal subsidies. In a sensitivity test, we simulate the impacts of 100 percent capital investment / capital costs (no displacement effects). The GSP impacts in NPV reduce from \$5.13 billion to \$2.34 billion. The employment impacts in 2020 reduce from 54 thousands to 52 thousands. Therefore, the GSP impacts are sensitive to the assumption on the percentage of capital investment / capital cost simulated in the REMI model.

Our final sensitivity test relates to the 5 percent discount rate used in the base case analysis. When a 2 percent discount rate is used in the simultaneous run, the Base Case NPV increase in GSP climbs from \$5.13 billion to \$7.48 billion. When a 7 percent discount rate is used, the Base Case estimate drops to an increase of \$3.97 billion. Changes in the discount rate do not affect the employment estimates.

Finally, we note that our results are similar with some recent studies. Roland-Holst (2009), in a recent study of the impacts of RPS Standards and energy efficiency improvements for the California economy, similar to those in the Pennsylvania case, projected a net increase of half a million jobs by 2050. If we adjust for the relative sizes of the two state economies, the results are very similar in percentage terms. Kammen (2007) estimated a large number of new jobs as well stemming from climate change legislation.

Conclusion

This chapter summarizes the analysis of the impacts of the *Pennsylvania Climate Action Plan* on the State's economy. We used a state of the art macroeconometric model to perform this analysis, based on data supplied from seven subcommittees who vetted them through an in-depth, consensus based technical assessment and stakeholder process. The results indicate that the majority of the greenhouse gas mitigation and sequestration work plans have positive impacts on the State's economy individually. On net, the combination of work plans has a Net Present Value of increasing GSP by about \$5.13 billion and increasing employment by 54 thousand full-time equivalent jobs by the Year 2020. The Commissioning and Retro-Commissioning buildings work plan and Industrial Natural Gas and Electricity Best Management Practices work plan contribute the highest GSP gains, which combined to account for about 33 percent of the total. Urban Forestry and Re-light PA contribute the highest employment gains, which combined to account for nearly 45 percent of the total job creation.

The economic gains stem primarily from the ability of mitigation work plans to lower the cost of production. This stems primarily from their ability to improve energy efficiency and thus lower production costs and higher consumer purchasing power. The results also stem from the stimulus of increased investment in plant and equipment.

Several tests were performed to determine the sensitivity of the results to major changes in key variables such as capital costs, fuel prices, and avoided costs of electricity generation. The tests indicate the results are robust, i.e., the overall results do not change much even when these variables are changed by plus and minus 50 percent.

Note that the estimates of economic benefits to Pennsylvania represent a lower bound from a broader perspective. They do not include the avoidance of damage from the climate change that continued baseline GHG emissions would bring forth, the reduction in damage from the associated decrease in ordinary pollutants, the reduction in the use of natural resources, the reduction in traffic congestion, etc.

Overall, the *Pennsylvania Climate Action Plan* is a win-win policy.

References

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Treyz, G. 1993. *Regional Economic Modeling: A Systematic Approach to Economic Forecasting and Policy Analysis*. Boston: Kluwer.

APPENDIX A

PENNSYLVANIA CLIMATE CHANGE ACT
71 P.S. §§ 1361.1 – 1361.8
2008, July 9, P.L. 935, No. 70
Effective: July 09, 2008

Note: This document is for informational use only. Official commonwealth publication of Pennsylvania laws can be found in Smith's Laws of Pennsylvania (1700 through Nov. 30, 1801), Laws of Pennsylvania (Dec. 1, 1801 to date), and Pennsylvania Consolidated Statutes.

Source: Purdon's Pennsylvania Statutes and Consolidated Statutes (used under agreement)
http://government.westlaw.com/linkedslice/default.asp?SP=pac-1000
Title 71 P.S. State Government
Chapter 6. Provisions Similar or Closely Related to Provisions of the Administrative Code
Secretary and Department of Environmental Protection
Pennsylvania Climate Change Act

§ 1361.1 Short Title

This act shall be known and may be cited as the Pennsylvania Climate Change Act.

§ 1361.2. Definitions

The following words and phrases when used in this act shall have the meanings given to them in this section unless the context clearly indicates otherwise:

"Baseline." A level of greenhouse gas emissions against which future emissions are measured.

"Carbon sequestration." The long-term storage of carbon or carbon dioxide in forests, forest products, soils, oceans or underground in depleted oil and gas reservoirs, coal seams and saline aquifiers.

"Climate change." Any alteration of the earth's climate due, at least in part, to emissions of greenhouse gases associated with human activities, including, but not limited to, the burning of fossil fuels, biomass burning, cement manufacture, agriculture, deforestation and other land-use changes.

"Cobenefits." The economic, social, environmental, public health and other benefits of climate change policies that are independent of any benefits for reducing or mitigating climate change.

"Committee." The Climate Change Advisory Committee established in section 5.

"Department." The Department of Environmental Protection of the commonwealth.

"Greenhouse gases" or **"GHGs."** Gases in the earth's atmosphere that absorb and reemit infrared radiation, including carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride.

"Secretary." The Secretary of Environmental Protection of the commonwealth.

§ 1361.3. Report on potential climate change impact and economic opportunities for this commonwealth

(a) Report required.--The department shall prepare and publish a report on the potential impact of climate change in this commonwealth. The report shall identify the following:

(1) Scientific predictions regarding changes in temperature and precipitation patterns and amounts in this commonwealth that could result from climate change. Such predictions shall reflect the diversity of views within the scientific community.

(2) The potential impact of climate change on human health, the economy and the management of economic risk, forests, wildlife, fisheries, recreation, agriculture and tourism in this commonwealth and any significant uncertainties about the impact of climate change.

(3) Economic opportunities for this commonwealth created by the potential need for alternative sources of energy, climate-related technologies, services and strategies; carbon sequestration technologies; capture and utilization of fugitive greenhouse gas emissions from any source; and other mitigation strategies.

(b) Cooperation.--In preparing the report, the department shall consult with Federal and other State agencies, academic institutions and the committee. The department may also evaluate the recommendations of climate change action plans prepared by counties and municipalities within this commonwealth. The report shall reflect any diversity of opinion among the entities consulted by the department.

(c) Deadline.--This report shall be completed, published and distributed to the General Assembly and made available to the public in printed form and on the department's Internet website within nine months of the effective date of this act and shall be revised every three years thereafter.

§ 1361.4. Greenhouse gases inventory

(a) Inventory required.--In consultation with the committee, the department shall annually compile an inventory of GHGs emitted in this commonwealth by all sources. This inventory shall establish GHG emission trends and the relative contribution of major sectors, including, but not limited to, the transportation, electricity generation, industrial, commercial, mineral and natural resources, production of alternative fuel, agricultural and domestic sectors.

(b) Baseline.--The department shall establish a baseline of GHG emissions that it shall use to project future GHG emissions in this commonwealth in the absence of government intervention.

(c) Coordination with action plan.--The inventory and baseline shall be presented to the Governor, the General Assembly and the committee every three years as part of the climate change action plan required under section 7.

§ 1361.5. Climate Change Advisory Committee

(a) Establishment.--There is established within the department the Climate Change Advisory Committee. The purpose of the committee shall be to advise the department regarding the implementation of the provisions of this act.

(b) Membership.--

(1) The committee shall be composed of residents of this commonwealth selected as set forth in this subsection. Members shall be appointed on account of their interest, knowledge or expertise regarding climate change issues. Members shall be selected to reflect a diversity of viewpoints on climate change issues from the scientific, business and industry, transportation, environmental, social, outdoor and sporting, labor and other affected communities.

(2) Eighteen members shall be appointed as follows:

(i) Six members appointed by the Governor.

(ii) Six members appointed by the Senate. Of these members, the Majority Leader of the Senate shall appoint four members, and the Minority Leader of the Senate shall appoint two members.

(iii) Six members appointed by the House of Representatives. Of these members, the Majority Leader of the House of Representatives shall appoint four members, and the Minority Leader of the House of Representatives shall appoint two members.

(3) The Secretary of Conservation and Natural Resources, the Secretary of Community and Economic Development and the Chair of the Pennsylvania Public Utility Commission, or their designees, shall be ex officio voting members of the committee.

(c) Appointment.--Members of the committee shall be appointed within 30 days of the effective date of this act.

(d) Terms of service.--A member shall be appointed for a term of four years. Of the initial members appointed by the Governor, three members shall serve initial terms of two years. Of the initial members appointed by the Majority Leader of the Senate, two members shall serve initial terms of two years. Of the initial members appointed by the Majority Leader of the House of Representatives, two members shall serve initial terms of two years. Of the initial members appointed by the Minority Leader of the Senate, one member shall serve an initial term of two years. Of the initial members appointed by the Minority Leader of the House of Representatives, one member shall serve an initial term of two years. After such initial terms, all appointments shall serve for a term of four years.

(e) Chairperson.--The chairperson of the committee shall be elected from among and by a majority vote of the members appointed under subsection (b)(2). The term of a chairperson shall be for two years, and an individual may serve no more than two consecutive terms as chairperson.

(f) Meetings.--Within 60 days of the effective date of this act, the department shall call the first meeting of the committee and shall establish a schedule for regular meetings of the committee to assist in the implementation of this act.

(g) Expenses.--Members of the committee shall serve without compensation but may be reimbursed from funds appropriated for such purposes for necessary and reasonable travel and other expenses incurred during the performance of their duties.

(h) Facilitator.--The department shall retain the services of a third-party facilitator to conduct the activities of the committee.

(i) Department responsibilities.--The department shall create and maintain an Internet website listing the membership, activities, meeting schedule, meeting agenda, expense reimbursements and other relevant information regarding the committee.

§ 1361.6. Voluntary greenhouse gas registry

Within 90 days of the effective date of this act, the department shall create a voluntary greenhouse gas registry through which interested businesses, governments, institutions and other entities can record any reductions in greenhouse gas emissions or any avoided emissions of greenhouse gas emissions that are achieved in the absence of any government mandate to reduce such emissions. The department shall develop guidelines and criteria for the operation of the registry and shall create a site on the department's publicly accessible Internet website for the public to examine a current list of registrants and emission reductions and avoidances.

§ 1361.7. Climate change action plan

(a) Action plan required.--Within 15 months from the effective date of this act and every three years thereafter, the department shall, in consultation with the committee, submit to the Governor a climate change action plan that:

(1) Identifies GHG emission and sequestration trends and baselines in this commonwealth.

(2) Evaluates cost-effective strategies for reducing or offsetting GHG emissions from various sectors in this commonwealth.

(3) Identifies costs, benefits and cobenefits of GHG reduction strategies recommended by the climate change action plan, including the impact on the capability of meeting future energy demand within this commonwealth.

(4) Identifies areas of agreement and disagreement among committee members about the climate change action plan.

(5) Recommends to the General Assembly legislative changes necessary to implement the climate change action plan.

(b) Publication.--The climate change action plan shall be published and distributed to the General Assembly and made available to the public in printed form and on the department's Internet website upon submission of the plan to the Governor.

§ 1361.8. Effect of Federal law

(a) Duty of secretary to monitor Federal law.--The secretary shall monitor the enactment of laws by the Congress of the United States to determine whether any law has been so enacted that it establishes a program of GHG inventory, registry or reporting requirements that are as or more comprehensive than those set forth in this act.

(b) Publication in Pennsylvania Bulletin.--If the secretary determines that such a law is enacted, the secretary shall publish this determination in the Pennsylvania Bulletin. The notice shall include a statement that affected entities shall be in compliance with this act or any subsequent act which imposes GHG inventory, registry or reporting requirements by submitting the same information to the department as is required to be submitted under Federal law.

APPENDIX B
MEMBERSHIP OF CLIMATE CHANGE ADVISORY COMMITTEE

Member Name	Job Title	Affiliation	Appointed By	Committee Position	Term Expires	Subcommittees for Members	Subcommittee Position
Richard Allan	President	R J Allan Consulting	Senate Minority	Appointed Member	July 9, 2010	Electricity / Industry & Waste	
Peter Alyanakian	Councilman	Media Borough	Senate Majority	Appointed Member	July 9, 2012	Land Use & Trans	
Robert Barkanic	Director of Environmental Management	PPL	Senate Majority	Appointed Member	July 9, 2010	Electricity / Res & Comm	
Laureen Boles	Environmental Planner	City of Philadelphia	Governor	Appointed Member	July 9, 2010	Res & Comm	
Terry Bossert	Partner	Post & Schell Attorneys at Law	Senate Majority	Appointed Member	July 9, 2012	Electricity / Industry & Waste	CHAIR for Industry & Waste
David Cannon	Vice President, Environment, Health and Safety	Allegheny Energy, Inc.	Senate Majority	Appointed Member	July 9, 2010	Electricity / Ag & Forestry	CHAIR Electricity
James Cawley	Chairman	PA PUC	Act 70	Ex Officio Member	N/A		
George Cornelius	Secretary	PA Dept. of Community & Economic Development	Act 70	Ex Officio Member	N/A		
Daniel Desmond	Partner	Peregrine Technology Partners	Governor	Appointed Member	July 9, 2012		
George Ellis	President	PA Coal Association	House Minority	Appointed Member	Not identified	Electricity / Industry & Waste	
Camille "Bud" George	Representative	PA House of Representatives	House Majority	Appointed Member	July 9, 2012	Electricity	
Fred Harnack	General Manager, Environmental Affairs	United States Steel Corporation	House - Minority	Appointed Member	Not identified	Industry & Waste / Land Use & Trans	
Sarah Hetznecker	Director of Project Development	Conergy	Governor	Appointed Member / CHAIR	July 9, 2010	Electricity / Ag & Forestry	
Jan Jarrett	President	PennFuture	Governor	Appointed Member	July 9, 2012	Electricity / Industry & Waste	
Vivian Loftness	Professor, School of Architecture	Carnegie Mellon University	Governor	Appointed Member	July 9, 2010	Res & Comm / Land Use & Trans	CHAIR for Res & Comm
Alan Magnotta	President	CECO Associates, Inc.	Senate Minority	Appointed Member	July 9, 2012	Industry & Waste	
Paul Opiyo	Executive Policy Specialist	PA Dept. of Community & Economic Development	Designee	Designee to Cornelius	N/A	Industry & Waste	
John Quigley	Secretary	PA DCNR	Act 70	Ex Officio Member / VICE CHAIR	N/A	Electricity / Ag & Forestry	Former CHAIR for Ag & Forestry
Ron Ramsey	Senior Policy Advisor	Nature Conservancy in PA, The	Governor	Appointed Member	July 9, 2012	Res & Comm / Land Use & Trans / Ag Forestry	
Paul Roth	Section Chief	PA Dept. of Conservation & Natural Resources	Designee	Designee to Quigley	N/A	Ag & Forestry	CHAIR Ag & Forestry
Greg Vitali	Representative	PA House of Representatives	House Majority	Appointed Member	July 9, 2012	Electricity / Land Use & Trans	
Nathan Willcox	Energy and Clean Air Advocate	PennEnvironment	House Majority	Appointed Member	July 9, 2010	Electricity / Res & Comm / Land Use & Trans	CHAIR for Land Use & Trans
Wayne Williams	Director, Bureau of Conservation, Economics and Energy Planning (CEEP)	PA PUC	Designee	Designee to Cawley	N/A	Electricity	Former CHAIR Electricity
Edward Yankovich	International Vice President, UMWA District #2	United Mine Workers of America	House Majority	Appointed Member	July 9, 2010	Electricity / Industry & Waste	

APPENDIX C

CCAC Work Plan Recommendations - Voting Record July 17, 2009

Work Plan Number	Potential Reductions (MMTCO2e)	CCAC Recommended?	Votes[1]			Allan	Alyanakian	Barkanic	Boles	Bossert	Cannon	Desmond	Ellis	George	Hamack	Hetznecker	Jarrett	Loftness	Magnotta	Opiyo	Quigley	Ramsey	Vitali	Willcox	Williams	Yankovich
			Yes	No	Abs																					
RC-1-4	31.9	YES [4]	18	2	1	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	Y	Y	A	Y	Y
RC-5	1.5	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
RC-6	12.9	YES	20	0	1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	A	Y	Y	Y	Y	Y	Y	Y	Y
RC-7	1.4	YES	14	7	0	N	Y	N	Y	Y	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
RC-8	1.9	YES	13	8	0	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
RC-9	1.4	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
RC-10	7.3	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
RC-11	5.7	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
RC-12	10.1	NO [1]	14	1	6	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	A	A	A	Y	Y	Y	A	A	A	Y	Y
RC-13	0.1	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
RC-14	NQ [2]	YES	17	1	2	N	Y	A	Y	Y	Y	Y	A	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
RC-15	NQ	YES	17	1	2	N	Y	A	Y	Y	Y	Y	A	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
RC-16	NQ	YES	17	1	2	N	Y	A	Y	Y	Y	Y	A	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Electricity 2	7.00	YES	13	8	0	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
Electricity 3	9.00	YES	13	8	0	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
Electricity 5	5.00	YES	20	1	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Electricity 6	5.00	YES	13	8	0	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
Electricity 7	0.10	YES	20	1	0	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Electricity 8	N/A	N/A [3]	-	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Electricity 9	4.00	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Electricity 10	15.00	YES	20	1	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
Electricity 11	NQ	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Electricity 12	NQ	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Electricity 1	4.00	N/A	-	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Electricity 4	11.00	N/A	-	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Industry #1	0.57	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry #2	5.00	YES	18	3	0	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
Industry #3	0.10	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Waste-1	0.10	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Waste-2	5.44	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Waste-3	NQ	NO [1]	19	0	2	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	A	Y	Y	Y	Y	Y	A	Y	Y
Waste-4	0.004	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Waste-5	0.10	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Waste-6	0.24	YES	19	1	1	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	A	Y	Y	Y	Y	Y	Y	Y	Y

CCAC Work Plan Recommendations - Voting Record July 17, 2009																									
Work Plan Number	Potential Reductions (MMTCO2e)	CCAC Recommended?	Votes			Allan	Alyanakian	Barkanic	Boles	Bossert	Cannon	Desmond	Ellis	George	Harnack	Hetznecker	Jarrett	Loftness	Magnotta	Opiyo	Quigley	Ramsey	Vitali	Willcox	Williams	Yankovich
			Yes	No	Abs																					
T-1	0.095	N/A	-	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
T-2	3.47	YES	14	7	0	Y	Y	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
T-3	0.68	YES	16	5	0	N	Y	N	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
T-4	0.07	N/A	-	-	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
T-5	3.51	YES	13	8	0	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
T-6	0.05	YES	13	8	0	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
T-7	0.12	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
T-8	0.99	YES	15	6	0	N	Y	N	Y	Y	Y	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
T-9	1.17	YES	20	1	0	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
T-10	0.76	YES	13	8	0	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
T-11	(See T-10)	YES	13	8	0	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
Ag-1	NQ	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ag-2	(See T-2)	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ag-3	0.62	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ag-4	0.26	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Ag-5	0.06	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
F-1	0.18	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
F-2	NQ	YES	14	6	1	N	Y	A	Y	Y	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N
F-3	0.18	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
F-4	3.98	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
F-5	29.21	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
F-6	0.04	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
F-7	1.20	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
F-8	0.26	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
F-9	0.47	YES	21	0	0	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Notes on voting record chart:

1. Voting count reflects the motion to recommend, except for RC-12 and Waste-3 where the motion was to **not recommend** the work plan. Refer to meeting minutes.
2. NQ = Not Quantifiable (assessment by Center for Climate Strategies analytical team)
3. N/A = Not Applicable - those work plans or policies that have already been enacted as state of federal law and were analyzed to assess their impact (Electricity 1, Electricity 4, T-1 and T-4) or were analyzed purely for illustrative/informative purposes (Electricity 8) and therefore did not require action from the CCAC.
4. RC 1-4 amended with replacement language stating summary of goals for high-performance buildings and recommending a stakeholder group outside Act 70 timeline.

APPENDIX D
Methods for Quantification

Memorandum

To: Pennsylvania Department of Environmental Protection (DEP)
Pennsylvania Climate Change Advisory Committee (CCAC) and Subcommittees

From: The Center for Climate Strategies

Subject: Quantification of Climate Mitigation Work Plans

Date: May 7, 2009

This memo summarizes key elements of the recommended methodology for estimating GHG impacts (emission reductions, costs, and cost effectiveness) for the draft work plans considered amenable to quantification. The quantification process is intended to support custom design and analysis of the draft work plans, and provide both consistency and flexibility. Feedback is encouraged.

Key guidelines include:

- <u>Focus of analysis:</u> **Net GHG reduction potential** in physical units of million metric tons (MMt) of carbon dioxide equivalent (CO_2e) and **net cost per metric ton reduced** in units of dollars per metric ton of carbon dioxide equivalent ($/t$CO_2e$). Where possible, full life cycle analysis is used to evaluate the net energy (and emissions) performance of actions (taking into account all energy inputs and outputs to production). Net analysis of the effects of carbon sequestration is conducted where applicable.
- <u>Cost-effectiveness:</u> Because monetized dollar value of GHG reduction benefits are not available, physical benefits are used instead, measured as dollars per metric ton of carbon dioxide equivalent ($/t$CO_2e$) (cost or savings per ton) or "cost effectiveness" evaluation. Both positive costs and cost savings (negative costs) are estimated as a part of compliance cost.
- <u>Geographic inclusion:</u> Measure GHG impacts of activities that occur within the state, regardless of the actual location of emissions reductions. For instance, a major benefit of recycling is the reduction in material extraction and processing (e.g., aluminum production). While the effects of a work plan may increase recycling in Pennsylvania, the reduction in emissions may occur where this material is produced. Where significant emissions impacts are likely to occur outside the state, this will be clearly indicated. These emissions reductions are counted towards the achievement of the state's emission goal, since they result from actions taken by the state.
- <u>Direct vs. indirect effects:</u> "Direct effects" are those borne by the entities implementing the work plan recommendation. For example, direct costs are net of any financial benefits or savings to the entity. "Indirect effects" are defined as those borne by the entities other than those implementing the work plan recommendation. Indirect effects will be quantified on a case-by-case basis depending on magnitude, importance, time available, need and availability of data. (See additional discussion and list of examples below.)

- Non-GHG (external) impacts and costs: Include in qualitative terms where deemed important. Quantify on a case-by-case basis as needed depending on need and where data are readily available.
- Discounting and annualizing: Discount a multi-year stream of net costs (or savings) to arrive at the "net present value cost" of the cost of implementing a work plan. Discount costs in constant 2007 dollars using a 5% annual real discount rate for the project period of 2009 through 2020 (unless otherwise specified for the particular work plan). Capital investments are represented in terms of annualized or amortized costs through 2020. Create an annualized cost per ton by dividing the present value cost or cost savings by the cumulative reduction in tons of GHG emissions.
- Time period of analysis: Count the impacts of actions that occur during the project time period and, using annualized emissions reduction and cost analysis, report emissions reductions and costs for the specific target year 2020. Where additional GHG reductions or costs occur beyond the project period as a direct result of actions taken during the project period, show these for comparison and potential inclusion. Note that the CCAC has adopted an additional target year of 2050. However, data are not available to perform an analysis of potential reductions and cost for 2050 at the work plan level. Approaches for developing the information to support consideration of an analysis for 2050 will be reviewed with the CCAC and DEP.
- Aggregation of cumulative impacts of work plans: In addition to "stand alone" results for individual work plans, estimate cumulative impacts of all work plans combined. In this process we avoid simple double counting of GHG reduction potential and cost when adding emission reductions and costs associated with all of the work plan recommendations. To do so we note and or estimate interactive effects between work plan recommendations using analytical methods where significant overlap or equilibrium effects are likely.
- Work plan design specifications and other key assumptions: Include explicit notation of timing, goal levels, implementing parties, the type of implementation mechanism, and other key assumptions as determined by the Pennsylvania CCAC and the DEP and other state agencies.
- Transparency: Include work plan design choices (above) as well as data sources, methods, key assumptions, and key uncertainties. Use data and comments provided by the CCAC and the DEP and other state agencies to ensure best available data sources, methods, and key assumptions using their expertise and knowledge to address specific issues in Pennsylvania. Modifications will be made through facilitated decisions.

For additional reference see the economic analysis guidelines developed by the Science Advisory Board of the US EPA available at:
http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/Guidelines.html.

Documentation of interactions between work plans and methods for addressing overlaps are provided in the individual work plans included in Appendices E through K to this report.

Examples of Direct/Indirect Net Costs and Savings

Note: These examples are meant to be illustrative.

Residential and Commercial / Industrial Sectors

<u>Direct Costs and/or Savings</u>

- Net capital costs (or incremental costs relative to standard practice) of improved buildings, appliances, equipment (cost of higher-efficiency refrigerator versus refrigerator of similar features that meets standards)
- Net operation and maintenance (O&M) costs (relative to standard practice) of improved buildings, appliances, equipment, including avoided/extra labor costs for maintenance (less changing of compact fluorescent light (CFL) or light-emitting diode (LED) bulbs in lamps relative to incandescent)
- Net fuel (gas, electricity, biomass, etc.) costs (typically as avoided costs from a societal perspective)
- Cost/value of net water use/savings
- Cost/value of net materials use/savings (for example, raw materials savings via recycling, or lower/higher cost of low-global warming potential (GWP) refrigerants)
- Direct improved productivity as a result of industrial measures (measured as change in cost per unit output, for example, for an energy/GHG-saving improvement that also speeds up a production line or results in higher product yield)

<u>Indirect Costs and/or Savings</u>

- Re-spending effect on economy
- Net value of employment impacts
- Net value of health benefits/impacts
- Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)
- Net embodied energy of materials used in buildings, appliances, equipment, relative to standard practice
- Improved productivity as a result of an improved working environment, such as improved office productivity through improved lighting (though the inclusion of this as indirect might be argued in some cases)

Electricity Generation, Transmission, and Distribution Sector

<u>Direct Costs and/or Savings</u>

- Net capital costs (or incremental costs relative to reference case technologies) of renewables or other advanced technologies resulting from policies

- Net O&M costs (relative to reference case technologies) renewables or other advanced technologies resulting from policies
- Avoided or net fuel savings (gas, coal, biomass, etc.) of renewables or other advanced technologies relative to reference case technologies resulting from policies
- Total system costs (net capital + net O&M + avoided/net fuel savings + net imports/exports + net transmission and distribution (T&D) costs) relative to reference case total system costs

Indirect Costs and/or Savings

- Re-spending effect on economy
- Higher cost of electricity reverberating through economy
- Energy security
- Net value of employment impacts
- Net value of health benefits/impacts
- Value of net environmental benefits/impacts (value of damage by air pollutants on structures, crops, etc.)

Agriculture and Forestry / Waste Management Sectors

Direct Costs and/or Savings

- Net capital costs (or incremental costs relative to standard practice) of facilities or equipment (e.g., manure digesters and associated infrastructure, generator; ethanol production facility)
- Net O&M costs (relative to standard practice) of equipment or facilities
- Net fuel (gas, electricity, biomass, etc.) costs or avoided costs
- Cost/value of net water use/savings

Indirect Costs and/or Savings

- Net value of employment impacts
- Net value of human health benefits/impacts
- Net value of ecosystem health benefits/impacts (wildlife habitat; reduction in wildfire potential; etc.)
- Value of net environmental benefits/impacts (value of damage by air or water pollutants on structures, crops, etc.)
- Net embodied energy of water use in equipment or facilities relative to standard practice
- Reduced VMT and fuel consumption associated with land use conversions (e.g., as a result of forest/rangeland/cropland protection policies)

Transportation and Land Use Sectors

Direct Costs and/or Savings

- Incremental cost of more efficient vehicles net of fuel savings.
- Incremental cost of implementing Smart Growth programs, net of saved infrastructure costs.
- Incremental cost of mass transit investment and operating expenses, net of any saved infrastructure costs (e.g., roads)
- Incremental cost of alternative fuel, net of any change in maintenance costs

Indirect Costs and/or Savings

- Health benefits of reduced air and water pollution.
- Ecosystem benefits of reduced air and water pollution.
- Value of quality-of-life improvements.
- Value of improved road safety.
- Energy security
- Net value of employment impacts

APPENDIX E
Electricity Generation, Transmission, and Distribution Work Plans

Summary of Work Plan Recommendations and Recent Actions (noted at bottom of table)

Work Plan No.	Work Plan Name	Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $)	Annual Results (2020) Cost-Effectiveness ($\$/tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $)	Cumulative Results (2009-2020) Cost-Effectiveness ($\$/tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)[1]
2	Reduced Load Growth	7	-$432	-$64	23	-$849	-$36	13 / 8 / 0
3	Stabilized Load Growth	9	-$593	-$64	27	-$990	-$36	13 / 8 / 0
5	Carbon Capture and Sequestration in 2014	5	$291	$58	13	$391	$31	20 / 1 / 0
6	Improve Coal-Fired Power Plant Efficiency by 5%	5	$8	$1.5	55	$101.9	$1.8	13 / 8 / 0
7	Sulfur Hexafluoride (SF6) Emission Reductions from the Electric Power Industry	0.1	$0.1	$0.6	0.7	$0.3	$0.4	20 / 1 / 0
8	Analysis to Evaluate Potential Impacts Associated with Joining RGGI	For comparative analysis only						NA
9	Promote Combined Heat and Power (CHP)	4	$53	$12	23	$209	$9	21 / 0 / 0
10	Nuclear Capacity	15	$832	$57	31	$655	$21	20 / 1 / 0
11	Greenhouse Gas Performance Standard for New Power Plants	Qualitative Work Plan--Not Quantified						21 / 0 / 0
12	Transmission and Distribution Losses	Qualitative Work Plan--Not Quantified						21 / 0 / 0
Sector Total After Adjusting for Overlaps		**32**	**$1,006**	**$31**	**131**	**$1,060**	**$8**	
Actions included in Business-As-Usual Inventory and Forecast[2]		**15**	**-$432 to $211**	**-$29 to 14**	**116**	**-$2,211 to $759**	**-$19 to $7**	
1	Act 129 of 2008 (HB 2200) (Already in Electricity Baseline Forecast)	4	-$258	-$65	40	-$1,409	-$35	NA
4a	Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard (No Price Suppression)	11	$285	$26	76	$1,560	$21	NA
4b	Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard (Moderate Price Suppression)	11	-$358	-$33	76	-$615	-$8	NA

[1] NA in this column means "not applicable." Electricity 1 and 4 are recent state actions that are being implemented by the state. For Electricity 8, the CCAC analyzed the potential impacts associated with joining the RGGI initiative only and, therefore, was not considered as a work plan recommendation.

[2] Totals are shown as a range reflecting the estimated GHG emission reductions and cost savings associated with Act 129 and the GHG emission reductions and range of costs / savings associated with the two Alternative Energy Portfolio Standard scenarios (i.e., without and without moderate price suppression effects). Note that since these important state actions are included in the business-as-usual (BAU) emissions forecasts, the emission reductions and costs associated with these recent state actions are not summed with the emission reductions and costs associated with the work plans that are calculated incremental to the baseline.

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; RGGI = Regional Greenhouse Gas Initiative.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans

Figure 1a. Contributions to Total Electricity Sector Reductions from Each Electricity Work Plan

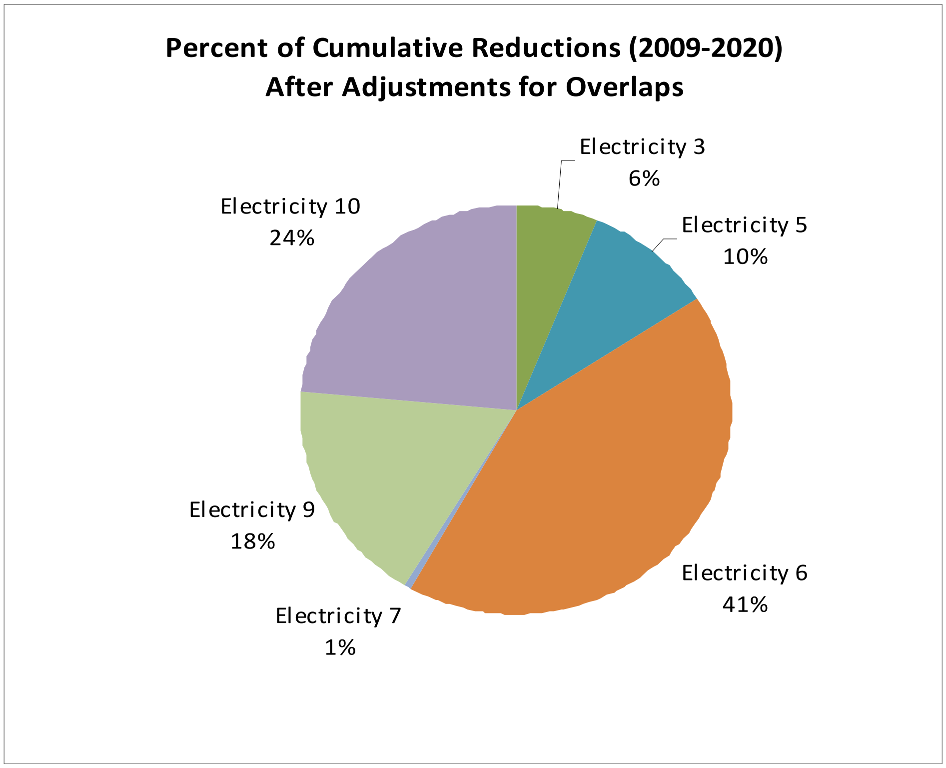
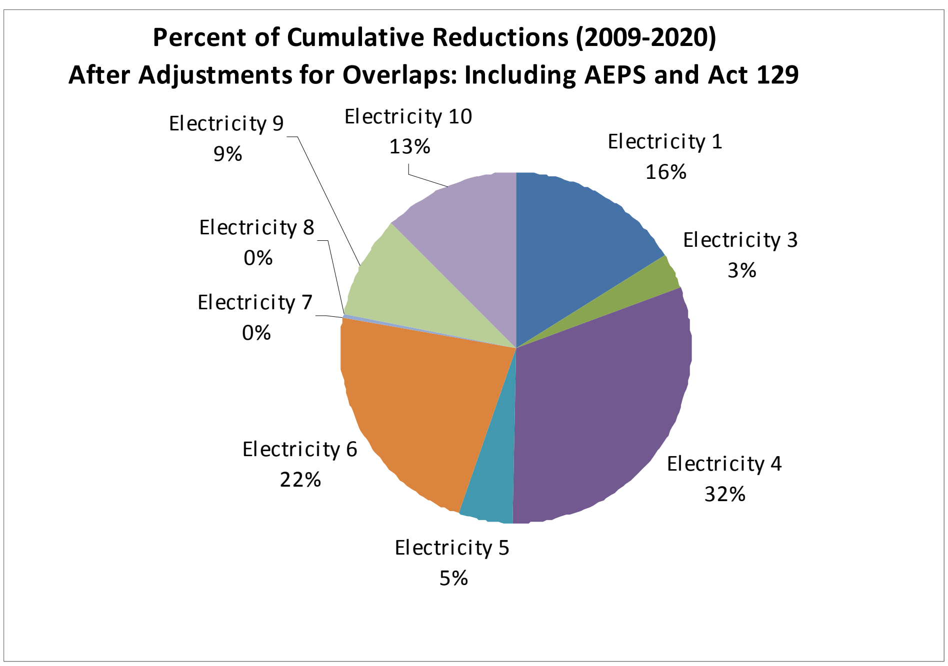


Figure 1b. Contributions to Electricity Sector Reductions from Each Electricity Work Plan: Including Act 129 (Electricity #1) and AEPS (Electricity #4)



Electricity 1. Act 129 of 2008 (HB 2200)

Summary: This initiative identifies the carbon emission benefits associated with the reduction of electricity consumption and peak load, as described in Act 129 of 2008. Act 129 requires:

- A reduction in electricity consumption, by May 31, 2011, of 1 percent below consumption levels for the period June 1, 2009, through May 31, 2010.
- A reduction in electricity consumption, by May 31, 2013, of 3 percent below consumption levels for the period June 1, 2009, through May 31, 2010 (additional reduction of 2 percent from the June 2009 through May 2010 baseline for a net total reduction of 3 percent).
- A reduction in peak demand, by May 31, 2013, of 4.5 percent of the highest 100 hours of demand. Note: The costs and benefits of this aspect of Act 129 have not been quantified. See the assumptions section below for the rationale.

Note that the imposition of requirements of Act 129 is not inclusive of the very modest consumption and associated system losses from municipalities that are service providers or the rural electric cooperatives.

Other Involved Agencies: The Pennsylvania Public Utility Commission (PUC) has implementation responsibility.

Possible New Measure(s): A report from the American Council for an Energy-Efficient Economy (ACEEE) drafted for the PUC and the Pennsylvania Department of Environmental Protection (DEP) provides the cost and supply data for the work plan. Act 129 does not specify how these reductions are to be achieved. Responses will be purely market-driven.

Work Plan Costs and Greenhouse Gas (GHG) Reductions:

Table 1.1. Work Plan Cost and GHG Results

Annual Results (2020)			Cumulative Results (2009-2020)		
GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/t$CO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2e$)
4.0	-$258	-$65	39.8	-$1,409	-$35

Notes: The cost estimates (columns 2 and 5) are incremental costs of energy-efficient measures including capital, O&M, and labor costs, above baseline measure costs. The cost estimates are calculated as the costs less avoided energy expenditures. Also, the difference between the 2020 cost-effectiveness (column 3) and the cumulative cost-effectiveness (column 6) is due, in part, to the effects of discounting the net cash flows over the analysis period of 2009–2020.

The net present value (NPV) of the cost savings resulting from implementation of Act 129 from 2009 through 2020 is estimated at approximately $1.4 billion. Some of this will be due to peak load reductions that result in lower wholesale energy and capacity charges, but not less energy used. (These are not quantified in this draft). Peak demand reductions are assumed to not have an impact on GHG emissions as noted below. There is the assumption that lower wholesale charges will be passed through to customers. Other savings will result through reducing energy consumption.

Quantification Approach and Assumptions

- Reductions from the work plan are assumed to begin in 2009–2011 and to be implemented at 0.33 percent per year through 2011 to achieve the 1 percent target by 2011. Reductions are then assumed to be 1 percent/year for 2012 and 2013, reaching the Act 129 target of 3 percent.
- GHG mitigation and costs from the peak demand reduction component of Act 129 are not quantified, as recommended by the subcommittee.
  - The costs and GHG reduction compliance pathways are deemed too uncertain for quantification. For instance, peak demand reductions could be met with peak shifting from peak periods where the marginal resource is natural gas turbines, to off-peak periods where the baseload resource is coal, which has a higher carbon dioxide (CO_2) emissions intensity (metric tons per megawatt-hour [t/MWh]). Other peak reductions might arise from the energy efficiency deployment obtained under the other components of Act 129. The costs of compliance equipment, such as smart meters and associated communications equipment that might also be used to meet the peak demand reduction, are also deemed too uncertain to quantify.
- Statewide load forecast from the PUC are used as the basis for the calculations. This includes the load reduction effects of Act 129 (which are already in the baseline), so reductions estimated here are likely to be slightly understated (by 3 percent of 3 percent).
- The above efficiency percentage targets are applied to residential, commercial, and industrial loads. The cost and supply of efficiency savings are thus dependent on the customer class load as a percentage of total load. Industrial loads grow more slowly than residential and commercial loads through 2020; thus, over time a smaller share of efficiency savings comes from the industrial sector.
- Energy efficiency costs are expressed as levelized costs over the life of the energy efficiency options over the planning period. The incremental costs (typically incurred in the first year of program implementation) are spread over all future years of the life of the energy efficiency measures.
- Efficiency investments installed under Act 129 with expected lifetimes shorter than the planning period are expected to be replaced with equipment with similar cost and performance characteristics. Efficient equipment is cost-effective to install initially, and it is assumed that it will be replaced at the end of its life. Thus, the electricity reductions in 2013 under Act 129 are held steady through 2030.
- The cost of the work plan is calculated by estimating the annual costs of energy efficiency less avoided electricity expenditures. These cash flows are then discounted at a real rate of 5 percent.
  - The NPV of cash flows is calculated beginning in 2009 through 2020.
- All prices are in 2007 dollars ($2007), as per the Center for Climate Strategies Quantification Memo. [weblink forthcoming]

Table 1.2. Cost of Energy Efficiency Measures

	2009		
Sector	$/MWh	$/MMBTU	Fixed Cost Rate
Residential	$53.70	$5.68	13%
Commercial	$31.47	$3.52	10%
Industrial	$26.03	$2.11	5%

  - Sum of Capital and Fixed Costs Program fixed costs are assumed to be part of each measure's capital cost. These include administrative, marketing, and evaluation costs of 5 percent.

- Source: ACEEE et al. (2009). Various pages.
- The cost of energy efficiency measures includes program and participant costs as is typically used in Total Resource Cost test. [Insert a footnote explaining this test or where an explanation can be found. Also, insert text leading in to Table 1.3.]

Table 1.3. Avoided Cost of Energy for Demand Side Measures

Sector	$/MWh	$/MMBTU
Residential	103.37	13.14
Commercial	87.14	10.72
Industrial	65.00	7.48

Quantification Approach and Data Sources:

- For electricity, retail end user prices for January 2009 from US EIA Monthly Electricity Profile, increased by 6.2 percent in 2010 to account for rate caps coming off for last of EDCs. Annual prices in 2011+ adjusted by change in AEO end user prices from table 74 of AEO 2009 supplemental tables. http://www.eia.doe.gov/cneaf/electricity/epm/table5_6_a.html
- For natural gas, retail annual 2008 prices by sector, annual changes from 2009 onward from Table 12 of AEO 2009 regional tables http://tonto.eia.doe.gov/dnav/ng/ng_sum_lsum_dcu_SPA_m.htm and http://www.eia.doe.gov/oiaf/aeo/supplement/stimulus/regionalarra.html.
- The costs to implement Act 129 are recoverable by utilities, so customers will be funding the efficiency deployment.
- Based on the costs of energy efficiency per MWh above, annual spending in 2013 will be approximately $177 million.
- Electricity transmission and distribution (T&D) losses are assumed to be 6.6 percent over the analysis period. Source: PA Electricity Inventory and Forecast.xls
- To estimate emission reductions from work plans that are expected to displace conventional grid-supplied electricity (i.e., energy efficiency and conservation), a simple, straightforward approach is used. We assume that these policy recommendations would

displace generation from an "average thermal" mix of fuel-based electricity sources of coal and gas. This mix is based on 90 percent coal, 10 percent gas for all years 2009-2030 based on U.S. Energy Information Administration (EIA) 2006 State Electricity Profile data.

- The average thermal approach is preferred over alternatives because sources without significant fuel costs would not be displaced—e.g., hydro, nuclear, or renewable energy generation.
  - Similarly, a "marginal" approach is not possible in Pennsylvania because the natural gas share of the annual generation portfolio (13.5 million (MM) MWh) of total generation (218 MM MWh in 2006) is only about 6 percent. This small amount does not provide adequate MWh to be "backed down" due to the energy efficiency deployment in the work plan.
- Given the generation fleet's coal and gas combustion efficiencies, this equates to a CO_2 intensity of approximately 0.87 metric tons (t)/MWh. This compares to the average statewide CO_2 intensity of 0.54 t/MWh (including hydro, nuclear, etc.).
- This approach provides a transparent way to estimate emission reductions and to avoid double counting (by ensuring that the same MWh from a fossil fuel source are not "avoided" more than once). The approach can be considered a "first-order" approach. That is, it does not attempt to capture a number of factors, such as the distinction between peak, intermediate, and baseload generation; issues in system dispatch and control; impacts of nondispatchable and intermittent sources, such as wind and solar; or the dynamics of regional electricity markets. These relationships are complex and could mean that policy recommendations affect generation and emissions (as well as costs) in a manner somewhat different from that estimated here. Nonetheless, this approach provides reasonable first-order approximations of emission impacts and offers the advantages of simplicity and transparency that are important for stakeholder processes.
  - Note that some renewable resources, like cofiring biomass with coal or dedicated biomass gasification have substantial fuel costs. However, because these resources are negligible in the reference case electricity supply forecast, they are not able to be "backed down" in the analysis.

- Cost to DEP—None.
- Cost to the commonwealth—Administrative.
- Cost to the regulated community or consumer—Act 129 requires specific reductions in load growth. It is reasonably anticipated that consumers will realize long-term cost savings. However, the costs of implementation will be borne by the rate base and will be quantified in filings to the PUC. Estimated gross cost savings are provided at the end of this work plan, and will need to be reconciled with the implementation costs.
- Are federal funds available?—Not applicable.
- Do these costs fund other programs?—Not applicable.

- Are cost savings realized from this initiative?—Yes, as noted above. Market forces will drive compliance options and the path forward. Actual savings will likely vary widely among the electric distribution company (EDC) territories, within the various rate classes and economic sectors and also based on socioeconomic factors for residential consumers.

Implementation Steps:

- Act 129 was signed into law on October 15, 2008.
- By January 15, 2009, the PUC must adopt an energy efficiency and conservation program that requires each EDC to develop and implement cost-effective energy efficiency and conservation plans to reduce consumption and peak load within their service territories.
- ACEEE has conducted a statewide assessment of cost-effective energy efficiency potential. For potential follow-up work plans to build on Act 129, see work plans Electricity 2 and 3.

Potential Overlap:

- See Appendix E2 for Overlap Analysis.

Subcommittee Recommendations

1. As this is existing law, there is technically no need to vote or recommend. Its estimated GHG reductions are built into the assumptions. The EGTD was generally very supportive of and committed to the opportunities in conservation and demand for increased energy efficiency.
2. Many members of the subcommittee expressed concern that the work plan reaches conclusions with respect to "cost effectiveness" yet DEP's macroeconomic analysis will not be completed until the end of 2009. Accordingly, several members wanted to express their concern that the economic assumptions and cost effectiveness figure may be suspect because they have not been subject to rigorous economic review and analysis with all costs and impacts addressed (i.e. displaced MW = displaced miners and generation employees). Other members expressed concern that any macroeconomic analysis address costs of inaction (i.e. impacts of global change in PA) as well as savings that might occur from GHG emissions reductions.

Electricity 2. Reduced Load Growth

Summary: This initiative identifies the carbon emission benefits associated with curbing the rate of growth in electricity consumption in PA. This strategy builds upon the conservation requirements of Act 129 of 2008, which specify 1 percent and 2 percent reductions in electricity consumption from 2010, by 2011 and 2013, respectively. Act 129 also requires the PUC to assess the potential for additional cost-effective reductions. The scenario developed in this work plan builds upon Act 129 by requiring biennial reductions in electricity consumption equal to 1.5 percent per biennial period (0.75 percent/year), beginning in 2015 and carrying through 2025. Therefore, the energy efficiency investments under this work plan reach 8.25 percent of load by the end of 2025 (11 years at 0.75 percent/year). These reductions are calculated from the previous year's estimated consumption.

Note that this analysis does not include the very modest consumption and associated system losses from municipalities that are service providers or the rural electric cooperatives.

Other Involved Agencies: PUC

Possible New Measure(s): A report from ACEEE has been drafted for the PUC and DEP and provides the cost and supply data for the work plan. See: http://www.aceee.org/pubs/e093.htm.

Work Plan Costs and GHG Reductions:

Table 2.1 Work Plan Costs and GHG Results ($2007)

Annual Results (2020)			Cumulative Results (2009-2020)		
GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/t$CO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2e$)
6.7	-$432	-$64	23.3	-$849	-$36

The NPV of the cost savings resulting from implementation of this work plan from 2009 through 2020 is estimated at approximately $930 million. The cost savings and emission reductions are additional to Act 129. The cost savings are more modest compared to Act 129 because the work plan is not implemented until 2015 and has reached efficiency investments equal to 4.5 percent of sales by 2020. These distant cash flows are then discounted back to the present.

Notes: The cost estimates (columns 3 and 6) are incremental costs of energy-efficient measures, including capital, O&M, and labor costs, above baseline measure costs. The cost estimates are calculated as the costs less avoided energy expenditures. Also, the difference between the 2020 cost-effectiveness (column 4) and the cumulative cost-effectiveness (column 7) is due, in part, to the effects of discounting the net cash flows over the analysis period of 2009–2020.

- Cost to DEP—None.
- Cost to the commonwealth—Act 129 requires the PUC to hire a program administrator to oversee this process and to provide assessments as to the cost-effectiveness and level of additional reductions that may be possible within PA. The cost for this service is unknown.

- Cost to the regulated community or consumer—To the extent that this work plan mirrors the funding mechanisms of Act 129, utility costs, up to a portion of revenues, will be recoverable, so customers will be funding the entire cost of the work plan up to that level. The ACEEE et al. (2009) report assumes that a portion of the cost of each efficiency measure may be spent by the end user and that utility incentives comprise the balance of the initial costs, but that these incentives will be funded by customers.[1]
    - Based on the costs of energy efficiency per MWh (discussed in Electricity 1), annual spending in 2020 will be approximately $300 million.
- Are federal funds available?—Federal funding is not required nor is it available at this time. Limited assistance may be available through the U.S. Department of Energy (DOE) State Energy Plan, but this would most likely be limited to policy analysis and possibly technical support.
    - Do these costs fund other programs?—No. Any costs are expected to result in changes to consumer behavior.

<u>Quantification Approach and Assumptions</u>

- Reductions from the work plan are assumed to begin in 2015 and are implemented at 0.75 percent/year through 2025 to achieve a rate of 8.25 percent by 2025.
- Efficiency investments installed under the work plan with expected lifetimes shorter than the planning period are expected to be replaced with equipment with similar cost and performance characteristics. Efficient equipment is cost-effective to install initially, and it is assumed that it will be replaced at the end of its life. Thus, the electricity reductions in 2025 under the work plan are held steady through 2030.
- For cost and other assumptions see Electricity #1—Act 129.

<u>Implementation Steps:</u> The following, and other, considerations could be examined as policy tools to support this measure:

- Act on the authority that Act 129 provides the PUC to require additional cost-effective reductions in electricity consumption.
- Conduct an assessment of electricity consumption reduction potential to determine if the requirements suggested within this work plan conform to Act 129 requirements.
- Enact a legislative amendment to the Alternative Energy Portfolio Standards (AEPS) establishing a dedicated market share for energy efficiency credits (new tier or carve out) that facilitates achieving this reduction measure by rewarding over compliance and providing a cost-effective manner to achieve greater reductions.
- Require electric distribution companies to invest in demand-side response initiatives, including rebates to consumers.

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[1] Source: ACEEE et al. (2009). Energy Efficiency, Demand Response, and Onsite Solar Energy Potential in Pennsylvania. April. P. 29. page 48. http://www.aceee.org/pubs/e093.htm

- Recommend that all cost-effective supply side and demand side response initiatives be considered as part of approvals for new generation.
- Consider the recommendations of residential and commercial subcommittee on implementing advanced building standards and benchmarking for the commercial, institutional, state and municipal government sectors. .
- Consider the rate decoupling and incentives language in Appendix E1.
- Work with neighboring states on establishing regional efficiency standards for appliances and electronics, where none currently exist or where minimum standards are less than optimal.
- Establish an aggressive phase-out of incandescent lights and/or establish a pricing/tax structure that preferentially treats lighting with a higher lumens-to-watts ratio.
- Eliminate consumer barriers to implementing energy efficiency.

Potential Overlap:

- See Appendix E2 for overlaps.

Subcommittee Recommendations

1. The EGTD was generally very supportive of and committed to the opportunities in conservation and demand for increased energy efficiency.
2. Many members of the subcommittee expressed concern that the work plan reaches conclusions with respect to “cost effectiveness” yet DEP’s macroeconomic analysis will not be completed until the end of 2009. Accordingly, several members wanted to express their concern that the economic assumptions and cost effectiveness figure may be suspect because they have not been subject to rigorous economic review and analysis with all costs and impacts addressed (i.e. displaced MW = displaced miners and generation employees). Other members expressed concern that any macroeconomic analysis address costs of inaction (i.e. impacts of global change in PA) as well as savings that might occur from GHG emissions reductions.

Electricity 3. Stabilized Load Growth

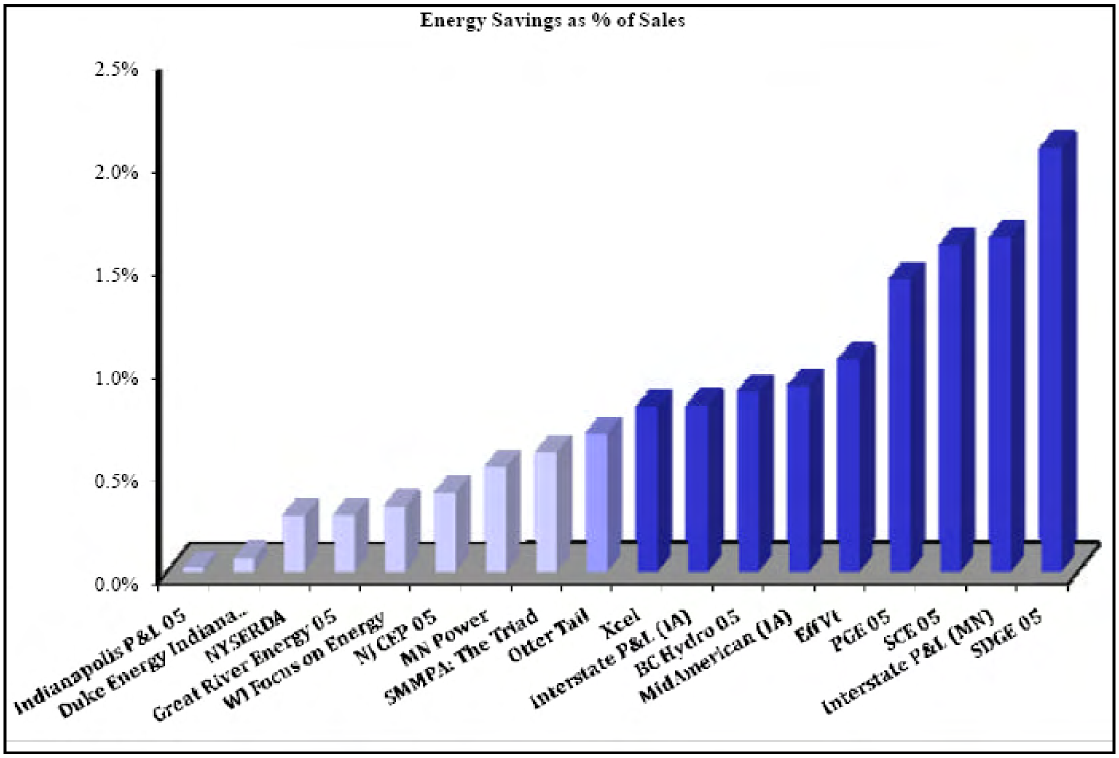
Summary: This measure builds upon the reductions required via Act 129 of 2008. Act 129 requires reductions in consumption of 1 percent by 2011 and 2 percent by 2013, for a total of 3 percent, measured against 2010 consumption. The Stabilized Load Growth (SLG) scenario further investigates the potential impact of annual consumption reductions of 0.75 percent/year in the period 2015 through the end of 2017, followed by a rate of consumption that is held static from 2018 through 2025. Historical annual load growth in PA has been approximately 1.5 percent/year, which is what would be reduced in the 2018–2025 period. Therefore, the energy efficiency investments under this work plan reach 14.4 percent of load by the end of 2025 (2015-2017 at 0.75 percent/year, 2018 at 0.85 percent/year, and 2019–2025 at 1.6 percent/year). The annual reductions in 2018–2025 would be based on the previous year's consumption figures and would allow a subsequent one-year "true-up" for electricity distribution companies to achieve stabilized consumption levels.

Note that this analysis does not include the very modest consumption and associated system losses from municipalities that are service providers or the rural electric cooperatives.

The demand reductions under this work plan can be compared to those occurring in other jurisdictions. Several states are mandating energy savings akin to the higher performers in Figure 3.1. Iowa's PUC has requested utilities to file plans to achieve savings equal to 1.4 percent of sales, up from 0.8 percent currently. New York has a target of 15 percent savings by 2015, which was started in 2007 equating to new energy efficiency investments equal to nearly 2 percent/year. The following figure shows incremental energy savings as a percentage of sales for surveyed utilities across the country.[2]

[2] Source: Quantec. (2008). Assessment of Energy and Capacity Savings Potential in Iowa Prepared for The Iowa Utility Association. February 15. p. I7-I10 No web link available.

Figure 3.1. Energy Savings as % of First-Year Sales



All of the seven organizations with above median DSM spending rates also achieved above median energy savings as a percentage of sales: SDG&E has the highest energy savings as a percentage of sales at about 2.1%, three times the median of 0.7%, while Xcel Energy, Interstate P&L (IA), BC Hydro, MidAmerican (IA) and Efficiency VT achieved savings rates of about 0.9% of sales; PG&E, SCE, and Interstate P&L (MN) achieved savings rates of about 1.5%.

Other Involved Agencies: PUC.

Possible New Measure(s): An ACEEE report drafted for the PUC and DEP provides the cost and supply data for the work plan. See: http://www.aceee.org/pubs/e093.htm.

Work Plan Costs and GHG Reductions:

Table 3.1 Work Plan Costs and GHG Results ($2007)

Annual Results (2020)			Cumulative Results (2009-2020)		
GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/$tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/$tCO_2e$)
9.2	-$593	-$64	27.2	-$990	-$36

The net present value of the cost savings resulting from implementation of this work plan from 2009_2020 is estimated at approximately $ 1.4 billion. The cost savings and emissions reductions are additional to Act 129.

Notes: The cost estimates (columns 2 and 5) are incremental costs of energy-efficient measures including capital, O&M, and labor costs, above baseline measure costs. The cost estimates are calculated as the costs less avoided energy expenditures. Also, the difference between the 2020 cost-effectiveness (column 3) and the cumulative cost-effectiveness (column 6) is due, in part, to the effects of discounting the net cash flows over the analysis period of 2009–2020.

- Cost to DEP—None.
- Cost to the commonwealth—Act 129 requires the PUC to hire a program administrator to oversee this process and to provide assessments as to the cost-effectiveness and level of additional reductions that may be possible within PA. The cost for this service is unknown. It is further assumed that the PUC would perform similar services to oversee the reductions that may be required if such an SLG initiative were to be implemented.
- Cost to the regulated community or consumer—To the extent that this work plan mirrors the funding mechanisms of Act 129, utility costs up to a portion of revenues will be recoverable, so customers will be funding the entire cost of the work plan up to that level. The ACEEE et al. (2009) report assumes that a portion of the cost of each efficiency measure may be spent by the end user, and that utility incentives comprise the balance of the initial costs, but that these incentives will be funded by customers.[3]
    - Based on the costs of energy efficiency per MWh (discussed in Electricity 1), annual spending in 2020 will be approximately $415 million.
- Are federal funds available?—Federal funding is not required, nor is it available at this time. Limited assistance may be available through the DOE State Energy Plan, but this would most likely be limited to policy analysis and possibly technical support.
- Do these costs fund other programs?—No. Any costs are expected to result in changes to consumer behavior.
- Are cost savings realized from this initiative?—Cost savings are expected, but this requires a detailed analysis. The assumption is that reductions will only be required such that can be sustained through cost-effective measures.

<u>Quantification Approach and Assumptions</u>

- Reductions from the work plan are additional to those under Act 129, and are assumed to begin in at the start of 2014 and are implemented through the end of 2017 at 0.75 percent of sales per year (for a total of 3 percent of sales). This reduction is expected to lower Pennsylvania's load growth rate from ~1.60 percent/year to about 0.85 percent/year. Then required reductions are equal to the load growth rate from the previous year from 2018 through 2025. By 2020, expected reductions are equal to approximately 6.3 percent of sales, and by 2025 reductions amount to 14.4 percent of sales.
- Efficiency investments installed under the work plan with expected lifetimes shorter than the planning period are expected to be replaced with equipment with similar cost and

[3] Source: ACEEE et al. (2009). Energy Efficiency, Demand Response, and Onsite Solar Energy Potential in Pennsylvania. April. P. 29. page 48. http://www.aceee.org/pubs/e093.htm

performance characteristics. Efficient equipment is cost-effective to install initially, and it is assumed that it will be replaced at the end of its life. Thus, the electricity reductions in 2025 under the work plan are held steady through 2030.

- For cost and other assumptions, see Electricity #1—Act 129.

Additional Assumptions:

- Adequate cost-effective reductions exist or will exist through 2025, to provide the approximate 27 MM MWh of curtailment, as compared to the unchecked, projected rate of growth in electricity consumption. The ACEEE report identifies cost-effective efficiency supplies in Table 3.2 of approximately 61 MM MWh, which significantly exceed the reductions projected under this work plan.

Table 3.2. Summary of Cost-Effective Energy Efficiency Potential by Sector (2025)[4]

Sector	Electricity	
	GWh	**% of Sales**
Residential	~19,000	10%
Commercial (non-CHP)	~18,000	9%
Industrial (non-CHP)	~13,000	7%
Combined Heat & Power	~11,000	6%
Total	**~61,000**	**33%**

- No reductions would be required if not supported through an analysis of cost-effective measures.

Implementation Steps: The following, and other, considerations could be examined as policy tools to support this measure:

- Act on the authority that Act 129 provides the PUC with the necessary authority to require additional cost-effective reductions in electricity consumption.
- Enact a legislative amendment to the AEPS establishing a dedicated market share for energy efficiency credits (new tier or carve out) that facilitates achieving this reduction measure by rewarding over compliance and providing a cost-effective manner to achieve greater reductions.
- Require electric distribution companies to invest in demand side response initiatives, including rebates to consumers.
- Recommend that all cost-effective supply side and demand side response initiatives be considered as part of approvals for new generation.
- Consider the recommendations of residential and commercial subcommittee on implementing advanced building standards and benchmarking for the commercial, institutional, state and municipal government sectors.

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[4] Source: ACEEE et al. (2009). Energy Efficiency, Demand Response, and Onsite Solar Energy Potential in Pennsylvania. April. P. 14. page 48. http://www.aceee.org/pubs/e093.htm

- Consider the rate decoupling and incentives language in Appendix E1.
- Work with neighboring states on establishing regional efficiency standards for appliances and electronics, where none currently exist or where minimum standards are less than optimal.
- Establish an aggressive phase-out of incandescent lights and/or establish a pricing/tax structure that preferentially treats lighting with a higher lumens to watts ratio.
- Include rate decoupling and incentives from the RC-12 work plan.
- Eliminate consumer barriers to implementing energy efficiency

Potential Overlap:

- See Appendix E2 for list of overlaps between work plans.

Subcommittee Recommendations

1. The EGTD was generally very supportive of and committed to the opportunities in conservation and demand for increased energy efficiency.
2. Many members of the subcommittee expressed concern that the work plan reaches conclusions with respect to "cost effectiveness" yet DEP's macroeconomic analysis will not be completed until the end of 2009. Accordingly, several members wanted to express their concern that the economic assumptions and cost effectiveness figure may be suspect because they have not been subject to rigorous economic review and analysis with all costs and impacts addressed (i.e. displaced MW = displaced miners and generation employees). Other members expressed concern that any macroeconomic analysis address costs of inaction (i.e. impacts of global change in PA) as well as savings that might occur from GHG emissions reductions.

Electricity 4. Alternative Energy Portfolio (Act 213 of 2004) Tier I Standard

Summary: Identifies GHG reductions associated with the existing AEPS Tier I requirement at 8 percent.

Other Involved Agencies: PUC and DEP have shared roles in administering the AEPS.

Existing Measure: The AEPS requires that all electricity consumed within PA by 2021 be comprised of at least 0.5 percent solar photovoltaic (PV) technology, 8 percent from other renewable (Tier I) sources, and 10 percent from other alternative energy (Tier II) sources. The AEPS matures in 2021, after which no further increase in renewable generation is required, but the standards from 2021 remain in effect.

Projected GHG Reduction:

There could be some additional CO_2 reductions through Tier II from sources such as large hydro and energy efficiency. The contribution of these resources to meeting the Tier II obligation is somewhat uncertain, because we already know that sufficient credits from waste coal have been generated to meet the entire Tier II requirements through at least 2021. The impact is that little incentive exists for the generation of electricity from new, zero-carbon-emitting sources due to the oversupply created by waste coal. For the 2007–2008 compliance period, the weighted-average Tier II compliance credit traded for $0.66.[5] This amount is too small to affect plant investment decisions. Because of the minimal value of credits associated with Tier II, it is assumed that the waste coal generation that is used to meet compliance with the AEPS would have happened without the regulation.

Hydroelectric—Uprates or upgrades to hydroelectric power generation can come from adding incremental (new) generation at existing plants or simply by improving efficiency. For example, of turbine design or electrical generators. With the enactment of the AEPS, such improvements are being seriously considered by generating companies. Therefore, it is important to note that if these improvements are made or incremental generation is brought on line, the resultant emission reductions that might accrue will be accounted for under Tier I of the AEPS, provided that these hydroelectric plants obtain certification from the Low Impact Hydro Institute (LIHI), as required under the AEPS. Any improvements or incremental generation from a hydroelectric plant that does not or cannot obtain LIHI certification will earn Tier II credits under the AEPS, but the emission reductions would not count against our total reductions from the AEPS.

Upgrading older hydropower generating systems is common practice in North America. Through rehabilitation, hydroelectric producers are increasing capacity and efficiency at existing facilities that are several decades old. Rewinding a generator or replacing a turbine runner can result in performance that not only equals, but also surpasses, the capabilities of the equipment when it was new. Rehabilitating existing plants is often a more economical way of adding capacity, when compared to building new facilities.

[5] http://www.puc.state.pa.us/electric/electric_alt_energy.aspx

Work Plan Costs and GHG Reductions:

Table 4.1a: Work Plan Cost and GHG Results Without Price Suppression Effects

Annual Results (2020)			Cumulative Results (2007-2020)		
GHG Reductions	Costs	Cost-Effectiveness	GHG Reductions	Costs	Cost-Effectiveness
($MMtCO_2e$)	(Million $)	($\$/tCO_2e$)	($MMtCO_2e$)	(NPV, Million $)	($\$/tCO_2e$)
11.0	$285	$26	75.9	$1,560	$21

Table 4.1b: Plan Cost and GHG Results
Moderate Fossil Fuel Prices / ½ ($50) Price Suppression Effects

Annual Results (2020)			Cumulative Results (2007-2020)		
GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)
11.0	$(358)	$(33)	75.9	$(615)	$(8)

Table 4.1c: Plan Cost and GHG Results
High Fossil Fuel Prices / Full ($100) Price Suppression Effects

Annual Results (2020)			Cumulative Results (2007-2020)		
GHG Reductions	Costs	Cost-Effectiveness	GHG Reductions	Costs	Cost-Effectiveness
($MMtCO_2e$)	(Million $)	($\$/tCO_2e$)	($MMtCO_2e$)	(NPV, Million $)	($\$/tCO_2e$)
11.0	$(1,001)	$(91)	75.9	$(2,790)	$(37)

Notes: The cost estimates (columns 2 and 5) are incremental costs of energy-efficient measures including capital, O&M, and labor costs, above baseline measure costs. The cost estimates are calculated as the costs less avoided energy expenditures. Also, the difference between the 2020 cost-effectiveness (column 3) and the cumulative cost-effectiveness (column 6) is due, in part, to the effects of discounting the net cash flows over the analysis period of 2009–2020.

Quantification Approach and Assumptions

The costs and GHG reductions from the AEPS are the difference between what is assumed to occur between the AEPS-case and the No AEPS-case. In the No-AEPS case, the new resources that would have been deployed are assumed to be 90 percent existing pulverized coal, 10 percent natural gas peaking gas. In the AEPS-case, the resources assumed to be deployed are listed in Table 4.3.

- **DRAFT TEXT ON PRICE SUPPRESSION**: The deployment of new renewables has the potential to reduce the prices of the existing electricity system. Known as price effects, or price suppression, new renewable resources can reduce locational marginal prices through the following mechanism. Although, new renewable electricity generation resources are expected to be more expensive than existing thermal (coal and gas) generation (See Appendix E3 for assumptions), the addition of renewables is expected to reduce the price of thermal resources as an increased supply of generation lowers prices. The increased supply moves the market clearing price down the generation merit order. A hypothetical example of adding new renewables is shown in Figures 1 and 2.[6] In this hypothetical example, the market price of electricity drops from $80/MWh to $60/MWh. The net effect is the new renewables lower the price of electricity for all consumers.

Figure 4.1: Typical Price Equilibrium

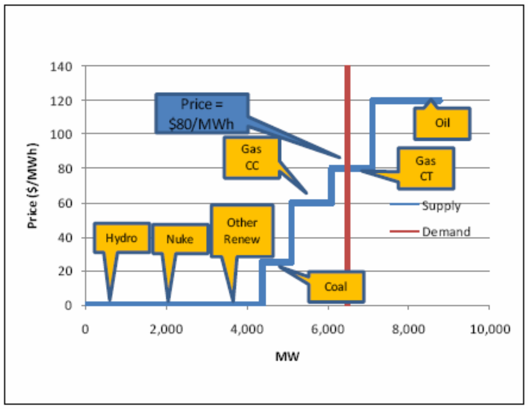
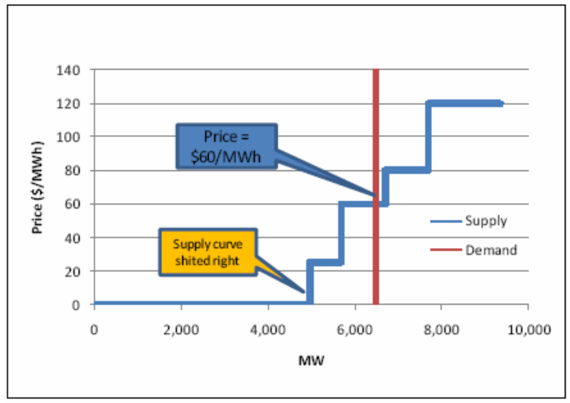


Figure 4.2: Equilibrium with Renewables



(Source: Summit Blue, Inc, 2008, pp. 4-144-145)

- The effects on market clearing prices from new renewables are highly dependent on the supply and demand characteristics of the electricity system. There are several recent studies in the Northeast that simulate the price effects of new renewables, two NY studies and one by the PJM.[7]
  - The Summit Blue study for NY shows an average of a 2 percent reduction in locational marginal prices ($2/MWh) for the renewables target of approximately 2 percent incremental renewables. This equates to about a price suppression effect of about $100 per MWh of new renewable energy.
  - The PJM study is of the most relevance to the current analysis because it employs the PROMOD dispatch model which has detailed representation of PJM load curves, transmission resources, and the generation fleet for the region.
    - The PJM study simulates 15,000 MW of new wind by 2013, which it estimates will generate 43,000 GWh of electricity. This wind generation represents approximately 5.5 percent of PJM RTO energy needs in 2013, according to the latest PJM forecast.[8]

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[6] Summit Blue, Inc (2008). New York Renewable Portfolio Standard Market Conditions Assessment Final Report. http://www.nyserda.org/Energy_Information/Market%20Conditions%20Final%20Report.pdf

[7] The sources include:
PJM (2009). Potential Effects of Proposed Climate Change Policies on PJM's Energy Market. http://www.pjm.com/documents/~/media/documents/reports/20090127-carbon-emissions-whitepaper.ashx
Summit Blue, Inc (2008). New York Renewable Portfolio Standard Market Conditions Assessment Final Report. http://www.nyserda.org/Energy_Information/Market%20Conditions%20Final%20Report.pdf p. 148

[8] PJM (2009). Load Forecast Report. January 2009. TableE-1. http://www.pjm.com/documents/~/media/documents/reports/2009-pjm-load-report.ashx

- The 5.5 percent wind scenario by 2013 in the PJM study is greater than the Tier I resources required under the AEPS by 2013, which is 4.05 percent including solar PV. There is no reason to assume that price suppression effects are exactly linearly related to renewables penetration. The Summit Blue report forecasted a $100/MWh price suppression benefit for only 2 percent new renewables. However, a conservative assumption is that the price suppression effects are partially a function of penetration.

Table 4.2: PJM Estimated Effects of New Wind Resources

Table 6: Amounts by Which 15,000 MW of Wind Mitigates Price and Cost Increases

	15,000 MW Wind
LMP ($/MWh)	$5-$5.50 per MWh
Wholesale Power Cost	$4-$4.5 billion
Customer Bill	$3.50-$4 monthly ($42-$48 annually)

Source: PJM (2009). Potential Effects of Proposed Climate Change Policies on PJM's Energy Market. p.17.

- **THREE SCENARIOS**: The above results from the PJM study are used to estimate the price effects of the AEPS for Pennsylvania. In their study, the PJM estimates that savings of $4-4.5 billion from the 43,000 GWh of wind generation in 2013. This equates to ~$100 per MWh of wind generation ($4.25 billion / 43,000 GWh) in the study.
  - NO PRICE SUPPRESSION: equates to the results described below for the workplan quantification. $0/MWh price suppression effect for each MWh of renewables.
  - MODERATE FOSSIL FUEL PRICES/ ($50, OR ½ OF THE $100 PRICE SUPPRESSION ESTIMATED BY PJM): There are significant uncertainties about simulating future market environments. Although the PJM study uses a state of the art dispatch model to simulated price impacts, the model outputs are only as good as the model inputs. The magnitude of the price suppression effect is highly dependent on the price of fuels that are setting the marginal price. In most cases, this is natural gas during peak periods, coal during off-peak and shoulder periods. The PJM study base case appears to employ a gas price assumption of $6.44/MMBtu, along with a comparable 2008 coal price, that drives the $100/MWh price suppression effect.[9] Since fossil fuel prices have since fallen below the levels used in the PJM study (Jan 2009), the more muted price effects of $50/MWh for each MWh of renewables is used for this analysis.

[9] PJM (2009). P. 7 footnote 7.

- HIGH GAS PRICES / FULL PRICE SUPPRESSION: The PJM and NY study were performed during the high gas price environment of 2008. To the extent that fossil fuel prices approximate the $6.44/MMBtu gas price in the PJM study, the price effects will be correspondingly large.

- For all scenarios: The maximum dollar per MWh of renewables is not used until the 2016-2020 period for Pennsylvania. For 2009-2016, a linear ramp-in rate towards the full 2016 value is used; 1/8 for 2009, 2/8 in 2010, 3/8 in 2011, etc until the full value is reached in 2016. 2017+ continue at full rate.
- The large negative costs (cost savings) for the price suppression scenarios are driven by the benefits that accrue from the $/MWh price suppression effect.
  - This value can be compared to the weighted average cost of new renewables for the AEPS in 2020, which is $55/MWh.
  - The cost of the avoided thermal mix (90 percent existing coal / 10 percent existing peaking gas), is estimated at approximately $49/MWh in 2020.
  - The $/MWh price suppression effect can be thought of as a credit to the cost of new renewables, or conversely, that the avoided thermal mix is $50 higher ($99) under the modest price suppression scenario and $100 ($149) higher in the full price suppression scenario.
- It is not clear if the PJM study included in its modeling the costs of potential new thermal capacity resources that may be necessary to integrate the wind resources into the system.
  - However, the CCAC analysis assesses a $4.50/MWh cost adder for new wind integration.
- The price suppression effects employed here are a statewide average. However, the benefits of new renewables in reducing marginal prices are likely to be greatest in the sub-regions that install the largest share of the new renewables.

Table 4.3. Tier One Resources Assumed to Be Deployed in 2020 Under the AEPS

Tier 1 alternative energy gross generation assumptions (% of *New* Renewable Resources)	**2010**	**2020**
Other Gases (CMM)	0%	0%
Petroleum	0%	0%
Nuclear	0%	0%
Hydroelectric (micro, large)	9%	3%
Geothermal	0%	0%
Solar/PV	9%	6%
Wind	72%	88%
MSW	0%	0%
Landfill Gas	4%	1%
Biomass	5%	2%
Other wastes	0%	0%

- Only the costs of and GHG benefits from Tier I resources are quantified under this work plan.
  - For the 2007-2008 compliance period, the weighted-average Tier II compliance credit traded for $0.66.[10] This amount is too small to affect plant investment decisions. Because of the minimal value of credits associated with Tier II, it is assumed that the waste coal generation that is used to comply with the AEPS would have happened without the regulation.
- The generation resources that are assumed to be avoided under this work plan are 90 percent existing pulverized coal, and 10 percent existing peaking gas. The weighted-average cost of generation for the avoided mix is $49.15 in 2020. The avoided CO_2 emissions associated with this mix is 0.86 tCO_2/MWh.
- While the other technologies are large, central station generation sources, the Tier I photovoltaic carve-out is distributed generation. As such, it has a different avoided cost assumption, because PV also avoids new transmission, distribution, and capacity. The PV carve-out assumes an avoided cost based on the weighted-average retail price of electricity for residential, commercial, and industrial customers. PV generation in 2020 to meet the 0.5 percent target in the AEPS is assumed to be 758 gigawatt hours (GWh), with an avoided cost of $96.67.
- See Appendix E3 for generation cost assumptions and sources.
- All hydro that is deployed under the AEPS is assumed to be small hydro. This is a conservative assumption, as small hydro costs are higher than large hydro costs.
- Cost to DEP—Administration of programs for the continued support of energy efficiency and renewables, particularly solar PV (e.g., Energy Harvest, Pennsylvania Economic Development Association (PEDA), Alternative Energy Investment Act, etc.)
- Cost to the commonwealth—Continued support of renewables, particularly solar.
- Cost to the regulated community or consumer—Distribution companies pass compliance costs on to the ratepayers. Until all of the EDC rate caps are removed, the impact will remain uncertain. The removal of the rate caps will have a far more pronounced impact on electricity rates than will the requirements of the AEPS.
- Are federal funds available?—Stimulus funds from the American Recovery and Reinvestment Act (ARRA) of 2009 are potentially available for renewable energy development, as well as federal production tax credits and investment tax credits. U.S. Department of Agriculture (USDA) Farm Bill appropriations can and have provided limited support. Moreover, as the total appropriations are increasing, the amount available via grant funding is being significantly scaled back in favor of loans.
- Do these costs fund other programs?—No.
- Are cost savings realized from this initiative?—Not directly. Indirect savings to the commonwealth will accrue subject to in-state low-carbon electricity development (manufacturing, installation, sales and service, etc.). Indirect costs include displaced coal industry jobs and other fossil fuel-related economic production and consumption.

[10] http://www.puc.state.pa.us/electric/electric_alt_energy.aspx

- Costs quantified in these workplans consider only microeconomic costs and benefits. The macroeconomic costs and benefits of the workplan includes employment impacts, changes in fossil fuel consumption patterns, and other factors.

Implementation Steps:

- Already being implemented.
- Legislation continues to be drafted that would require additional increases in the amount of alternative energy.
- Act 1 incentives for renewable resources.
- Federal incentives for renewable electricity.

Potential Overlap:

- See Appendix E2 for Overlap Analysis.

Subcommittee Recommendations

1. As this is existing law, there is technically no need to vote or recommend.
2. In the final conference call June 23, 2009, 2 of the 5 members present (no subcommittee quorum) objected to the following language in the implementation steps: "Legislation continues to be drafted that would require additional increases in the amount of alternative energy. Pennsylvania has the lowest percentage requirements of any surrounding state renewable portfolio standards. Because the geographic scope from which projects may be considered eligible (Illinois to North Carolina) for Act 213 compliance is much broader than was originally intended, and in order to ensure that more renewable energy and associated new jobs are created in PA, the requirements of the AEPS could be increased." Their concern was the implied suggestion the subcommittee supported the expansion of the AEPS requirements. Because this work plan discusses existing law they viewed this as unnecessary editorializing. On a voice vote of 3-2 the subcommittee elected to retain the language.
3. A number of members raised the issue of considering transmission needs for effective implementation of this work plan.

Electricity 5. Carbon Capture and Sequestration in 2014

Note: Replaces Tier 1 at 15 percent, Tier 1 at 20 percent, Tier 3: Carbon Capture and Sequestration work plans.

Summary: This work plan is a carbon capture retrofit to existing supercritical pulverized coal plants starting in 2015 through 2019. In addition, the work plan calls for installation of an integrated coal gasification combined-cycle (IGCC) plant in the state in 2020. We assume an IGCC with a capture schedule of 600 megawatts (MW) beginning in 2020, based on typical IGCC plant capacity proposals in states, such as Minnesota (Excelsior Energy), Washington (Energy Northwest), and the Ohio Valley (AEP).

Other Involved Agencies: PUC.

Possible New Measure(s):

Retrofits of existing supercritical pulverized coal plants entail amine scrubbing with a CO_2 capture rate of 90 percent and an increase in heat rate requirements of 31.3 percent. The reduction in efficiency is compensated by an increase in capacity of the existing plant, as the amine-scrubbing system diverts steam for power generation or consumes additional power for CO_2 compression.

IGCC power plants use coal fuel an input to produce electricity. The technology is based around a gasifier that produces a mixture of hydrogen and carbon monoxide called syngas. This syngas is burned in a gas turbine that is used to drive a generator. Much like in natural gas combined-cycle (NGCC) power plants, the turbine exhaust is used in a heat recovery generator to create steam to drive a steam turbine generator.

IGCC technologies with CO_2 capture are equipped with three more processes than the conventional IGCC technology without capture. The first is a process of reacting syngas with steam to produce CO_2 and hydrogen through shift reactors. The second process separates the CO_2 from the remaining gas. The final process compresses and dries the CO_2. Adding CO_2 capture technology to IGCC plants has a significant impact on overall plant efficiency.

Work Plan Costs and GHG Reductions:

Avoided emissions are calculated on the basis of known potential up-rates and new build generation displacing a mix of 90 percent coal and 10 percent gas at a combined average of 1,872 pounds (lb)/MWh. We assume a base case in which 90 percent of CO_2 emissions are sequestered, though there is substantial uncertainty regarding the long-term leakage of CO_2 in various sequestration configurations. Higher leakage would reduce the cost-effectiveness of carbon capture for reducing GHG emissions.

Table 5.1. Work Plan Costs and GHG Results ($2007)

Annual Results (2020)			Cumulative Results (2009-2020)		
GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/t$CO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2e$)
5.0	$291	$58	12.6	$391	$31

- The above analysis assumes a 90 percent capture (10 percent leakage) rate consistent with the Congressional Research Service report. However, the Electricity Subcommittee was also interested in a sensitivity analysis of the costs with higher leakage rates.
  - Assuming a 50 percent capture rate, the 2020 cost per ton of carbon dioxide equivalent (CO_2e) mitigated rises to $104/metric ton, with a 2020 reduction of 2.8 million metric tons of carbon dioxide equivalent ($MMtCO_2e$). Cumulative costs (2009–2020) are estimated at 7 $MMtCO_2e$, with a discounted cost of $56/ton.

Table 5.2. Carbon Capture Technology Assumptions for Year 2020

IGCC with Carbon Capture Characteristics	$2007 New Plant	Source
Unit Size MW	600 MW	Based on numerous IGCC proposals including Excelsior (Minnesota), AEP (Ohio Valley), and Energy Northwest (Washington).
Heat Rate MBTU/MWh	10,334	Congressional Research Service, p. 97.
Capacity Factor	85 percent	Congressional Research Service, p. 97
Installed Capital Costs $/kW	$4,662.61	Congressional Research Service, p. 97
O&M Costs $/MWh	$11.51	Congressional Research Service, p. 97
Economic Life/years	50	Assumption
Fuel $/MBTU	$2.02	U.S. EIA, AEO 2009 (April 2009 update related to federal stimulus), Table 12
Net Generation Cost $/MWh	$98.12	Calculation
Avoided Price of Power $/MWh	$49.15	Calculation based on existing 90 percent new coal and 10 percent gas plant mix.
MW Capacity	600	
MWh Generation	4,467,600	

The above technology assumptions include the cost of both the IGCC plant as well as carbon capture equipment and operations. The Congressional Research Service study bases IGCC minus carbon capture costs on a survey of five IGCC plant proposals throughout the United States, including the Edwardsport plant in Indiana and the Mountaineer plant in West Virginia. Carbon capture equipment costs are based on applying a 43 percent adder, which in turn is based on EIA estimates of carbon capture capital costs above those for stand-alone IGCC plants. O&M costs are based on CRS's review of EIA's 2008 long-term forecast.

Given the site-specific nature of sequestration configurations, and given the lack of sufficient operational experience in carbon capture worldwide, the above cost figures may not reflect the actual cost of carbon capture in sites in Pennsylvania.

Table 5.3. Carbon Capture Retrofit Technology Assumptions for Year 2020

IGCC with Carbon Capture Characteristics	**$2007** **New Plant**	**Source**
Unit Size MW	267	Based on HB80 load-serving requirements
Heat Rate MBTU/MWh	15,817	Congressional Research Service, p. 97.
Capacity Factor	85%	Congressional Research Service, p. 97
Installed Capital Costs $/kW	$2,141	Congressional Research Service, p. 97
O&M Costs $/MWh	$13.12	Congressional Research Service, p. 97
Economic Life/years	50	Assumption
Fuel $/MBTU	$2.02	U.S. EIA, AEO 2009 (April 2009 update related to federal stimulus), Table 12
Net Generation Cost $/MWh	$85.52	Calculation
Avoided Price of Power $/MWh	$49.15	Calculation based on existing 90% new coal and 10% gas plant mix.
MW Capacity	267	Based on HB80 load-serving requirements
MWh Generation	1,987,492	

The above costs and heat rate are based on the Congressional Research Service's review of the 2007 MIT study *The Future of Coal*. O&M costs are based on a review by CRS of the National Energy Technology Laboratory's (NETL's) study of the Conesville plant in Ohio.

The assumed capacity of retrofits to existing supercritical pulverized coal plants is based on regulated load-serving entities (LSEs) sourcing a maximum of 3 percent of total electric energy sold to retail customers in the state from coal-fired plants with carbon capture, as a part of the Tier II tranche of resources. The assumption does not ramp up the maximum from carbon capture for subsequent years, even through the overall Tier II requirement rises over time. Thus, the energy requirement would grow only based on load growth.

It is assumed that an acceptable CCS plant is one athat captures 40 percent of its CO_2 from 2015 to 2019, 60 percent from 2019 to 2024, and 90 percent from 2024 onward. We apply those percentages to overall existing coal generation in the state.

Future Fuels has proposed a 150-MW IGCC plant near Good Spring, PA (Schuylkill County), to be supplied by anthracite from a nearby mine.

<u>Economic Cost:</u> Market forces will drive investments into infrastructure, to uprate capacity. These up-front costs will yield greater energy generation capacity and efficiency, leading to increased sales and, eventually, increased profits.

Implementation Steps: The following, and other, considerations could be examined as policy tools to support this measure:

- Leveraging federal stimulus funds for carbon capture and sequestration (CCS), which amounts to $3.5 billion and when combined with existing federal funds (primarily from the Energy Policy Act of 2005), results in $8 billion in total federal support for CCS.
- CCS portfolio requirements for LSEs, similar to what the Illinois has supported, which is set at 5 percent with a cap on overall rate impacts.
- Loan guarantees for early-stage development of CCS infrastructure, to reduce financing costs to bring them closer to government borrowing rates.
- Funding for technical assessments of CCS potential in the state.
- Investment tax credits to cover up-front capital costs.
- Production tax credits over a specified period of generation.
- Direct cost sharing of project development costs through appropriations.
- Streamlined permitting for generation and associated transmission.
- Given the long lead times for CCS and other developing technologies, there is considerable uncertainty regarding the timing, technical issues, permitting, and financing associated with retrofitting existing pulverized coal plants with CCS.

Potential Overlap:

- See Appendix E2 for Overlap Analysis.

Subcommittee Recommendations

1. The EGTD was generally supportive of the prospects for carbon capture and sequestration (CC&S) given its potential for utilization of PA coal resources and potential contribution to PA's economy.
2. A number of utility EGTD members expressed concern that the deadlines in the bill are overly aggressive and do not account for the limitations of engineering, planning, financing, permitting and construction, especially for a technology not yet operative at a scaled up level for a supercritical coal-fired power plant.
3. At least one member voted against the work plan concerned that construction of a plant coupled with failure of CC&S would leave the commonwealth with another major source of GHG: "The above analysis does not account for the possibility of a viable sequestration site not being developed in Pennsylvania. In terms of GHG reductions, this would be effectively equivalent to a "0 percent" capture rate. If a new power plant is brought on line to test and advance CCS, and then a viable sequestration site is not completed, the end result would be a net increase in GHG emissions. This increase could however be offset if less efficient power plants are being taken off line or producing less power in lieu of the new plant's power production." Other members countered that such a new, more efficient plant, even with a failure or delay of CC&S, would be more efficient than older plants it might replace with respect to tons of CO_2 per MWh.

4. Many members of the subcommittee expressed concern that the work plan reaches conclusions with respect to “cost effectiveness” yet DEP’s macroeconomic analysis will not be completed until the end of 2009. Accordingly, several members wanted to express their concern that the economic assumptions and cost effectiveness figure may be suspect because they have not been subject to rigorous economic review and analysis with all costs and impacts addressed (i.e. displaced MW = displaced miners and generation employees). Other members expressed concern that any macroeconomic analysis address costs of inaction (i.e. impacts of global change in PA) as well as savings that might occur from GHG emissions reductions.

Electricity 6. Improve Coal-Fired Power Plant Efficiency by 5 Percent

Summary: Require a 5 percent increase in energy efficiency at coal-fired power plants by 2025. Each facility would have the flexibility to meet this efficiency requirement at the least-cost method available. This measure is assumed to be implemented linearly in 2015 following scheduled outage in PJM queue.

Other Involved Agencies: Work plan measures would need to be designed so as not to trigger the "Major Modification" clause in the EPA New Source Review (NSR) program for major stationary sources in attainment areas for the National Ambient Air Quality Standards. NSR requires plant owners to undergo review for environmental controls in case of major modifications beyond routine maintenance, repair, and replacements. Determination of what measures trigger NSR is made on a case-by-case basis, with numerous efforts by EPA to create broader guidelines to inform plant owners what measures trigger NSR.

One provision that is currently delayed by EPA until at least 2010 is how numerous physical and operational changes are aggregated in determining whether the measures trigger NSR. The delayed rule, originally issued on January 15, 2009, determined that such changes can be aggregated only if they are "substantially related" and occur within 3 years of the other changes. However, the recent delay points to continued case-by-case determination of if and how numerous changes trigger NSR. This analysis includes design and operational changes that may or may not trigger NSR. The analysis avoids modeling added plant capacity associated with efficiency improvements as one effort to avoid assumptions that would more likely trigger NSR.

The typical methods that could be utilized for compliance with this measure are listed in the table from the Australian Greenhouse Gas Office publication below. [Insert the table number.] This analysis excludes the table's list of "retrofit improvement" measures as an attempt to screen measures that are more likely to be considered to be "major modifications" under NSR.

Possible New Measure(s): An affected electricity generating unit (EGU) may improve efficiency to minimize system losses as a means to reduce CO_2 emissions. For instance, a 15 percent increase in efficiency at an EGU would result in a 13 percent decrease in CO_2 emissions. Upgrades can include improvements to the boiler, turbine, and control systems. Examples of turbine improvements include installing high-efficiency turbine blades, which allow for increased power generation and an efficiency improvement of 0.98 percent. Fuel consumption reduction can occur with improvements to feed water heater material within a turbine system, leading to a 1 percent–5 percent increase in efficiency. Upgrading the software of the control system that monitors and fine-tunes combustion can improve efficiency by 0.3 percent–3 percent.

Table 6.1. Work Plan Cost and GHG Results

Annual Results (2020)			Cumulative Results (2009-2020)		
GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/$tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/$tCO_2e$)
5.4	$8.0	$1.5	55.4	$101.9	$1.8

Quantification Approach and Assumptions

- The measures selected in the analysis draw upon the Australian Greenhouse Gas Office study detailed below, with a cross-reference check with the NETL's *Reducing CO_2 Emissions by Improving the Efficiency of the Existing Coal-Fired Power Plant Fleet* (July 2008), which also lists potential efficiency improvement measures, though without associated cost information. The measures, listed in order of lowest to highest cost on a CO_2 reduction basis are:
    - Reducing turbine gland leakage (0.84 percent efficiency improvement).
    - Refurbishing feed heaters (1 percent efficiency improvement).
    - Improving combustion control (0.84 percent efficiency improvement).
    - Reducing steam leaks (1.1 percent efficiency improvement).
    - Lowering excess air operation (1.22 percent efficiency improvement).
- The costs of these measures are estimated as follows:

Table 6.2: Assumed Cost of Measures in this Work Plan

Measure	Cost in 2008 US dollars
Turbine gland leak	$0.05
Feedheater refurbish	$0.91
Combustion control	$1.05
Steam leak reduction	$1.39
Low excess air	$3.33

The above costs are small, but higher than a recent McKinsey estimate for "improved heat rates of base-load pulverized coal power plants" of $-15/ton.[11]

- Whether all the above measures can be implemented in a single plant is dependent upon plant-specific physical and operational conditions. Further, whether all measures can be implemented with additive efficiency benefits is also a plant-specific determination. The analysis did not include multiple measures affecting a single aspect of a plant (e.g., numerous feedheater-related measures) to avoid overlapping measures as best as possible.
- The result of the measures is to improve heat rate efficiency, thereby reducing CO_2 emissions from existing plant capacity. While the Australian study lists the total

[11] Reducing Greenhouse Gas Emissions: How Much at What Cost? p.59
http://www.mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf

efficiency of the above measures at 4.84 percent, we draw upon NETL's study, which lists ranges of efficiency improvements from the above measures, and increase the efficiency benefit of feed heater refurbishment from 0.84 percent (as listed in the Australian study) to 1 percent (which is within the range of potential efficiency improvement cited in the NETL study), to reach a total of 5 percent efficiency improvement.

- Costs are based on the Australian study's estimate of cost per unit of reduced CO_2 emissions. The Australian study assumes an 8 percent discount rate over 25 years.
- Implementation is assumed to affect all existing coal-fired generation in the state beginning in 2010.
- Cost to DEP—The cost to DEP will be in terms of staff man hours invested in developing any new regulation, or guidance document, that will be required for this effort. Also, any additional conditions that need to be added to permits will require additional staff time invested by regional office personnel.
- Cost to the regulated community or consumer—A study conducted by the Australian Greenhouse Office (January 2000) evaluated the costs and benefits of efficiency improvements to electric generating units. This paper can be found at http://www.environment.gov.au/settlements/ges/publications/pubs/skmreport.pdf.
- The availability of federal funds for such improvement projects is unknown.
- The cost to other programs at the federal level is unknown.
- The cost of the measures that fall under this work plan are significantly higher should the modifications trigger NSR, which would then require additional pollution control measures at the retrofitted plants.

The table below, from the Australian Greenhouse Office (January 2000) report *Integrating Consultancy Efficiency Standards for Power Generation* illustrates the cost in terms of tons of CO_2 reduced for a variety of power plant efficiency improvement steps. For each efficiency improvement action, the cost can be determined based on the expected ton/CO2e reduction. All data in this table are in terms of Australian dollars and metric tons.

Table 6.3. Coal Plant Efficiency Measures

Action	Efficiency Improve-ment, * %	CO_2 emission reduction kg/MWh	Capex $/kW	Opex $/MWh	CO_2 reduction cost $/t#	Notes
Restore the plant to design conditions:						
Operate boiler at the design O_2						
Restore and maintain airheaters						
Minimise boiler tramp air	0.42	6	0	0.023	4.00	1
Reinstate any feedheaters out of service (Plant X)	0.46	6	5.5	0	9.75	2
Reinstate any feedheaters out of service (Plant Y)	1.97	27	5.8	0	2.81	2
Refurbish feedheaters(3)	0.84	11	1	0	1.15	2
Reduce steam leaks	1.1	14	2	0	1.77	1
Reduce turbine gland leakage	0.84	11	0.055	0	0.06	1
Changes to operational settings:						
Low excess air operation (1)	1.22	19	0	.08	4.23	3
Improved combustion control	0.84	11	0	0.015	1.33	1
Increased condenser cleaning						
Increased boiler cleaning						
Retrofit improvements:						
Coal drying with heat recovery	4.5	55	177	1.44	63	1
Extra airheater surface in the boiler	2.1	26	8.2	0.013	2.11	3
Install additional sootblowers						
Install new high efficiency turbine blades	0.98	13	22.1	0	21.42	1
Change to steam driven feed pumps						
Install variable speed drives	1.97	27	5	0	2.41	1
Install on-line condenser cleaning system	0.84	11	2.8	0.019	4.79	1
Install new cooling tower film pack	1.97	27	11	0	5.35	1
Install intermittent energisation to ESP's	0.32	4	0.4	0.007	2.82	1

Notes:
* One percent change produces one percent change in fuel flow and CO_2 intensity.
# Discount rate 8%, 25 years
1 Based on information supplied in survey
2 Three estimates based on survey data and on plant performance model. Result is plant specific (Plant X and Y).
3 Based on estimates from plant performance model, with in-house cost data

Potential Overlap:

- See Appendix E2 for Overlap Analysis.

Subcommittee Recommendations

1. The EGTD was supportive of efforts to improve the efficiency of existing coal-fired power plants and saw such initiatives as feasible subject to the New Source Review (NSR) discussion below.

2. Utility members of the EGTD believe based on their experience and pending litigation the projects listed as efficiency improvement opportunities would generally be viewed by DEP, USEPA and others as triggering NSR under the federal Clean Air Act. The utility members pointed out this position has and would dramatically and fundamentally alter the "cost

effectiveness" and economics of the work plan. NSR triggers would implicate a host of other, significant emissions control modifications that would potentially render the efficiency costs insignificant. Accordingly, they view this work plan as impracticable absent some resolution of the NSR issue. The issue is not the feasibility of the work plan recommendations, but that DEP itself contends such projects require significant capital expenditure beyond the costs of the efficiency project.

3. Many members of the subcommittee expressed concern that the work plan reaches conclusions with respect to "cost effectiveness" yet DEP's macroeconomic analysis will not be completed until the end of 2009. Accordingly, several members wanted to express their concern that the economic assumptions and cost effectiveness figure may be suspect because they have not been subject to rigorous economic review and analysis with all costs and impacts addressed (i.e. displaced MW = displaced miners and generation employees). Other members expressed concern that any macroeconomic analysis address costs of inaction (i.e. impacts of global change in PA) as well as savings that might occur from GHG emissions reductions.

Electricity 7. Sulfur Hexafluoride (SF_6) Emission Reductions from the Electric Power Industry

Summary: This initiative uses a pollution prevention approach, including a best management practice (BMP) manual and recordkeeping and reporting requirements, to ensure that all SF_6 emission reductions are quantified and permanent.

Other Involved Agencies: EPA

Possible New Measure(s): SF_6 is identified as the most potent non-CO_2 GHG, with the ability to trap heat in the atmosphere 23,900 times more effectively than CO_2. Approximately 80 percent of SF_6 gas produced is used by the electric power industry in high-voltage electrical equipment as an insulator or arc-quenching medium. SF_6 is emitted to the atmosphere during various stages of the equipment's life cycle. Leaks increase as equipment ages. The gas can also be accidentally released at the time of equipment installation and during servicing. Table 7.1 presents SF_6 emission estimates for Pennsylvania.

Table 7.1. SF_6 Emissions Estimates for Pennsylvania

Basis	Year	SF_6 Emissions	$MMtCO_2e$	
CIRA-2003	1990	SF_6 from Electric Utilities	0.8	87%
CIRA-2003	1990	SF_6 from Magnesium	0.1	13%
		Total	0.9	100%
CIRA-2003	1999	SF_6 from Electric Utilities	0.9	76%
CIRA-2003	1999	SF_6 from Magnesium	0.3	24%
		Total	1.2	100%
PEC-2007	1990	SF_6 from Electric Utilities	1.2	
PEC-2007	2000	SF_6 from Electric Utilities	0.6	
PEC-2007	2020	SF_6 from Electric Utilities	0.3	

A regulatory program could be developed in Pennsylvania that uses a pollution prevention approach, including a BMP manual and recordkeeping and reporting requirements to ensure that all SF_6 emission reductions are quantified and permanent. The reduction of SF_6 emissions from the electric power industry is available as one of the offset opportunities for any cap-and-trade program established for large emitters under the Northeast Regional Greenhouse Gas Initiative (RGGI).

As part of this regulatory program, a manual could be developed that would identify BMPs that would be required of all owners and operators of electric power systems. BMPs practices could include proper handling techniques, identification and elimination of leaks, and the replacement of equipment that does not meet specific leak rate thresholds. An example of BMPs would be the recent Duquesne Light Company decommissioning of an old substation to recover the SF_6 gas and reclaim it to American Society for Testing and Materials (ASTM) standards. The project resulted in the removal of approximately 7,300 lbs of SF_6 that otherwise would have been emitted to the atmosphere. As a part of SF_6 Emission Reduction Partnership for Electric Power Systems, Exelon's PECO subsidiaries set a SF_6 goal in March 2006, to commit to an SF_6 leak rate of no more than 10 percent for 2006. To help achieve this goal, the companies provided additional training to substation personnel to minimize SF_6 gas leaks and revised the gas handling procedures. Annual recordkeeping and reporting requirements would be required to ensure the quantification and reduction of SF_6 emissions.

<u>Work Plan Costs and GHG Reductions:</u>

EPA identifies several categories of reduction measures. The following text is from the EPA Web site:[12]

- **Recycling Equipment**
  - The capital costs of recycling equipment range from around $5,000 to over $100,000 per utility. For this analysis, typical recycling expenditures have been set at $25,500 per utility. However, this capital investment produces O&M savings of nearly $1,600 per year per utility due to reduced purchases of SF6.
- **Leak Detection and Repair**
  - There are no capital costs associated with leak detection and repair and O&M costs are estimated to be $2,190 per utility due to the increased labor costs associated with this option.
- **Equipment Replacement/Accelerated Capital Turnover**
  - The capital costs of this option vary by equipment type. Circuit breakers (below 34.5 kV) may be replaced with vacuum breakers. The replacement cost varies from $25,000 to $75,000 per unit. Medium and high voltage breakers are expected to continue to use SF6 because no other option is currently available. Older breakers are assumed to leak more and are being replaced by new equipment (as part of routine turnover) at a cost of approximately $200,000 to $750,000 per unit. Additional research into the existing equipment stock and potential for replacement will be necessary to develop cost estimates for emission reductions.
- **Advanced Leak Detection Technologies**
  - The capital cost per GasVue leak detection camera is approximately $100,000. Additional research into the potential emission reductions from this option will be necessary to develop estimates for O&M costs and the total cost of emission reductions.

Summary of Measures and Costs

The most promising options to reduce SF6 emissions from electric power systems are SF6 recycling and SF6 leak detection and repair. SF6 recycling could reduce emissions by about 10 percent, and is currently cost-effective. Leak detection and repair could reduce emissions cost-effectively by 20 percent.[13]

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[12] US EPA. Final Report on U.S. High Global Warming Potential (High GWP) Emissions 1990-2010: Inventories, Projections, and Opportunities for Reductions. Chapter 3: Cost And Emission Reduction Analysis Of Sf6 Emissions From Electric Power Transmission And Distribution Systems In The United States. http://www.epa.gov/highgwp/pdfs/chap3_elec.pdf

[13] http://www.epa.gov/highgwp/pdfs/chap3_elec.pdf p. 3-3.

Actual EPA partnership experience shows that even greater reductions have been experienced. The 2007 annual report shows that partner emission rates have declined by nearly 60 percent, from more than 15 percent of consumption to 5.5 percent.[14]

Table 7.1. Summary of Emission Mitigation from SF6 Partnership (2007)

TABLE 1 **Summary of Partnership SF_6 Emissions, Nameplate Capacity, and Emission Rate**

	1999	2000	2001	2002	2003	2004	2005	2006	2007
Total SF_6 Emissions (lbs)	693,416	638,106	617,704	546,528	527,090	498,543	460,828	377,374	326,878
Total SF_6 Nameplate Capacity (lbs)	4,563,183	4,614,480	4,610,478	5,180,931	5,395,612	5,432,255	5,670,725	5,827,600	5,899,489
SF_6 Emission Rate[a]	15.2%	13.8%	13.4%	10.5%	9.8%	9.2%	8.1%	6.5%	5.5%

a – Emission rate is defined as total emissions divided by total nameplate capacity (i.e., the total quantity of SF6 contained in electrical equipment).

Table 7.2. Work Plan Cost and GHG Results

Annual Results (2020)			Cumulative Results (2009-2020)		
GHG Reductions ($MMtCO_2e$)	**Costs (Million $)**	**Cost-Effectiveness ($/$tCO_2e$)**	**GHG Reductions ($MMtCO_2e$)**	**Costs (NPV, Million $)**	**Cost-Effectiveness ($/$tCO_2e$)**
0.1	$0.1	$0.59	0.73	$0.29	$0.39

Quantification Approach and Assumptions

- The SF_6 program is assumed to be implemented linearly over a 5-year period beginning in 2012. By the end of 2016, SF_6 reductions are assumed to be 30 percent of forecasted emissions from the electricity sector. The reductions are split into 20 percent leak detection and 10 percent recycling.
    - Note that future reductions could be much larger than this, based on actual experiences by SF_6 partner utilities between 2000 and 2007.
- The cost estimates employ an 8 percent discount rate, a 10-year project lifetime, and an SF6 price of $8/lb. Mitigation costs for leak detection are estimated at $0.44/$tCO_2e$, and recycling equipment at $0.90/$tCO_2e$.[15]
- SF_6 emissions from the electric power sector are estimated at 0.6 $MMtCO_2e$ in 2000 and at 0.3 $MMtCO_2e$ in 2020. Emissions in the interim period are linearly interpolated. Emissions are held constant at 2020 levels through 2030.

Other Costs and Benefits

- Industry—Mitigating emissions is cheaper than purchasing new SF_6 supplies. These benefits are not quantified here for lack of specific cost data.

[14] http://www.epa.gov/electricpower-sf6/documents/sf6_2007_ann_report.pdf page 3.
[15] http://www.epa.gov/highgwp/pdfs/chap3_elec.pdf Exhibit 3.4.

- DEP—No costs authorized or anticipated. Therefore, development of any regulatory program would be required to be accomplished through existing resources and budget.
- Funding sources—EPA's voluntary cooperative program is implemented under federal funding independent of Pennsylvania's budget process.

Implementation Steps: EPA's voluntary cooperative program is implemented and summarized at http://www.epa.gov/electricpower-sf6/. Pennsylvania's major power producers are participants.

Potential Overlap: Not applicable.

Subcommittee Recommendations

1. While the EGTD was supportive of SF6 reductions, because of a) the small amount of CO2 equivalents that could be reduced, b) the long term trend downwards of SF6 releases and c) ongoing industry and USEPA efforts to further reduce losses, we view this as a work plan of limited value or potential. However it is forwarded to warrant future review and updating.

Electricity 8. Analysis to Evaluate Potential Impacts Associated With Joining the Regional Greenhouse Gas Initiative

Summary: Examine the potential CO_2 emission reductions associated with joining RGGI.

Other Involved Agencies: PUC and DEP.

Possible New Measure(s):

RGGI is composed of individual CO_2 Budget Trading Programs in each participating state. These programs are implemented through state regulations, based on a RGGI Model Rule (http://www.rggi.org/docs/Model%20Rule%20Revised%2012.31.08.pdf), and are linked through CO_2 allowance reciprocity. Regulated power plants are able to use a CO_2 allowance issued by any of the participating states to demonstrate compliance with the state program governing their facility. Taken together, the individual state programs function as a single regional compliance market for trading carbon emissions. To reduce GHG emissions, the RGGI participating states are using a market-based cap-and-trade approach that includes:

- Establishing a multistate CO_2 emissions budget (cap) that will decrease gradually until it is 10 percent lower than at the start.
- Requiring electric power generator to hold allowances covering their CO_2 emissions.
- Providing a market-based emissions auction and trading system where electric power generators can buy, sell, and trade CO_2 emission allowances.
- Using the proceeds of allowance auctions to support low-carbon-intensity solutions, including energy efficiency and clean renewable energy, such as solar and wind power.
- Employing offsets (GHG emission reduction or sequestration projects at sources beyond the electricity sector) to help companies meet their compliance obligations.

RGGI's phased approach means that reductions in the CO_2 cap provide predictable market signals and regulatory certainty. Electricity generators will be able to plan for and invest in lower-carbon alternatives and avoid dramatic electricity price impacts.

The RGGI target is to hold state CO_2 emissions from the power sector constant at 2009 levels until 2014. Beginning in 2015, CO_2 emissions will be reduced by 2.5 percent/year below 2009 emissions for 4 years through the end of 2018, at which time capped emissions are targeted at 10 percent below 2009 emissions.

Table 8.1 shows the forecasted Pennsylvania business-as-usual (BAU) emissions and corresponding RGGI target. The final row of the table shows the required reductions to meet the RGGI target. Note that the effects of energy efficiency investments required under Act 129 (2008) are included in the BAU emissions forecast, as are the renewable energy requirements from the AEPS.

Table 8.1. Pennsylvania Forecasted Emissions and the RGGI Targets 2009–2020

Electricity Sector Emissions--Million Metric Tons CO2 Equivalent ($MMTCO_2e$)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total (Production-Based)	**115**	**117**	**120**	**122**	**123**	**125**	**126**	**128**	**129**	**131**	**133**	**134**
Total (Consumption-Based—Not used in analysis	**83**	**85**	**86**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**97**
RGGI CAP	115	115	115	115	115	115	112	109	107	104	104	104
Required Reductions From BAU (Production Based Emissions less RGGI Cap)	-	2.3	4.5	6.4	8.0	9.6	14.0	18.4	22.9	27.4	29.0	30.5

Although the first RGGI compliance target ends in 2018, this analysis considers emissions and reductions out to 2020, because this is the Pennsylvania Climate Change Advisory Council's terminal analysis year.

Pennsylvania's BAU emissions are forecasted to grow by over 1.5 $MMtCO_2e$/year between 2005 and 2020. This equates to an increase in emissions of 10 $MMtCO_2e$ between 2009 and 2014, after which the 2.5 percent annual reductions are required. Between 2015 and 2020, Pennsylvania's power sector emissions are forecasted to grow by an additional 9 $MMtCO_2e$.

By 2020, the forecast predicts that RGGI compliance would require approximately 30 $MMtCO_2e$ reductions from the electricity sector. There are two categories of reductions that need to occur to meet the RGGI target:

1. Reduce the 2009–2020 forecasted BAU emissions increase of 19 $MMtCO_2e$ to hold state emissions constant at 2005 levels.
2. Reduce the additional 11 $MMtCO_2e$ required to reach the 10 percent below 2005 RGGI target.

Several conclusions can be drawn from this analysis regarding potential RGGI compliance. First, Pennsylvania's emissions growth needs to begin to slow immediately to for the state to realistically meet the RGGI target. Because of their low-cost and short lead times, demand-side management measures are the optimal choice to stabilize emission levels. Second, in the longer term, reductions in the carbon intensity of the electricity generated in Pennsylvania will be required to meet the RGGI targets. Finally, these two considerations should be viewed as a *portfolio of reductions* in the electricity sectors. Cost savings (negative cost measures) from demand side-options can be viewed to "pay" for higher-cost fuel-switching measures on the supply side. While demand-side management (DSM) requires capital outlays that are typically paid for by consumers, these investments cost less than new supply-side investments, and mitigate cost increases from low-carbon generation, as well as T&D investments.

Potential Costs and Supplies of GHG Emissions Reductions for Pennsylvania

Modeling of the costs to the state from joining RGGI proceeds in a stepwise fashion.[16] The approach is to aggregate the statewide GHG emissions reductions that are grid connected. First is an analysis of the reductions in GHG emissions from reduced electricity consumption.

[16] The modeling done for the RGGI states cost approximately $1 million. The CCAC does not have the resources to perform this type of analysis.

Table 8.2. Demand-Side GHG Reductions Identified in CCAC Work Plans

		Annual Results (2020)	
Work Plan No.	**Work Plan Name**	**GHG Reductions (MMtCO2e)**	**Cost Effectiveness ($/tCO2e)**
Electricity 3	Stabilized Load Growth (Industrial Sector Only)	3	-$64.43
RC-1	High Performance State and Local Government Buildings	2.7	-$8.00
RC-2	High Performance School Buildings	1.9	-$8.00
RC-3	High Performance Commercial (private) Buildings	9.0	-$8.00
RC-4	High Performance Homes (Residential)	18.3	-$8.00
RC-5	Commission Buildings	1.5	-$0.39
RC-6	Re-Light PA	12.9	-$64.02
RC-8	Appliance Standards	1.9	-$35.51
	Total Demand Side Reductions	**51**	**-$26.05**

- The costs of RGGI compliance are likely to be dominated by the negative cost energy efficiency (demand side) measures. A study conducted by the University of Maryland (January 2007) evaluated the costs and benefits of participating in the Regional Greenhouse Gas Initiative. This study can be found at http://www.cier.umd.edu/RGGI/documents/UMD_RGGI_STUDY_Jan07.pdf

  The main conclusions of this study indicate that, overall, joining RGGI would only have a limited impact on the economy and electric power markets in Maryland. Similar conclusions hold for the current RGGI region and affected areas outside this region.

  Electricity Bill Impacts in MD: Overall, electricity bills are forecast to decrease over $100 million in 2010 and more than $200 million by 2025. This is a result of energy efficiencies, which will lower customers' demands. Since the heaviest users will save the most, more than half the savings (between 53 percent and 63 percent) will go to industrial and commercial customers. On average, a residential ratepayer will see a modest reduction – about $22 savings in 2010 per household.

  Overall Economic Impacts in MD: Will have little net impact on the Maryland economy. The positive economic impacts from reduced electricity costs and energy efficiency investments are partially offset by reduced investment and profits in the electricity generating sector. Overall RGGI is predicted to have a positive economic impact on Gross State Product of approximately $100 million in 2010, increasing to about $200 million in 2015 and subsequent years. This impact is expected to create approximately 1200 jobs across the state by 2010, increasing to 2800 jobs by 2025. Such positive impacts are less than 0.1 percent of overall Maryland gross state product and employment in all years.

  - The costs to Pennsylvania are not necessarily reflective of the above modeled costs to Maryland.

Table 8.3. Low-Cost Supply-Side GHG Reductions Identified in CCAC Work Plans (From 6-15-09 Sector Work Plans)

		Annual Results (2020)	
Work Plan No.	**Work Plan Name**	**GHG Reductions ($MMtCO_2e$)**	**Cost Effectiveness ($\$/tCO_2e$)**
Waste 1	Landfill Methane Displacement of Fossil Fuels	0.1	-$0.80
Waste 5	Waste-to-Energy Digesters	0.1	$1.00
Waste 6	Waste-to-Energy MSW	0.24	-$34.00
Forestry 8	Wood to Electricity	0.26	$0.67
Forestry 9	Combined heat and power	0.47	–$45.30
Ag-4	Ag Digesters (Methane)	0.20	-$0.25
Electricity 6	Improve Coal-Fired Power Plant Efficiency by 5%	5	$15.21
Electricity 7	Sulfur Hexafluoride (SF6) Emission Reductions from the Electric Power Industry	0.1	$0.59
Electricity 9	Promote Combined Heat and Power (CHP)	4	$12.20
Electricity 10	Nuclear (Uprates Only)	4	$19.72
	Total Supply Side Reductions	**15**	**$13.44**

These electricity supply options do not include new renewables supplies and fuel switching from coal-to-gas.

Offsets

Another source of supplies for RGGI compliance comes from offsets. The RGGI program has included flexibility mechanisms to limit costs to the regulated sector. One of these mechanisms creates offset allowances from CO_2 mitigation projects outside of the power sector. Offsets are initially allowed in the program up to 3.3 percent of an entity's compliance obligation. If annual average allowance prices exceed $7 (in $2005), then this amount increases to 5 percent, and if annual allowance prices exceed $10, then this amount increases to 10 percent. At the 10 percent level, international CO_2 reduction credits are also allowed.[17] In the reference case 3.3 percent of obligations, total offsets allowed by Pennsylvania entities in 2020 would be approximately 4.4 $MMtCO_2e$.

The following list identifies the categories of offset projects currently allowed, and representative costs/to of CO_2. The costs are approximate and are taken from the relevant CCAC subcommittee work plans dated 6/15/2009 or later:

- Landfill methane capture and destruction (-$1/ton)
- Reduction in emissions of sulfur hexafluoride (SF6) in the electric power sector ($2/ton)
- Sequestration of carbon due to afforestation (-$10/ton)

[17] http://www.rggi.org/docs/program_summary_10_07.pdf. pp. 6-11.

- Reduction or avoidance of CO_2 emissions from natural gas, oil, or propane end-use combustion due to end-use energy efficiency in the building sector (-$25/ton)
- Avoided methane emissions from agricultural manure management operations (-$1/ton)

The offset accreditation process will likely entail some administrative costs that are not included in the above CCAC costs. Given the low or negative costs of the above measures, plus accreditation costs, a generic cost estimate for RGGI offsets is estimated at $5/ton CO_2e. Assuming that the costs of offsets credited in the RGGI program reflect the microeconomic quantification for the CCAC process, then they could exhibit a significant downward cost of compliance for regulated actors.

Summary

The above categories of costs and supplies are summarized in Table 8.4.

Table 8.4. Summary of GHG Reduction Measures

Category of Measures	PA Supply of GHG Reductions (MMtCO2e)	Cost Effectiveness ($/tCO2e)	Comment
Demand Side	51	-$26.05	Placeholders pending overlaps and cost information
Supply Side (CCAC)	15	$13.44	Includes overlaps
Offsets	4.4	$5.00	3.3% cap on offsets. See text for cost information
Total	**70**	**-$15.69**	**Weighted average cost/ton**

Limitations and Uncertainties

- As of 2007, Pennsylvania is a large exporter of electricity. The reference case GHG forecast assumes this will continue through 2020 as the growth in electricity generation is equivalent to growth in electricity sales. However, if Pennsylvania cannot site new fossil based generation resources at this rate, then GHG emissions from the power sector will be low than reported here.
- Similarly, the compliance costs estimated above require the timely implementation of policies to develop the GHG reduction measures identified under the CCAC process.
- Other costs: Cost to DEP & PUC – The cost will be in terms of staff man hours invested in developing any new regulation, or guidance document, that will be required for this effort. Also, additional staff time invested by regional office personnel necessary to update permits.

Quantification Approach and Assumptions

- Emissions reductions required to meet RGGI targets are based on PA production-based inventory which includes all electricity generated, including exported electricity.

- Power sector emissions are assumed to be held constant at 2009 levels through the end of 2014. Beginning in 2015, emissions are reduced by 2.5 percent of 2009 levels.
- The generation resources that are assumed to be avoided under this work plan are 90 percent existing pulverized coal, and 10 percent existing peaking gas. The weighted average cost of generation for the avoided mix is $9.15 in 2020. The avoided CO_2 emissions associated with this mix is .86 tons CO_2 /MWh.

Implementation Steps: New legislation and new regulation based on RGGI Model Rule is required.

Potential Overlap: See Appendix E2 for Overlap Analysis.

Subcommittee Recommendations:

1. This is an added work plan that was not in the original DEP portfolio and was reviewed in response to a public comment.
2. The EGTD voted against including this work plan for a number of reasons: a) RGGI is several years into its process and given the time it took RGGI states to develop, promulgate and implement regulations, it would be infeasible for PA to join, b) RGGI essentially sets targets and does not identify the sources of reduction and thus is duplicative of the efforts of the CCAC, c) RGGI would have more costly effects on PA as a coal-rich energy exporter, d) RGGI would be unlikely to gain any political support for the above and other reasons, and e) RGGI would introduce a state-specific cap and trade in the face of pending federal cap and trade legislation.
3. The data and CCS analysis on RGGI is, however, a useful addition to the DEP’s climate change library so the EGTD recommends the work plan be viewed as an appendix or attachment by DEP so as not to lose the data and analysis.
4. A number of members expressed concern that a Maryland economic study was cited for how RGGI might affect Pennsylvania ratepayers, although in view of the vote against the work plan, this concern becomes moot for the time being. Those members would, however, caution DEP about relying on non-PA assessments and extrapolating to Pennsylvania with respect to energy costs and economic impact.

Electricity 9. Promote Combined Heat and Power (CHP)

Summary: This initiative encourages distributed CHP systems to reduce fossil fuel use and GHG emissions. Reductions are achieved through the improved efficiency of CHP systems, relative to separate heat and power technologies, and by avoiding the T&D losses associated with moving power from central generation stations to distant locations where electricity is used.

Other Involved Agencies: N/A

Possible New Measure(s):

CHP is a term used to describe scenarios in which waste heat from energy production is recovered for productive use. The theory of CHP is to maximize the energy use from fuel consumed and to avoid additional GHG's by the use of reclaimed thermal energy. The reclaimed thermal energy can be used by other nearby entities (e.g., within an industrial park or district steam loop) for productive purposes. Generating stations in urban areas may have existing opportunities or may require the co-location of new industry. For Pennsylvania, the largest source of new, cost-effective CHP potential is in industrial facilities that have continuous thermal loads for domestic hot water and process heating (ACEEE et al., 2009). CHP units are typically sized to the minimum thermal load for the facility.

Potential Work Plan Costs and GHG Reductions:

Table 9.1 Work Plan Costs and GHG Results ($2007)

Annual Results (2020)			Cumulative Results (2009-2020)		
GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/$tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/$tCO_2e$)
4.4	$53	$12	23.2	$209	$9

The composition of the costs presented in Table 9.1 differs according to the type of CHP. Commercial CHP has the highest costs, in part because of the relatively low capacity factor (47 percent in 2010, rising to 64 percent in 2020) implied in the ACEEE et al. (2009) report. These low capacity factors are somewhat unusual because CHP units, especially commercial applications, are typically sized to the meet the constant thermal demand of the facility. These units are then run at maximum capacity to generate the required thermal output.

The cost and emission estimates assume three types of technologies are representative of the CHP portfolio in the future. Table 9.2 reflects the assumptions for each technology.

- Biofuel CHP supply: Ethanol and biodiesel production requires the distillation of separating mixtures based on differences in their volatilities in a boiling liquid mixture. Thus, it requires significant thermal inputs. The goal of the federal renewable fuels standard of 10.21 percent for 2009 (11.1 billion gallons of renewable fuel), is required by the Energy Independence and Security Act of 2007 (EISA), which targets 40 billion gallons by 2022.

- Act 78, a state law passed in July 2008, requires that every gallon of gasoline and diesel fuel contain a percentage of ethanol and biodiesel, respectively. The law targets 20 percent biodiesel and all gasoline sold at retail must contain 10 percent ethanol, once in-state cellulosic ethanol production reaches 350 million gallons.[18]

- The Agriculture Subcommittee work plan #2 on advanced biofuels targets 545 million gallons of biofuels being produced in PA by 2020. This is the target used for the biofuels CHP component of this work plan. This analysis assumes biofuels processing CHP supply provides useful thermal output equal to the heat requirements of processing of the 545 million gallons of biofuels. We assume the biofuels processing requires heat inputs equal to 38 percent of fuel energy content (an energy balance of 2.62, similar to the energy balance of cellulosic ethanol).

    - The biofuels component of the work plan is relatively modest, as exhibited in Table 9.2. Installed capacity in 2020 is only estimated at approximately 180 MW.

- The CHP supply estimates in the ACEEE et al. (2009) report targets the year 2025. For interim years such as 2020, supplies are linearly interpolated. The growth rate for 2026-2030 is 8.3 percent, 6.0 percent, and 0 percent for commercial, industrial, and biofuels processing, respectively.
- The avoided CO_2 emission rates are assumed to be the same as in work plan #1.
- The fuel for commercial and industrial and biomass processing CHP is 100 percent natural gas.
- T&D losses are 6.6 percent.
- Industrial retail electricity prices are the avoided electric prices for industrial and biofuels CHP. Commercial retail electricity prices are the avoided electric price for commercial CHP. The avoided CO_2 emissions associated with this mix is 0.86 tCO_2/MWh, from a 90 percent coal, 10 percent gas mix.
- Estimating the costs of CHP into the distant future is tentative, because cost estimates are highly sensitive to natural gas prices, the cost of avoided power, and the assumption about the CO_2 intensity of displaced electricity.

CHP potentials come from ACEEE et al. (2009) Table E-14. Market Penetration Results for $500/kW Incentive Case. This is the aggressive policy case where clean public energy funds subsidize the capital costs to install CHP at a rate of $500 per kilowatt (kW). This quantification incorporates the total social costs, including private and public costs, into the cost per $MMCO_2e$ measure.

[18] http://apps1.eere.energy.gov/states/state_news_detail.cfm/news_id=12212/state=PA

Table 9.2. CHP Technology Assumptions

	$2007	For Year 2020		
Avoided T&D Charges	**Commercial**	**Industrial**	**Biofuels Processing**	
Demand and Energy Charge kW month	4.45	$10.83	10.83	PPL GS-3 charges for comm. LP-6 charges for industrial, biofuels (>69 kv)
Distribution Charge Kw month (comm)	4.69			PPL GS-3 charges for comm. LP-6 charges for industrial, biofuels (>69 kv)
Distribution Charge Customer/Month (Ind)		$891.00	891.00	PPL GS-3 charges for comm. LP-6 charges for industrial, biofuels (>69 kv)
T&D Losses (%)	6.6	6.6	6.6	PA Assumption
CHP Characteristics				
Heat Recovered from CHP Power to heat ratio (%)	70	90	0	Source: Catalogue of CHP Technologies. EPA CHP Partnership. Introduction p. 7
CHP Unit Size MW	0.25	10.00	10.00	
CHP Technology	MicroTurbine	Gas Turbine	Gas Turbine	
Heat Rate MBTU/MWh	11,750	10,800	10,800	ACEEE, et al (2009) p. 212
Capacity Factor (%)	64%	75%	85%	Calc for comm/ind based on ACEEE. Biofuels assumption
Installed Capital Costs $/kW	2,240	1,400	1,400	2010-2015 Costs as average for the period. Plus after treatment costs of $200/kw
O&M Costs $/kWh	0.01	0.01	0.01	2010-2015 Costs as average for the period
Economic Life/years	15.00	15.00	15.00	Assumption
Avoided Boiler Characteristics				
Displaced boiler efficiency (%)	80%	80%	80%	Assumption
Fixed O&M $/MBTU	0.07	0.07	0.07	Assumption
Variable O&M $/MBTU	0.07	0.07	0.07	Assumption
Net Generation Cost $/MWh	147.02	61.09	60.14	Calc
Avoided Price of Power $/MWh	98.83	70.04	70.04	Assumption
MW Capacity	386	661	118	Ind/Comm from ACEEE, et al (2009)
MWh Generation	2,171,000	4,345,000	1,274,512	Ind/Comm from ACEEE, et al (2009)

Implementation Steps:

The key to implementing CHP systems is to provide adequate incentives for the development of infrastructure to capture and utilize the waste heat. Such incentives could come in many forms, such as recruiting suitable end users to a centralized location to utilize the waste heat, a feed-in tariff for CHP electricity, including CHP electricity in energy efficiency or renewables targets, tax credits, grants, zoning, and offset credits for avoided emissions.

The following are policies that can potentially increase the installed capacity of CHP in Pennsylvania:

- Create or expand markets for CHP units by using incentives designed to promote implementation for residential, commercial, and industrial users.
- Promote CHP technologies through provisions for tax benefits, attractive financing, utility rebates, and other incentives.
- Remove barriers to CHP development, such as utility rate structures that allow discounted electric rates to compete with CHP. Also, design interconnection standards to facilitate economical and efficient CHP connection to the grid.
- Consider the economic and environmental benefits of CHP as a resource in each electric utility's Integrated Resource Plan. Potential measures include training and certification of installers and contractors, net metering and other pricing arrangements, clear and consistent interconnection standards, and creation of and support for biomass fuel markets.

Potential Overlap:

- See Appendix E2 for Overlap Analysis.

Subcommittee Recommendations

1. The EGTD was generally supportive of this work plan and its potential to make the energy chain more efficient. However, there is significant concern about the many barriers which are alluded to in the work plan. Its potential may be more remote than suggested notwithstanding its attraction. The major issue here is the very broad assumptions and scenarios that underlie these CO_2 reductions and costs. The many barriers (legal, technical, economic, political, geographical) would have to be further assessed.
2. Many members of the subcommittee expressed concern that the work plan reaches conclusions with respect to "cost effectiveness" yet DEP's macroeconomic analysis will not be completed until the end of 2009. Accordingly, several members wanted to express their concern that the economic assumptions and cost effectiveness figure may be suspect because they have not been subject to rigorous economic review and analysis with all costs and impacts addressed (i.e. displaced MW = displaced miners and generation employees). Other members expressed concern that any macroeconomic analysis address costs of inaction (i.e. impacts of global change in PA) as well as savings that might occur from GHG emissions reductions.

Electricity 10. Nuclear Capacity

<u>Summary</u>: This work plan focuses on capacity uprates at existing nuclear plants in PA. DEP estimates 1,050 MW of additional potential capacity at PA nuclear power plants (Limerick, Peach Bottom, Susquehanna, Three Mile Island). Of this total, approximately 150 MW is expected to be available by 2012.[19] Of the remaining 900 MW, we assume that a bit less than half of the remaining MW capacity will be developed (i.e., ~400 MW) for a total of 550 MW by 2020. Therefore, the nuclear uprate schedule for the state is assumed to be 150 MW in 2012, and an addition of 100 MW of capacity in 2014, 2016, 2018, and 2020.

For new plant build, PPL Electric Utilities is proposing a 1600-MW Bell Bend plant at the site of the Susquehanna 1 and 2 that is also analyzed under this work plan.

<u>Other Involved Agencies:</u> Not applicable.

<u>Possible New Measure(s):</u>

<u>Nuclear Uprates</u>—To increase the power output of a reactor, typically a more highly enriched uranium fuel is added. This enables the reactor to produce more thermal energy and therefore more steam, driving a turbine generator to produce electricity. To accomplish this, such components as pipes, valves, pumps, heat exchangers, electrical transformers, and generators must be able to accommodate the conditions that would exist at the higher power level. For example, a higher power level usually involves higher steam and water flow through the systems used in converting the thermal power into electric power. These systems must be capable of accommodating the higher flows.

In some instances, facilities will modify and/or replace components to accommodate a higher power level. Depending on the desired increase in power level and original equipment design, this can involve major and costly modifications to the plant, such as the replacement of main turbines. All of these factors must be analyzed by the facility as part of a request for a power uprate, which is accomplished by amending the plant's operating license. The analyses must demonstrate that the proposed new configuration remains safe and that measures continue to be in place to protect the health and safety of the public. Before a request for a power uprate is approved, the Nuclear Regulatory Commission must review these analyses.

<u>Potential GHG Reduction:</u>

Avoided emissions are calculated on the basis of known potential uprates and new plant build displacing a mix of 90 percent coal and 10 percent gas at a combined average of 1,872 lb/MWh.

The costs and GHG reductions for this work plan are estimated in Table 10.1.

[19] From an email from Joe Sherrick at DEP on June 17, 2009.

Table 10.1. Work Plan Costs and GHG Results

Annual Results (2020)			Cumulative Results (2009-2020)		
GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/$tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/$tCO_2e$)
14.7	$832	$57	31.0	$655	$21

- Nuclear uprate costs are based on FPL Energy's proposed uprate of its Florida-based Turkey Point and St. Lucie pressurized water reactor units to be completed in 2011. Pressurized water reactors exist at the Beaver Valley and Three Mile Island plants in Pennsylvania.

- The generation resources that are assumed to be avoided under this work plan are 90 percent existing pulverized coal, and 10 percent existing peaking gas. The weighted-average cost of generation for the avoided mix is $49.15 in 2020. The avoided CO_2 emissions associated with this mix is 0.86 tCO_2/MWh.

Table 10.2: Nuclear Technology Assumptions

Nuclear Characteristics	$2007 New Plant	For Year 2020 Uprate	Source
Unit Size MW	1,600	varies	New Plant: PPL's proposed Bell Bend plant. Uprate: staff assumption based on common unit uprate proposals—e.g., FPL's proposed 378-uprate proposal for 4 units.
Heat Rate MBTU/MWh	10,400	10,400	ACEEE, et al (2009) p. 212
Capacity Factor	90%	90%	Assumption
Installed Capital Costs $/kW	$7,310.31	$3,892	New Plant: Climate Strategies ESD Policy Options Document (September 23, 2008) for the Florida Governor's Action Team on Energy and Climate Change. Uprate: FPL proposed 2011 uprate for Turkey Point and St. Lucie plants.
O&M Costs $/kWh	$13.33	$3.1	New Plant: Climate Strategies ESD Policy Options Document (September 23, 2008) for the Florida Governor's Action Team on Energy and Climate Change. Uprate: Same as above, minus fixed O&M costs.
Economic Life/years	50	50	Assumption
Fuel $/MBTU	$1	$1	Climate Strategies ESD Policy Options Document (September 23, 2008) for the Florida Governor's Action Team on Energy and Climate Change
Net Generation Cost $/MWh	$122.99	$66.20	Calculation
Avoided Price of Power $/MWh	$49.15	$49.15	Calculation based on 90% new coal and 10% new gas plant mix.
MW Capacity	1,600	550	Described Above
MWh Generation	12,614,000	3,153,600	Calculation

Implementation Steps:

- Market forces will drive investments into infrastructure, to uprate capacity. These up-front costs will yield greater energy generation capacity and efficiency, leading to increased sales and, eventually, increased profits.
- These actions are currently being implemented
- Market-driven initiative .
- Are cost savings realized from this initiative?—Not directly. Indirect savings to the commonwealth will accrue subject to in-state low-carbon electricity development (manufacturing, installation, sales and service, etc.). Indirect costs include displaced coal industry jobs and other fossil fuel-related economic production and consumption.

Potential Overlap:

- See Appendix E2 for Overlap Analysis.
- RGGI work plan.

Subcommittee Recommendations

1. This work plan incorporates both existing facility uprates, some of which, are already in progress as well as new nuclear capacity.
2. With respect to existing plant uprates, the EGTD generally supported increase in capacity for existing facilities, but a number of members believed they did not have enough information on life cycle costs to move forward (e.g., waste stream management and costs). One member voted against the work plan being opposed to any new nuclear capacity, but the EGTD decision to not recommend moots this concern for the time being. In any event, some members pointed out, the listed projects are already in motion.
3. With respect to new capacity, a number of members believed there was inadequate data or discussion to warrant moving forward especially given the plan complexity, technical uncertainties and relation to national and state energy policy.
4. The EGTD did decide to recommend DEP further analyze and review this work plan even though it does not yet seem ready for DEP action going forward. A number of members suggested this could be reviewed in three years as part of the periodic DEP review of its nascent action plan.

Electricity 11. Greenhouse Gas Performance Standard for New Power Plants

Summary: Because of the complexity and technical uncertainties associated with the original work plan, it was withdrawn from analytical consideration. The Electricity Generation Transmission and Distribution (EGTD) Subcommittee elected to include this as a non-quantified, policy recommendation for further review by DEP. Some subcommittee members acknowledged that some versions of proposed federal legislation contain performance standards. The following proposed language was drafted by the EGTD Chair and DEP and approved by the subcommittee and full committee.

Subcommittee Recommendations

1. Because of the complexity and technical uncertainties in this work plan, it was withdrawn from CCS analysis and the EGTD elected to include it as a non-quantified, policy recommendation for further review by DEP.
2. Some members pointed out that some versions of proposed federal legislation contain such performance standards.
3. Proposed language drafted by the EGTD Chair and DEP was distributed to the subcommittee on June 24, 2009 and comments are now coming in.
4. Subject to EGTD approval, that statement would read:

"A Greenhouse Gas Performance Standard for New Power Plants work plan is a potential policy measure to ensure that newly added fossil fuel-fired electric generating capacity would be consistent with the efforts of the commonwealth to establish and maintain a climate change action plan. It would involve detailed technical and economic assessments potentially leading to a standard that would provide an equitable working environment for all sectors of Pennsylvania's economy, and that would balance the goal of reducing greenhouse gas emissions with the capability of meeting future energy demand within the commonwealth. Such a performance standard could conceivably set standards unachievable by existing or proposed coal-fired generation and only possible through carbon capture and sequestration. (CCS) CCS is not currently commercially available at the scale required nor are there other technologies on the immediate horizon that could significantly reduce CO2 emissions. Generators could possibly meet the overall greenhouse gas reduction standards through the purchase of an equivalent volume of Certified Emissions Reductions, but this would also involve a detailed analysis of the available market and how it could be structurally related to a performance standard. Accordingly, the subcommittee recommends that if DEP wishes to include such a work plan/standard, it be promoted as a non-quantifiable policy initiative in the Climate Change Action Plan."

Electricity 12. Transmission & Distribution Losses

Summary: This work plan analyzes the potential GHG reductions associated with reducing average electric transmission & distribution losses (“system losses”) by 1%.

Other Involved Agencies: Pennsylvania Public Utility Commission

Possible New Measure(s): All electricity transmission and distribution (T&D) systems have inherent energy losses associated with moving electricity through lines and equipment operations that are integral to the movement and delivery of the electricity. Even though energy losses will inevitably occur, there are strategies available to minimize these losses.

The primary areas where improvements could be made to help reduce T&D losses are as follows:

- Improvements in transmission and distribution system equipment, materials and management.
- Demand side management and end-use consumer improvements.
- Expand use of clean distributed generation.
- Policy changes.

Possible actions in the identified primary areas for T&D improvements include:

1. Improvements in transmission and distribution systems.
    - Replace existing transformers with higher efficiency transformers*
    - Improve the measurement, accounting and reporting of T&D losses
    - Overloaded lines are less efficient- therefore add transmission lines to reduce losses
    - Replace existing wires with higher capacity wires
    - Improve communications on T&D systems
    - Use high voltage DC transmission
    - Use high temperature super conductors

    * DOE published new energy conservation efficiency standards for distribution transformers on October 12, 2007. These new standards will start in 2010.

2. End-use consumer improvements
    - Demand side management strategies implemented
    - Energy efficiency improvements
    - Load factor improvements
    - Power factor improvements

    Utility representatives offered the suggestion of reduced demand by the end user as the most cost effective way to reduce transmission losses. As the transmission and distribution system becomes more congested especially at peak demand times the reduction of demand becomes more significant for reducing losses.

3. Expand use of Clean Distributed Generation
    - Combined Heat and Power (CHP) applications
    - Energy recycling
    - Micro grid expansion
    - Small-scale or residential size clean energy generation

Projected GHG Reduction: **0.8 MMTCO2e**

The following steps were used in calculating the emissions reduction:

- Consumption and system loss data was obtained for each of the eight electric distribution companies (EDCs) in PA for years 2001 through 2006. This data was obtained from the PUC's *Electric Power Annual Outlook* reports.
- Average rates of consumption and system losses were calculated for each EDC under a business as usual (BAU) scenario. Average growth rates in consumption ranged from 0.32 percent to 2.11 percent. Average rates for systems losses, by EDC, ranged from 5.65 percent to 8.87 percent.
- Projections for BAU rates for consumption and system losses were made beginning with the last year of reported data to the PUC (2006).
- A similar set of projections was developed for system losses that assumes a 1 percent reduction from the BAU system loss rate.
- The sum total MWh from system losses for each scenario (BAU and 1 percent reduction) was then multiplied by a five-year (2000 through 2004) statewide average CO_2 emission factor (1,279 pounds of CO_2 per MWh) that is reflective of the generation fleet in PA. The emissions rates were calculated from generation and emissions data reported to the U.S. DOE's Energy Information Administration (EIA).
- Emissions were converted to million metric and the difference between the two scenarios was calculated.

A series of tables summarizing the estimated CO_2 reductions potential of this initiative are included in this work plan immediately following "Potential Overlap."

Economic Cost: Industry and DOE representatives cautioned that life cycle cost analysis must be considered regarding improvements to the transmission and distribution systems. The economics of improvements to the lines and other physical equipment may be capital cost prohibitive thus reduction in demand may be the most cost effective way to reduce losses.

Implementation Steps:

- Allow CHP generators to build private wires and micro-grids
- Provide a mechanism to fairly compensate distributed generation for power provided to the grid

Potential Overlap:

- Act 1, Act 129, Reduced Load Growth, Stabilized Load Growth, AEPS Tier I (8 percent, 15 percent, 20 percent) work plans
- *All actions that increase or reduce electricity consumption will have a direct and obvious effect on the emissions reductions estimated in this work plan but will not impact the system loss rates.*

Subcommittee Recommendations

1. Because of the complexity, technical uncertainties and relation to national and state energy policy in this work plan, it was withdrawn from CCS analysis and the EGTD elected to include it as a non-quantified, policy recommendation for further review by DEP.

Consumption - Business as Usual (BAU) Scenario										
		Average Growth Rate per EDC								
		1.07%	1.96%	1.30%	0.32%	2.11%	1.25%	1.38%	1.74%	
		Duquesne	MetEd	Penelec	PennPower	PECO	PPL	UGI	West Penn	Total MWh
Consumption (MWh) by Compliance Year	2007	14,138,380	14,337,188	14,286,471	4,736,809	40,411,755	38,889,219	1,016,001	21,225,591	149,041,414
	2008	13,860,634	14,240,733	14,379,251	4,695,840	40,014,695	39,090,157	1,002,824	21,043,842	148,327,976
	2009	13,912,935	14,277,544	14,014,184	4,535,373	40,213,471	38,240,700	1,016,682	20,746,301	146,957,190
	2010	13,834,322	14,733,664	14,407,425	4,678,881	41,000,090	38,207,300	1,030,731	21,188,571	149,080,984
	2011	13,981,805	15,022,597	14,595,299	4,693,910	41,865,717	38,683,176	1,044,975	21,557,735	151,445,214
	2012	14,130,861	15,317,197	14,785,623	4,708,987	42,749,619	39,164,979	1,059,415	21,933,331	153,850,011
	2013	14,281,505	15,617,573	14,978,429	4,724,112	43,652,183	39,652,783	1,074,055	22,315,471	156,296,112
	2014	14,433,756	15,923,841	15,173,749	4,739,286	44,573,803	40,146,662	1,088,897	22,704,268	158,784,263
	2015	14,587,630	16,236,114	15,371,617	4,754,509	45,514,881	40,646,693	1,103,944	23,099,840	161,315,227
	2016	14,743,144	16,554,511	15,572,064	4,769,781	46,475,827	41,152,952	1,119,199	23,502,304	163,889,781
	2017	14,900,315	16,879,152	15,775,125	4,785,101	47,457,062	41,665,516	1,134,665	23,911,779	166,508,717
	2018	15,059,163	17,210,159	15,980,834	4,800,471	48,459,014	42,184,464	1,150,345	24,328,389	169,172,840
	2019	15,219,704	17,547,657	16,189,226	4,815,890	49,482,119	42,709,876	1,166,242	24,752,258	171,882,972
	2020	15,381,956	17,891,774	16,400,335	4,831,359	50,526,825	43,241,832	1,182,358	25,183,511	174,639,951
	2021	15,545,938	18,242,640	16,614,197	4,846,878	51,593,588	43,780,414	1,198,696	25,622,278	177,444,629
	2022	15,711,669	18,600,385	16,830,848	4,862,446	52,682,873	44,325,703	1,215,261	26,068,690	180,297,875
	2023	15,879,166	18,965,147	17,050,324	4,878,064	53,795,156	44,877,784	1,232,054	26,522,879	183,200,574
	2024	16,048,448	19,337,061	17,272,661	4,893,733	54,930,922	45,436,742	1,249,080	26,984,981	186,153,630
	2025	16,219,536	19,716,269	17,497,899	4,909,452	56,090,668	46,002,661	1,266,341	27,455,135	189,157,960

Consumption – Recessionary and Efficiency Impacts*										
		Average Growth Rate per EDC								
		1.07%	1.96%	1.30%	0.32%	2.11%	1.25%	1.38%	1.74%	
		Duquesne	MetEd	Penelec	PennPower	PECO	PPL	UGI	West Penn	Total MWh
Consumption (MWh) by Compliance Year	2007	14,138,380	14,337,188	14,286,471	4,736,809	40,411,755	38,889,219	1,016,001	21,225,591	149,041,414
	2008	13,860,634	14,240,733	14,379,251	4,695,840	40,014,695	39,090,157	1,002,824	21,043,842	148,327,976
	2009	13,167,602	13,528,696	13,660,288	4,461,048	38,013,960	37,135,649	952,683	19,991,650	140,911,577
	2010	13,272,943	13,636,926	13,769,571	4,496,736	38,318,072	37,432,734	960,304	20,151,583	142,038,870
	2011	13,379,127	13,746,021	13,879,727	4,532,710	38,624,617	37,732,196	967,987	20,312,796	143,175,181
	2012	13,486,160	13,855,989	13,990,765	4,568,972	38,933,613	38,034,054	975,731	20,475,298	144,320,582
	2013	13,594,049	13,966,837	14,102,691	4,605,524	39,245,082	38,338,326	983,536	20,639,101	145,475,147
	2014	13,702,801	14,078,572	14,215,513	4,642,368	39,559,043	38,645,033	991,405	20,804,213	146,638,948
	2015	13,812,424	14,191,201	14,329,237	4,679,507	39,875,515	38,954,193	999,336	20,970,647	147,812,060
	2016	13,922,923	14,304,730	14,443,871	4,716,943	40,194,519	39,265,827	1,007,331	21,138,412	148,994,556
	2017	14,034,307	14,419,168	14,559,422	4,754,678	40,516,076	39,579,953	1,015,389	21,307,519	150,186,513
	2018	14,146,581	14,534,521	14,675,897	4,792,716	40,840,204	39,896,593	1,023,512	21,477,980	151,388,005
	2019	14,259,754	14,650,798	14,793,304	4,831,058	41,166,926	40,215,766	1,031,701	21,649,803	152,599,109
	2020	14,373,832	14,768,004	14,911,651	4,869,706	41,496,261	40,537,492	1,039,954	21,823,002	153,819,902
	2021	14,488,822	14,886,148	15,030,944	4,908,664	41,828,231	40,861,792	1,048,274	21,997,586	155,050,461
	2022	14,604,733	15,005,237	15,151,192	4,947,933	42,162,857	41,188,686	1,056,660	22,173,567	156,290,864
	2023	14,721,571	15,125,279	15,272,401	4,987,517	42,500,160	41,518,195	1,065,113	22,350,955	157,541,191
	2024	14,839,343	15,246,281	15,394,580	5,027,417	42,840,161	41,850,341	1,073,634	22,529,763	158,801,521
	2025	14,958,058	15,368,252	15,517,737	5,067,636	43,182,883	42,185,144	1,082,223	22,710,001	160,071,933

*The two tables above compare what was projected during the analysis considered by the CCAC but data from PJM and the Energy Information Administration indicate that electricity consumption in 2008 was down 2.7% below 2007, electricity consumption during the first six months of 2009 was down 5% below 2008 and that EIA projects only a 0.8 annual growth out to 2020 due in large part to increased energy efficiency standards for new appliances.

System Losses - Business as Usual (BAU) Scenario										
		Average System Loss Rate per EDC								
		5.77%	7.87%	8.87%	6.49%	6.65%	7.18%	5.65%	6.53%	
		Duquesne	MetEd	Penelec	PennPower	PECO	PPL	UGI	West Penn	Total MWh
System Losses (MWh) by Compliance Year	2007	803,683	1,110,810	1,263,229	304,805	2,637,920	2,744,325	57,075	1,394,798	10,316,645
	2008	812,251	1,132,593	1,279,702	305,784	2,693,614	2,778,506	57,863	1,419,100	10,479,412
	2009	820,910	1,154,804	1,296,390	306,766	2,750,484	2,813,112	58,663	1,443,824	10,644,952
	2010	829,662	1,177,450	1,313,295	307,751	2,808,554	2,848,150	59,474	1,468,980	10,813,315
	2011	838,507	1,200,540	1,330,420	308,740	2,867,850	2,883,624	60,296	1,494,573	10,984,550
	2012	847,446	1,224,083	1,347,769	309,731	2,928,399	2,919,540	61,129	1,520,613	11,158,709
	2013	856,480	1,248,088	1,365,344	310,726	2,990,226	2,955,903	61,973	1,547,106	11,335,846
	2014	865,611	1,272,564	1,383,148	311,724	3,053,358	2,992,719	62,830	1,574,061	11,516,014
	2015	874,839	1,297,519	1,401,184	312,726	3,117,822	3,029,993	63,698	1,601,486	11,699,268
	2016	884,165	1,322,964	1,419,456	313,730	3,183,648	3,067,732	64,578	1,629,388	11,885,662
	2017	893,591	1,348,908	1,437,966	314,738	3,250,864	3,105,941	65,471	1,657,777	12,075,255
	2018	903,117	1,375,360	1,456,717	315,749	3,319,499	3,144,626	66,375	1,686,660	12,268,104
	2019	912,745	1,402,332	1,475,713	316,763	3,389,583	3,183,793	67,293	1,716,046	12,464,267
	2020	922,475	1,429,832	1,494,956	317,780	3,461,147	3,223,447	68,223	1,745,944	12,663,805
	2021	932,310	1,457,872	1,514,451	318,801	3,534,221	3,263,595	69,165	1,776,364	12,866,779
	2022	942,249	1,486,461	1,534,199	319,825	3,608,838	3,304,244	70,121	1,807,313	13,073,250
	2023	952,294	1,515,611	1,554,205	320,852	3,685,031	3,345,399	71,090	1,838,801	13,283,284
	2024	962,446	1,545,333	1,574,472	321,883	3,762,832	3,387,066	72,073	1,870,838	13,496,943
	2025	972,706	1,575,638	1,595,004	322,917	3,842,276	3,429,252	73,068	1,903,433	13,714,295

CO2 Emissions Associated with System Losses Reduced by 1%				
		Total MWh	CO2 Tons	MMTCO2
System Losses (MWh) by Compliance Year	2007	9,284,980	5,937,745	5.39
	2008	9,431,471	6,031,426	5.47
	2009	9,580,457	6,126,702	5.56
	2010	9,731,983	6,223,603	5.64
	2011	9,886,095	6,322,158	5.73
	2012	10,042,838	6,422,395	5.83
	2013	10,202,262	6,524,346	5.92
	2014	10,364,413	6,628,042	6.01
	2015	10,529,341	6,733,513	6.11
	2016	10,697,096	6,840,793	6.20
	2017	10,867,730	6,949,913	6.30
	2018	11,041,293	7,060,907	6.40
	2019	11,217,840	7,173,809	6.51
	2020	11,397,424	7,288,653	6.61
	2021	11,580,101	7,405,474	6.72
	2022	11,765,925	7,524,309	6.82
	2023	11,954,955	7,645,194	6.93
	2024	12,147,249	7,768,166	7.05
	2025	12,342,865	7,893,262	7.16

CO2 Emissions Associated with System Losses BAU				
		Total MWh	CO2 Tons	MMTCO2
System Losses (MWh) by Compliance Year	2007	10,316,645	6,597,494	5.98
	2008	10,479,412	6,701,584	6.08
	2009	10,644,952	6,807,447	6.17
	2010	10,813,315	6,915,115	6.27
	2011	10,984,550	7,024,619	6.37
	2012	11,158,709	7,135,995	6.47
	2013	11,335,846	7,249,274	6.58
	2014	11,516,014	7,364,491	6.68
	2015	11,699,268	7,481,682	6.79
	2016	11,885,662	7,600,881	6.89
	2017	12,075,255	7,722,126	7.00
	2018	12,268,104	7,845,452	7.12
	2019	12,464,267	7,970,899	7.23
	2020	12,663,805	8,098,503	7.35
	2021	12,866,779	8,228,305	7.46
	2022	13,073,250	8,360,344	7.58
	2023	13,283,284	8,494,660	7.70
	2024	13,496,943	8,631,295	7.83
	2025	13,714,295	8,770,292	7.95

CO2 Reduction BAU vs. 1% Reduction in System Losses				
		MMTCO2		
		BAU	1% Red.	Delta
Consumption (MWh) by Compliance Year	2007	5.98	5.39	0.60
	2008	6.08	5.47	0.61
	2009	6.17	5.56	0.62
	2010	6.27	5.64	0.63
	2011	6.37	5.73	0.64
	2012	6.47	5.83	0.65
	2013	6.58	5.92	0.66
	2014	6.68	6.01	0.67
	2015	6.79	6.11	0.68
	2016	6.89	6.20	0.69
	2017	7.00	6.30	0.70
	2018	7.12	6.40	0.71
	2019	7.23	6.51	0.72
	2020	7.35	6.61	0.73
	2021	7.46	6.72	0.75
	2022	7.58	6.82	0.76
	2023	7.70	6.93	0.77
	2024	7.83	7.05	0.78
	2025	7.95	7.16	0.80

Appendix E1: Incentives Work Plan

Summary: Amplify the future impacts of utility demand-side management programs by removing the financial disincentives to program success which are characteristic of traditional ratemaking practices, developing rate decoupling and related rate redesigns and/or positive performance incentives to spur higher levels of energy savings and GHG reductions.

Goals: To be determined

Possible Vehicles: This strategy builds upon the energy efficiency and conservation program of Act 129 / House Bill 2200 which mandates the introduction of utility demand-side management (DSM) programs. States which have the most successful energy efficiency programs, i.e., those which achieve superior rates of electric energy savings, tend on the whole to have adopted incentives for utilities.[20] An analysis of state-level data from across the nation indicates a pronounced relationship between the use of incentives and reductions in annual electricity sales. States which were the most aggressive, employing both performance incentives as well as rate decoupling, achieved savings rates 3.2-fold higher than the scale achieved in states with no DSM incentives (such as Pennsylvania). The following table illustrates this relationship.

Table 1
Relationship Between Reduced Statewide Electricity Sales
And Use of Utility DSM Incentives[21]

State Approach to Electric Efficiency Incentives	Average Incremental Savings in Electricity Use
No incentives	0.19%
Performance incentives only	0.34%
Rate decoupling only	0.34%
Both performance incentives and decoupling	0.60%

Traditional ratemaking impedes full utilization of energy efficiency opportunities by eroding utility revenues as these programs are implemented. The linkage between efficiency, energy sales and utility financial margins arises from rate designs which make utility profits dependent upon sales volume, and which fail to provide returns on efficiency investments comparable to those realized by investments in traditional capacity.

Mechanisms for addressing the financial impacts to utilities include performance target incentives, shared savings incentives, and rate-of-return adders, as well as rate decoupling to address both lost margin recovery and the throughput incentive. In-depth discussions of these issues and regulatory approaches can be found in the references cited at the end of this work plan.

[20] For simplicity's sake, the term 'incentives' is used here to refer to both rate decoupling and positive performance incentive mechanisms. It does not include basic program cost recovery which is already allowed under Act 129.
[21] The figures in this table were developed using the data on statewide electricity sales and electric utility incentives published in *The 2008 State Energy Efficiency Scorecard*, American Council for an Energy Efficient Economy, October 2008, pages 9-17.

The need to reformulate utility incentives and disincentives is gaining increasing scrutiny in states across the nation that are seeking more effective strategies for accelerating energy efficiency utilization. Each of the top performing states now use some form of incentives for DSM. This trend is on the rise. Today, more than half the states (29) use some form of financial incentives for DSM. As state investments in energy efficiency programs increase, the attention to appropriate price signals for DSM is likewise growing.

Assumptions: To be determined

Economic Cost: To be determined

Implementation Steps:

- Enabling legislation is needed
- The PUC will need to determine the specific form of incentives to be used

Potential Overlap:

- Reduced Load Growth

Other Involved Agencies: PUC, state legislature

SOURCES OF FURTHER INFORMATION

American Council for an Energy Efficient Economy, *the 2008 State Energy Efficiency Scorecard*, October 2008.

American Council for an Energy Efficient Economy, Aligning *Utility Interests with Energy Efficiency Objectives: A Review of Recent Efforts at Decoupling and Performance Incentives,* October 2006.

ICF International, *Utility Performance Standards, Oversight, and Cost Recovery,* Briefing for the Maryland Energy Administration, September 2007.

National Association of Regulatory Utility Commissioners, *Decoupling for Electric & Gas Utilities: Frequently Asked Questions*, September 2007.

Regulatory Assistance Project, *Energy Efficiency Policy Toolkit*, January 2007.

Regulatory Assistance Project, *Overview of Utility Incentives*, Presentation to the New Mexico Public Regulation Commission, July 2008.

Regulatory Assistance Project, *Revenue Decoupling Standards and Criteria*, Report to the Minnesota Public Utilities Commission, June 2008.

USEPA and USDOE, *Aligning Utility Incentives with Investment in Energy Efficiency, A Resource of the National Action Plan for Energy Efficiency*, November 2007.

Appendix E2: Overlap Analysis

Work Plan	Potentially Overlapping Work Plan	Overlap Adjustment To	Notes	Resolution
Electricity -3 Stabilized Load Growth	Electricity -2 Reduced Load growth.	Electricity -2	Electricity 2 and 3 are substitutes for each other.	Reductions from Electricity 2 are eliminated
Electricity -3 Stabilized Load Growth	Industry-2 Industrial Gas and Electricity	Electricity -3	Industry 2 targets 9% industrial efficiency by 2020 while Electricity-3 is only 7%. The issue for the interaction between these work plans is not overlaps, but assurance that in combination they do not exceed industrial electric efficiency supplies in PA. By 2020, the combined GWh of both work plans exceeds by approximately 350 GWh the linear implementation of the two 2025 industrial estimates in ACEEE et al (2009) of 9,900 and 13,000 GWh (pp. 14, 30).	2020 reductions of electric industrial energy efficiency are reduced by 350 GWh (10% of industrial electric efficiency reductions, 3% of total reductions under Electricity 3).
Electricity-8 RGGI	Electricity 3, Electricity-9 CHP, Electricity-6 Nuclear, Industry 2-Industrial gas and Electricity	Electricity-8 RGGI	RGGI analysis would only develop a statewide cost curve using other electricity work plans	Only "new" reductions from elements of the supply curve that are not part of an existing work plan will be included in this work plan.
Electricity -3 Stabilized Load Growth	RC-3, RC-4: High Performance Commercial and High Performance Homes (Residential) (private) Buildings	Electricity-4	2020 commercial efficiency reductions under RC-3 are estimated at 9,001 GWh versus only 3,300 for Electricity 3. 2020 residential reductions under RC-4 are estimated at 17,541 GWh versus only 3,400 for Electricity 3.	100% of residential and commercial reductions from Electricity 3 are eliminated due to overlaps
Electricity -3 Stabilized Load Growth	RC-5 Commissioning and Retrocommissioning	Electricity-3	Retrocommissioning accounts for 300 of 17,260 GWh commercial reductions in 2025 in ACEEE et al (2009) p. 143	All residential and commercial reductions in Electricity 3 were eliminated due to overlaps from RC-3 and RC-4.
Electricity -3 Stabilized Load Growth	RC-1, RC-2: High Performance State and Local Government Buildings, Schools	None	Typically there is very little overlap between utility/EDC programmatic activity with government green building programs	None required
Electricity -3 Stabilized Load Growth	RC-6 Re-Light Pennsylvania	Electricity-3	Lighting accounts for a significant portion of 2025 reductions in ACEEE et al (2009) p. 143	All residential and commercial reductions in Electricity 3 were eliminated due to overlaps from RC-3 and RC-4. Lighting reductions kept in RC-6.
Electricity -3 Stabilized Load Growth	RC-7 Re-Roof Pennsylvania	Electricity-3	Cool roofs accounts for 230 of 17,260 GWh commercial reductions in 2025 in ACEEE et al (2009) p. 143	All residential and commercial reductions in Electricity 3 were eliminated due to overlaps from RC-3 and RC-4. Cool roof reductions kept in RC-7.
RC-8 PA Buys EE Appliances	Electricity-3 Stabilized Load Growth	Electricity-3	Appliance standards account for 2,200 GWh of reductions in 2025 in ACEEE et al (2009) p. 46	All residential and commercial reductions in Electricity 3 were eliminated due to overlaps from RC-3 and RC-4. Appliance reductions kept in RC-8.

Appendix E3: Generation Cost Assumptions and Sources

SUPPLY SIDE ASSUMPTIONS

Fuel prices: U.S. EIA, AEO 2009 (April 2009 update related to federal stimulus), Table 12 - prices for coal and natural gas for electric generation in the Middle Atlantic region. http://www.eia.doe.gov/oiaf/aeo/supplement/stimulus/regionalarra.html.

- Nuclear fuel prices are based on NYSERDA fuel costs [placeholder].
- Biomass fuel costs assumed to be $5.78 /MMBTU.[22]
- Waste coal prices are based on a study for U.S. EPA (see waste coal assumptions below).
- Municipal solid waste fuel prices are placeholders.
- LFG fuel costs are assumed to be $1/MMBTU for gas collection and treatment.

Equipment life: We assume a 30-year life for all technologies except nuclear which has an estimated 50 year life.

Cost of capital: 10 percent weighted average cost of capital with a 50 percent debt and 50 percent equity proportion. Cost of debt is 8 percent and cost of equity is 12 percent for all technologies.

Assumed tax credit over life of technology: Available federal tax credits are assumed to apply to relevant generation units over the life of the plant, though the federal production tax credit applies to different renewable fuels over different periods of generation. We assume 2007-level tax credits. For biomass technologies, we assume the federal tax credit for open-loop biomass. For PV, which receives a federal investment tax credit in lieu of production tax credit eligibility, and the federal government currently permits interchanging the PTC with the ITC, we assume a levelized level of tax support similar to that for wind, which was 2 cents/kWh in 2007. DSIRE database (www.dsireusa.org) for federal tax incentives. For small hydro, we apply the federal production tax credit for small hydropower facilities (irrigation and hydro installation at dams previously without power generation). Federal nuclear tax credit is assumed to be $18 in 2009 and discounted at the estimated inflation rate of 2 percent per year.

[22] US EIA. (2001). Biomass for Electricity Generation. Adjusted to $2007. http://www.eia.doe.gov/oiaf/analysispaper/biomass/pdf/biomass.pdf

Table 1: Summary of 2020 Costs

Generation Modeling Assumptions	2020					
	Fuel Cost $/MMBTU (Waste coal in $/MWh)	Capital Cost $/kW	Capacity Factor	Tax Credits	Integration Cost	Generation Cost $/MWh
Coal (new supercritical)	$2.02	$2,427	85%	-	-	$61.57
Coal (existing pulverized)	$2.02	$801	56%	-	-	$46.71
Waste Coal	$8.92	$2,460	85%	-	-	$50.10
IGCC	$2.02	$3,280	85%	-	-	$72.37
IGCC with carbon capture	$2.02	$4,662	85%	-	-	$98.12
CCGT	$7.27	$1,158	85%	-	-	$70.77
Combustion NG (peaker)	$7.27	$657	50%	-	-	$84.85
Combustion NG (existing peaker)	$7.27	$217	50%	-	-	$71.14
Nuclear	$1.03	$7,310	90%	-$13.72	-	$109.21
Biomass Co-Firing	$5.78	$461	85%	-$10.00	-	$51.44
Biomass Gasification	$5.78	$2,104	85%	-$20.00	-	$83.11
PV	-	$4,218	13%	-$20.00	-	$383.24
Hydro repower	-	$1,603	50%	-	-	$45.43
Small hydro	-	$2,098	30%	-$10.00	-	$34.79
Wind	-	$1,412	27%	-$20.00	$4.50	$59.40
Landfill gas	$1.00	$1,300	80%	-$10.00	-	$35.74
Municipal Solid Waste	$2.14	$5,950	85%	-$10.00	-	$144.15
CCS Retrofit Pulv Coal	$1.98	$2,141	85%	-	-	$84.94
Avoided Cost of Generation $/MWh (90% existing coal, 10% existing gas peakers)						**$49.15**

Pulverized Coal (Existing)

- Capital cost of $800 Kw means that existing coal fleet is assumed to be nearly fully depreciated (versus $2,400 kw for new coal). Fixed costs include unallocated depreciation, boiler modifications, emissions equipment, or newer coal plants in the PA coal fleet. O&M costs include compliance with New Source Review standards.
- Heat rate: 10,307 for all years. This is the generation weighted average for PA's coal fleet for 2005. Source: eGrid 2007
- O&M cost: Both fixed and variable based on Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008)..
- Transmission cost: ICF Electric Modeling Assumptions for NYSERDA, p. 83.
- Capacity factor: From Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).Heat rate: Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).

Pulverized Coal (New Supercritical)

- Capital and O&M costs include compliance with New Source Review standards
- Capital cost: Overnight total plant cost based on Congressional Research Service's *Power Plants: Characteristics and Costs* , p. 97 (November 2008). The CRS study includes data from numerous planned plants as well as U.S. EIA data on operations and future cost trends.
- O&M cost: Both fixed and variable based on Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008)..
- Transmission cost: ICF Electric Modeling Assumptions for NYSERDA, p. 83.
- Capacity factor: From Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).Heat rate: Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).

IGCC--Coal

- Capital cost: Total plant cost and interest during construction data from Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).
- The analysis assumes no IGCC plants until 2015.
- O&M cost: Both fixed and variable based on Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).
- Transmission cost: ICF Electric Modeling Assumptions for NYSERDA, p. 83.
- Capacity factor: From Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).
- Heat rate: ICF Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).

IGCC with Carbon Capture—

- Capital cost: Total plant cost and interest during construction data from Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008). The study draws upon work from MIT's 2007 *Future of Coal* study.
- The analysis assumes no IGCC with carbon capture plants until 2020. O&M cost: Both fixed and variable based on Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).Transmission cost: ICF Electric Modeling Assumptions for NYSERDA, p. 83.
- Capacity factor: From Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).Heat rate: ICF Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).

Natural Gas – Combined Cycle

- Capital cost: Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).O&M cost: Both fixed and variable based on Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).
- Transmission cost: ICF Electric Modeling Assumptions for NYSERDA, p. 83.
- Capacity factor: Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008).Heat rate: ICF Electric Modeling Assumptions for NYSERDA, p. 82. ICF's values are for 2010, 2015, 2020 and 2025, with straight-line extrapolation applied in this analysis for interim years Congressional Research Service's *Power Plants: Characteristics and Costs*, p. 97 (November 2008)..

Natural Gas – Combustion (Peaker)

Capital cost: Energy and Environmental Economics Inc. GHG Modeling for the California Public Utility Commission, New Natural Gas Combustion Turbine Generation, Resource, Cost, and Performance Assumptions, version 3 (October 2007), p. 3. O&M cost: Both fixed and variable based on Energy and Environmental Economics Inc. GHG Modeling for the California Public Utility Commission, New Natural Gas Combustion Turbine Generation, Resource, Cost, and Performance Assumptions, version 3 (October 2007), p. 3.

- Transmission cost: ICF Electric Modeling Assumptions for NYSERDA, p. 83.
- Capacity factor: Assumption
- Heat rate: Energy and Environmental Economics Inc. GHG Modeling for the California Public Utility Commission, New Natural Gas Combustion Turbine Generation, Resource, Cost, and Performance Assumptions, version 3 (October 2007), p. 3.

Natural Gas – Combustion (Existing Peaker)

- Capital cost of $217 kw means that existing gas fleet is assumed to be nearly fully depreciated (versus $650 kw for new peaking gas). Fixed costs include unallocated depreciation, boiler modifications, emissions equipment, or newer gas plants in the PA coal fleet. O&M costs include compliance with New Source Review standards.
- Heat rate: 8,131 is average for all NG plants in PA for 2005. Source: eGrid 2007

- Transmission cost: ICF Electric Modeling Assumptions for NYSERDA, p. 83.
- Capacity factor: Same capacity factor for new peaker.

New Nuclear Plant

- Capi**tal cost**: Based on Center for Climate Strategies ESD Policy Options Document (September 23, 2008) for the Florida Governor's Action Team on Energy and Climate Change, Energy Supply and Demand Technical Work Group, p. A-32.[23] We assume new nuclear does not come on-line until 2020 per ICF Electric Modeling Assumptions for NYSERDA, p. 82.
- Transmission cost: Lower range of potential interconnection costs from ICF Electric Modeling Assumptions for NYSERDA, p. 83.
- O&M cost: Both fixed and variable based on Based on ESD Policy Options Document (September 23, 2008) for the Florida Governor's Action Team on Energy and Climate Change, Energy Supply and Demand Technical Work Group, p. A-32.
- Capacity factor: Based on Based on ESD Policy Options Document (September 23, 2008) for the Florida Governor's Action Team on Energy and Climate Change, Energy Supply and Demand Technical Work Group, p. A-32.
- Heat rate: ICF Electric Modeling Assumptions for NYSERDA, p. 82.
- Tax credit: Federal tax credit of $18 ($2009) is applied to new advanced nuclear plants applies to the first eight years of plant operation. Because the tax credit is not adjusted for inflation by the US government, its real value is assumed to decline by 2 percent year starting in 2009.

Nuclear Uprate

- Capital cost: Based on FPL Energy’s proposed uprate of its Turkey Point and St. Lucie pressurized water reactor units to be completed in 2011. http://www.fpl.com/environment/nuclear/power_uprate_faq.shtml

  Such reactors exist at the Beaver Valley and Three Mile Island plants in Pennsylvania.
- Transmission cost: Default value of $25/kW.
- O&M cost: Assumes same variable O&M cost as new nuclear plant capacity in this analysis, but no fixed O&M due to addition to existing capacity and low overall O&M cost of uprates.
- Capacity factor: Based on Based on ESD Policy Options Document (September 23, 2008) for the Florida Governor's Action Team on Energy and Climate Change, Energy Supply and Demand Technical Work Group, p. A-32.
- Heat rate: ICF Electric Modeling Assumptions for NYSERDA, p. 82.

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[23] http://www.flclimatechange.us/ee.cfm

Biomass Co-Firing

- Capital cost: Based on Black and Veatch Economic Impact of Renewable Energy in Pennsylvania (2004), p. D-15, for 2-10 percent co-firing in pulverized coal plant. Costs vary by boiler type and biomass percentage of total generation in a unit.
- Transmission: No additional transmission investment is assumed.
- Fixed O&M Cost: Based on Black and Veatch Economic Impact of Renewable Energy in Pennsylvania (2004), p. D-15, for 2-10 percent co-firing in pulverized coal plant.
- Variable O&M Cost: Based on Based on Black and Veatch Economic Impact of Renewable Energy in Pennsylvania (2004), p. A-9, for 2-10 percent co-firing in pulverized coal plant. The $0 value falls between other estimates, including negative costs (PS technology mitigation template summary for NYSERDA) and positive costs (ICF).
- Fuel cost: Assumption of $2/mmBtu.
- Capacity factor: Based on pulverized coal capacity factor in this analysis (85 percent).
- Heat rate: Assumption based on heat rate for supercritical pulverized coal plant discussed above.

Biomass Gasification

- Capital cost: Total plant cost and interest during construction data from ICF Electric Modeling Assumptions for NYSERDA, p. 91. ICF assumes no biomass gasification plants until 2015, and estimates $1,920 in 2015, $1,860 in 2020 and $1,759 in 2025. 2026-2030 costs based on average annual change in cost between 2020-2025.
- O&M cost: Both fixed and variable based on ICF Electric Modeling Assumptions for NYSERDA, p. 91. ICF's values are for 2015, 2020 and 2025, with straight-line extrapolation applied in this analysis for interim years.
- Transmission cost: Assumes same as for a CCGT per ICF Electric Modeling Assumptions for NYSERDA.
- Fuel cost: Assumption of $2/mmBtu.
- Capacity factor: Assumption of 85 percent.
- Heat rate: ICF Electric Modeling Assumptions for NYSERDA, p. 91.

PV (crystalline)

- Capital cost: ICF Electric Modeling Assumptions for NYSERDA, p. 91. ICF estimates $4,289 in 2010, $4009 in 2015, $3,729 in 2020 and $3,391 in 2025. Interim values are based on straight-line reduction within each 5-year period. 2026-2030 values based on average cost reduction between 2021 and 2025 (1.9 percent/year).
- Transmission: Assumes distributed solar. Central-station PV will entail more cost.
- O&M: ICF Electric Modeling Assumptions for NYSERDA, p. 91.

- Capacity factor: Based on PV Watts Version 1, using the ACEEE study of PV potential in PA (December 2008) for locations (Pittsburgh = 20 percent of all capacity, Philadelphia = 32 percent, rest = 48 percent). PV Watts estimates a 12.5 percent capacity factor for Pittsburgh, 13.8 percent capacity factor for Philadelphia, and we use Williamsport capacity factor of 12.6 percent for rest of state, with weighted average.

Hydro Repower

- The assumptions below are based on new conventional hydropower. However, the values fall within the range of the high variation in values for "incremental hydro" found in Black and Veatch's Economic Impact of Renewable Energy in Pennsylvania (2004).
- Capital cost: Based on U.S. EIA's Annual Energy Outlook 2007, Table 39 for new conventional hydropower. 2005 dollars. Capital costs were within the range of hydro upgrades considered in Avista (Washington, Montana) 2007 IRP ($1,478 to $2,168) so we retain it here, recognized the high uncertainty of such costs (as expressed by Avista in its IRP).
- Transmission cost: Default assumption of $25/kW similar to the majority of other technologies analyzed
- O&M cost: U.S. EIA AEO 2007 for new conventional hydropower.
- Capacity factor: Assumption, p. 115, for new conventional hydropower.

Small Hydro

- Capital cost: Based on 2009 capital costs in ESD Policy Options Document (September 23, 2008) for the Florida Governor's Action Team on Energy and Climate Change, Energy Supply and Demand Technical Work Group, p. A-7.
- Transmission cost: Default assumption of $25/kW similar to the majority of other technologies analyzed.
- O&M cost: Based on ESD Policy Options Document (September 23, 2008) for the Florida Governor's Action Team on Energy and Climate Change, Energy Supply and Demand Technical Work Group, p. A-7.
- Capacity factor: ESD Policy Options Document (September 23, 2008) for the Florida Governor's Action Team on Energy and Climate Change, Energy Supply and Demand Technical Work Group, p. A-8.

Wind

- Wind capital cost: ICF Electric Modeling Assumption for NYSERDA, p. 91. Assumes 1 percent reduction in costs starting in 2010 per ICF study (p. 92)
- Wind O&M cost: ICF Electric Modeling Assumption for NYSERDA, p. 91.
- Wind transmission cost: ICF Electric Modeling Assumption for NYSERDA, p. 95. Assumes "Step 1" transmission which presumes easiest combination of terrain and distance, and which represent 64 percent (32,411 MW) of modeled resources in PJM by ICF.

- Wind capacity factor: Based on averaging of all Class 3-5 wind resources for PJM in ICF study (p.97) for all levels of transmission difficulty.
- Integration costs: Based on the Midwest Integration Cost Study in 2006 which found a 25 percent penetration of wind in Minnesota (MISO) leads to $4.5/MWh in total integration costs. Cost is applied to all units of wind in this study, which is conservative for lower penetrations of wind compared to total generation. See http://www.awea.org/newsroom/releases/Groundbreaking_Minnesota_Wind_Integration_Study_121306.html.

Combined Heat-And-Power Assumptions
See CHP Work Plan

Waste Coal

- We assume that waste coal is consumed by advanced fluidized bed coal plants, which can handle low-grade fuels more effectively compared to pulverized coal.
- Capital cost: Based on advanced fluidized bed coal-fired plant from EPRI *Program on Technology Innovation: Integrated Technology Options* (November 2008), p. 4-5. ICF relies in Black and Veatch's *Economic Impact of Renewable Energy in Pennsylvania* for its data.
- Transmission cost: Default assumption of $25/kW.
- Fixed and Variable O&M: Based on ICF's *Technical Support Document: Waste Coal-Fired Units in the CAIR and CAIR FIP*, p. 8. Originally in 1999 dollars.
- Capacity factor: on ICF's *Technical Support Document: Waste Coal-Fired Units in the CAIR and CAIR FIP*, p. 9.
- Fuel costs: Based on *Technical Support Document: Waste Coal-Fired Units in the CAIR and CAIR FIP.* The study uses U.S. EIA waste coal price forecast data and assumes heat content of 8,000 Btu/pound, combined with the heat rate assumption used in this analysis (10,200 Btu/MWh)
- Heat rate: ICF *Technical Support Document: Waste Coal-Fired Units in the CAIR and CAIR FIP*.

Landfill Gas

- Capital cost: Based on U.S. EPA's Landfill Methane Outreach Program's *LFGE Project Development Handbook*, p. 4-5, capital cost for internal combustion engines above 800 kW.
- Transmission cost: Default assumption of $25/kW similar to the majority of other technologies analyzed.
- O&M cost: Based on U.S. EPA's Landfill Methane Outreach Program's *LFGE Project Development Handbook*, p. 4-5, O&M costs for internal combustion engines above 800 kW.
- Capacity factor: Black and Veatch's *Economic Impact of Renewable Energy in Pennsylvania*, p. D-18.

Municipal Solid Waste

- Capital cost: Based on Black & Veatch's *Renewable Energy Technology Assessments* for Kau'I Island Utility Cooperative, p.7-8. Assumes a combined biomass and trash facility with separate fuel streams, boilers and steam cycles for each feedstock.
- Transmission cost: Default assumption of $25/kW similar to the majority of other technologies analyzed.
- O&M cost: Black & Veatch's *Renewable Energy Technology Assessments* for Kau'I Island Utility Cooperative, p.7-8.
- Capacity factor: Assumption of 85 percent.

Fuel cost: Black & Veatch's *Renewable Energy Technology Assessments* for Kau'I Island Utility Cooperative, p.7-8. Fuel costs are highly dependent on trash tipping fees, which are not incorporated in this fuel cost assumption.

Five Percent Efficiency Upgrades For Existing Coal-Fired Plants

Cost and efficiency improvements: Based on cost estimates on an avoided CO2 emissions basis in the Australian Greenhouse Office (January 2000) Report, *Integrating Consultancy Efficiency Standards for Power Generation*. The study's efficiency improvement estimates for several measures (excluding reduction of turbine gland leakage and low excess air operation) was corroborated in NETL's *Reducing* CO_2 *Emissions By Improving the Efficiency of the Existing Coal-Fired Power Plant Fleet* (July 2008).

APPENDIX F
Residential and Commercial Sector Work Plans

Summary of Work Plan Recommendations

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
		GHG Reduc-tions ($MMtCO_2e$)	Costs (Million $)	Cost-Effective ness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effective ness ($\$/tCO_2e$)	
1-4	High-Performance Buildings (Total for RC-1 Through RC-4)	31.9	-$256.3	-$8.0	139.7	-$1,653	-$11.8	21 / 0 / 0
1	High-Performance State and Local Government Buildings	2.7			11.3			
2	High-Performance School Buildings	1.9			7.8			
3	High-Performance Commercial (Private) Buildings	9.0			37.4			
4	High-Performance Homes (Residential)	18.3			83.1			
5	Commissioning and Retrocommissioning PA Buildings	1.5	-$17	-$11.2	9.6	-$71	-$7.4	21 / 0 / 0
6	Re-Light Pennsylvania	12.9	-$823	-$64	103.2	-$4,020	-$39	20 / 0 / 1
	Residential	3.5	-$328	-$95	30.0	-$1,887	-$63	
	Commercial—lighting power density	5.3	-$367	-$69	30.7	-$806	-$26	
	Commercial—fixture performance	4.0	-$136	-$34	33.9	-$1,039	-$31	
	Commercial—daylighting	0.8	-$64	-$82	5.0	-$204	-$41	
	Commercial—controls	2.1	$108	$52	14.3	$511	$36	
	Commercial—parking lot lighting	1.1	-$117	-$103	10.5	-$613	-$58	
	Commercial—exit signs	0.0	-$1	-$64	0.1	-$6	-$44	
7	Re-Roof Pennsylvania	1.4	$472	$327	4.3	$1,064	$247	14 / 7 / 0
	Light-colored, insulated roofs	0.2	-$4	-$18	0.8	$13	$17	
	Green roofs	0.1	$77	$614	0.3	$147	$462	
	PV roof	1.1	$399	$359	3.2	$903	$282	
8	PA buys EE appliances	1.9	-$68	-$36	12.4	-$291	-$24	13 / 8 / 0
9	Geothermal Heating and Cooling	1.4	$224	$158	8.0	$879	$109	21 / 0 / 0
10	DSM - Natural Gas	7.3	-$51	-$7	40.5	-$357	-$9	21 / 0 / 0
11	Conservation and Fuel switching for Heating Oil	5.7	-$21	-$4	35.8	$140	$4	21 / 0 / 0
13	DSM - Water	0.1	-$255	-$1,944	0.8	-$1,011	-$1,285	21 / 0 / 0
14	Renew PA buildings PA Values Embodied Energy in Building Materials, Including Historic Structures	Not quantified						17 / 1 / 2
15	Sustainability Education Programs	Not quantified						17 / 1 / 2
16	Adaptive Building Reuse	Not quantified						17 / 1 / 2
Sector Total After Adjusting for Overlaps		32.25	-$538	-$17	214.5	-$3,668	-$17	
Reductions From Recent Federal		5.07	-$145	-$28	29.9	-$567	-$19.0	

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/tCO_2e$)	
Federal Appliance Standards - Electricity		4.77			28.7			
Federal Appliance Standards - Natural Gas		0.3			1.2			
Sector Total Plus Recent Actions		37.4	-$683	-$18	244.4	-$4,235	-$17	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

RC-1 – RC-4. High-Performance Buildings

Buildings are a major source of demand for energy and materials that produce by-product greenhouse gases. It will require immediate and significant action in the building sector to slow the growth rate of greenhouse gas emissions in Pennsylvania.

Recently, Architecture 2030 has issued **The 2030 Challenge** asking the global architecture and building community to adopt the following targets:

- All new buildings, developments and major renovations shall be designed to meet a fossil fuel, greenhouse gas (GHG)-emitting, energy consumption performance standard of 50 percent of the regional (or country) average for that building type.
- At a minimum, an equal amount of existing building area shall be renovated annually to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 50 percent of the regional (or country) average for that building type.
- Architecture 2030 established the following fossil fuel reduction standard for all new buildings and major renovations:

  60 percent of buildings in 2010
  70 percent of buildings in 2015
  80 percent of buildings in 2020
  90 percent of buildings in 2025
  100 percent* of buildings in 2030
  *(using no fossil fuel greenhouse gas emitting energy to operate).

Architecture 2030 envisioned that these targets would be accomplished by implementing innovative sustainable design strategies, generating on-site renewable power and/or purchasing (20 percent maximum) renewable energy and/or certified renewable energy credits.

The main goals for this work plan generally come from the Architecture 2030 Challenge building goals, with some revisions from subcommittee. These goals are summarized in the following tables. Following the tables are proposed vehicles to meeting these goals.

The GHG emission reductions for Pennsylvania through 2020 were estimated assuming that these goals are met. The key assumptions and results of that analysis are shown below.

The quantification analysis helps provide an overall indication of potential GHG emission reductions. However, to better understand the changes to Pennsylvania's building sector equipment and practices, analysis on individual work plans is also needed. The other work plans for quantification will help indicate the ability for the state to meet the goals listed here, and will also provide estimates of the costs for meeting these goals.

The CCAC endorses these goals and recommends RC-1 for new and existing commonwealth buildings and RC-2 for new schools as mandatory. The Committee recommends evaluating the viability of remaining goals by identifying funding sources to address implementation costs. CCAC further recommends a subcommittee be convened by DEP to provide this evaluation.

Goals:

New Buildings Goals and standards

		2015	2020	2030
New Commercial (commonwealth owned or operated) RC-1	Overall goal (relative to 2005 building)	60% fossil fuel and electricity reduction	80% fossil fuel and electricity reduction	100% fossil fuel and electricity reduction
	Performance standard	LEED Silver ENERGY STAR 85	LEED Silver ENERGY STAR 85	Not specified
	Fraction of buildings that meet standard	100% of new buildings	100% of new buildings	100% of new buildings
	Deployment of renewable energy	Not specified	Not specified	Not specified
New Commercial (Schools) RC-2	Overall goal (relative to 2005 building)	50% fossil fuel and electricity reduction	70% fossil fuel and electricity reduction	80% fossil fuel and electricity reduction
	Performance standard	LEED Silver ENERGY STAR 85	LEED Silver ENERGY STAR 85	Not specified
	Fraction of buildings that meet standard	100% of new buildings	100% of new buildings	100% of new buildings
	Deployment of renewable energy	Not specified	Not specified	Not specified
New Commercial (private)	Overall goal (relative to 2005 building)	50% fossil fuel and electricity reduction	70% fossil fuel and electricity reduction	80% fossil fuel and electricity reduction

		2015	2020	2030
RC-3	Performance standard	LEED Silver ENERGY STAR 75	LEED Silver ENERGY STAR 85	Not specified
	Fraction of buildings that meet standard	100% of new buildings	100% of new buildings	100% of new buildings
	Deployment of renewable energy	Not specified	Not specified	Not specified
New Residential RC-4	Overall goal (relative to 2005 building)	50% fossil fuel and electricity reduction	70% fossil fuel and electricity reduction	80% fossil fuel and electricity reduction
	Performance standard	HERS 50	HERS 40	HERS 30
	Fraction of buildings that meet standard	100% of new buildings	100% of new buildings	100% of new buildings
	Deployment of renewable energy	Not specified	Not specified	Not specified

Existing Buildings Goals and standards

		2015	2020	2030
Existing Commercial (commonwealth owned or operated) RC-1	Overall goal (relative to 2005 building)	40% fossil fuel and electricity reduction	50% fossil fuel and electricity reduction	70% fossil fuel and electricity reduction
	Performance standard	ENERGY STAR 75	LEED EB Silver ENERGY STAR 80	LEED EB Silver ENERGY STAR 85
	Fraction of buildings that meet standard	20% of existing buildings	50% of existing buildings	100% of existing buildings
	Deployment of renewable energy	Not specified	Not specified	Not specified
Existing Commercial (Schools) RC-2	Overall goal (relative to 2005 building)	30% fossil fuel and electricity reduction	50% fossil fuel and electricity reduction	70% fossil fuel and electricity reduction
	Performance standard	ENERGY STAR 75	LEED EB Silver ENERGY STAR 80	LEED EB Silver ENERGY STAR 85
	Fraction of buildings that meet standard	20% of existing buildings	50% of existing buildings	100% of existing buildings
	Deployment of renewable energy	Not specified	Not specified	Not specified
Existing	Overall goal	30% fossil fuel	40% fossil fuel	50% fossil fuel

		2015	2020	2030
Commercial (private) RC-3	(relative to 2005 building)	and electricity reduction	and electricity reduction	and electricity reduction
	Performance standard	ENERGY STAR 75	LEED EB Silver ENERGY STAR 80	LEED EB Silver ENERGY STAR 85
	Fraction of buildings that meet standard	20% of existing buildings	50% of existing buildings	100% of existing buildings
	Deployment of renewable energy	Not specified	Not specified	Not specified
Existing Residential RC-4	Overall goal (relative to 2005 building)	60% fossil fuel and electricity reduction	80% fossil fuel and electricity reduction	100% fossil fuel and electricity reduction
	Performance standard	HERS 50	HERS 40	HERS 40
	Fraction of buildings that meet standard	20% of existing buildings	50% of existing buildings	100% of existing buildings
	Deployment of renewable energy	Not specified	Not specified	Not specified

Notes: Energy reductions refer to on-site energy consumption.

Possible Vehicles to Support Work Plan Goals

RC-1: High-Performance State and Local Government Buildings

In addition to work plans RC-5 through RC-13, which are technology and action-based work plans that will contribute to meeting the High-Performance Building goals, the following vehicles are presented for consideration:

- “High-Performance PA Buildings”—All Commonwealth of Pennsylvania-owned or -funded construction projects must meet a performance level equivalent to a minimum of LEED Silver plus an Energy Star rating of 85.

- The Department of General Services (DGS) is building a benchmarking database and will be utilizing existing contract capacity with the Penn State Facilities Engineering Institute to begin the auditing/benchmarking process for commonwealth-owned facilities. Other implementation steps could include:

    - Revise facility manager job descriptions and train staff to incorporate benchmarking into their standard operating procedures.
    - Revise Guaranteed Energy Savings Act (GESA)/energy service company (ESCO) language to incorporate Energy Star performance-based requirements.
    - Mandate all FY 2009–2010 and future GESA/ SCO projects adopt the Energy Star performance-based requirements.

- Continue working with EPA to streamline the work process and minimize the costs associated with implementing Energy Star performance requirements into building operational procedures.
- Ask the (PUC) to develop and mandate that all PA utilities conform to a uniform billing structure and format to allow automated billing data entry into the Energy Star Portfolio Manager database.
- Hire and train in-house staff to run program, or educate existing qualified ESCOs on new requirements.

* "Green Strings"—All commonwealth funding programs, whether grants, loans, tax credits, tax incentives, etc., will have at least a minimal expectation of energy/resource conservation results.

  - The intent of this initiative is to educate involved parties, inform the commonwealth, and potentially reduce the GHG impacts of building projects. If projects with similar costs and benefits are proposed, the project with the lowest GHG impact will be given preference.
  - Commonwealth agencies to include in their decision-making processes appropriate and careful consideration of GHG emission effects from proposed actions, and their alternatives. This will be done to understand, minimize, and/or avoid potential adverse effects from GHG emissions from the proposed actions, as much as possible. commonwealth agencies will integrate the GHG emission impacts as early in their planning processes as possible.
  - Commonwealth agencies to require analysis of GHG impacts in all award and approval (permits, grants, procurements, etc) decisions. Entities submitting applications for consideration will be required to include a comprehensive analysis of the GHG impacts of the proposed project. The commonwealth agencies are only requiring an analysis be performed.

* Require U.S. Environmental Protection Agency (EPA) Energy Star Portfolio Manager benchmarking for all commonwealth-owned and -leased facilities by 2009.

* Establish a goal of minimum Energy Star rating of 75 for all commonwealth buildings by 2020.

* Implement the equivalent of LEED for Existing Buildings (LEED-EB), Green Globes, or other certification for ongoing operation and maintenance (O&M) and Energy Star ratings for all commonwealth buildings. Meet at least the equivalent of LEED-EB Silver certification and an Energy Star score of 75 for all existing buildings by 2020.

* Establish a Pennsylvania Community and Local Government Climate Change Collaborative Clearinghouse to overcome barriers to progress on climate change actions. The project would do the following:

  - Assist communities to develop comprehensive plans that include buildings, transportation, agriculture, land-use planning, and commercial and industrial operations.
  - Provide grants and incentives for communities to conduct inventories and develop plans to monitor their progress.

- Compile data and offer awards to communities that exceed their goals or demonstrate other significant progress.

RC-2: High-Performance School Buildings

In addition to work plans RC-5 through RC-13, which are technology and action-based work plans that will contribute to meeting the High-Performance Building goals, the following vehicles are presented for consideration:

- Require EPA Energy Star Portfolio Manager benchmarking for all commonwealth-owned and -leased educational facilities by 2010.
- Establish a goal of minimum Energy Star rating of 75 for all public school buildings by 2020.
- Continue implementation of *Illuminating Education* program—Current Governor's Green Government Council/Office of Energy and Technology Development (GGGC/OETD) program to distribute compact fluorescent lamps (CFLs) to middle school students in PA as part of an overall energy curriculum program.
- Continue efforts of *Pennsylvania State System of Higher Education (PASSHE*) *Energy Consumption Reduction*—Continue emphasis on existing efforts to reduce energy consumption at Pennsylvania state universities through full implementation and seek new energy saving initiatives to meet or exceed the 1.5 percent annual energy use intensity (EUI) reduction goal. The following are some of the tools available to achieve this goal (Projected GHG reduction from PASSCHE EUI goal as estimated by the Department of Environmental Protection are included; these projected reductions are not included in the quantitative analysis):

    - Guaranteed Energy Saving Program (GESA) (0.04 million metric tons of carbon dioxide equivalent (MMtCO_2e))
    - Energy manager staffing (0.005 MMtCO_2e)
    - Aggressive building operating system control (0.005 MMtCO_2e)
    - Behavioral changes (0.02 MMtCO_2e)
    - LEED and Energy Star efforts (0.01 MMtCO_2e)
    - Total Reduction: 0.08 MMtCO_2e

- Increase utilization of campus energy managers.

    - About half of the PASSHE universities have established positions for energy managers. These positions are typically funded out of energy consumption and unit cost savings achieved through the work of the energy manager.
    - Energy managers utilize the building control systems to aggressively manage the heating, ventilation, and air conditioning systems (and sometimes lighting) to minimize energy consumption while maintaining an environment conducive to the university’s mission.
    - Energy managers are also instrumental in managing and successfully implementing university GESA projects.

- Implement a *Green Campus Initiative* for all Pennsylvania colleges, universities, private schools, and secondary schools to minimize environmental impacts and create "learning labs" for sustainability.

    - Develop and support an effective process to promote energy and sustainability concepts.
    - Provide leadership and resources to schools for a comprehensive approach to lower energy use and energy costs, reduce GHG emissions from buildings and transportation, improve water and wastewater management, increase recycling, reduce disposal of hazardous waste, and promote procurement of environmentally friendly products.
    - Use a team-based approach that engages administrative staff, students, faculty and technical experts.

RC-3: High-Performance Commercial Buildings (Private) Buildings

In addition to work plans RC-5 through RC-13, which are technology and action-based work plans that will contribute to meeting the High-Performance Building goals, the following vehicles are presented for consideration:

- Incorporate green building requirements in the statewide building code (Uniform Construction Code [UCC]).

    - This could be a phased-in approach that begins in the first years with Energy Star standards, and expands to cover high-performance standards for energy, water, stormwater, materials, etc. The ultimate goal will be zero-carbon buildings[1] throughout the commonwealth – a goal that is aligned with the 2030 Challenge.
    - UCC improvements will need to include a much higher level of administration and enforcement than what currently exists. Statewide emphasis on training must occur.

- *High-Performance Tax Credits*—Tax credits for private-sector construction projects that meet a performance level equivalent to a minimum of LEED Silver plus an Energy Star rating of 85.
- Require energy information to be included in a "seller's disclosure" for commercial real estate transfers. Alternatively, require an Energy Star portfolio manager energy use index. The "seller's disclosure" consists of a property disclosure statement; the seller is currently not obligated by the statute to make any specific investigation. A third-party-verified energy audit should be an additional document and not part of "seller's disclosure."
- Implement an *Airport Efficiency Initiative* - Under this initiative, the Governor of Pennsylvania would issue an Executive Order requesting all Federal Aviation Regulation (FAR) Part 139 airports to improve their energy efficiency by 10 percent. The individual airports (which include all facilities leased or owned by the airport) will be given flexibility to achieve the efficiency goal. This will allow each facility to find the most cost-effective options to meet the target. Under the Executive Order, applicable airports would be

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[1] A zero-carbon house is a building where net carbon dioxide emissions resulting from all energy used in the dwelling are zero or better. This includes the energy consumed in the operation of the space heating/cooling and hot-water systems, ventilation, all internal lighting, cooking and all electrical appliances.

encouraged to coordinate with Pennsylvania Department of Transportation's (PennDOT's) Air Services Committee to develop plans to achieve the energy efficiency goal. An example of a similar initiative includes Washington State Governor Gary Locke's 10 percent energy efficiency goal for airports. The Seattle Tacoma International Airport (SEA-TAC) achieved this goal by installing 60 motor controllers on escalators, replacing inefficient lighting with energy-efficient fixtures, and retrofitting older heating and cooling systems with more efficient equipment.

RC-4: High-Performance Homes (Residential)

In addition to work plans RC-5 through RC-13, which are technology and action-based work plans that will contribute to meeting the High-Performance Building goals, the following vehicles are presented for consideration:

- Incorporate green building requirements in the statewide building code (UCC).
  - Require all new residential construction in Pennsylvania to achieve a minimum of LEED certification.
  - This could be a phased-in approach that begins in the first years with Energy Star standards, and expands to cover high-performance standards for energy, water, stormwater, materials, etc. The ultimate goal will be zero-carbon residential buildings[2] throughout the commonwealth.
  - UCC improvements will need to include a much higher level of administration and enforcement than what currently exists. Statewide emphasis on training must occur.
- Provide tax credits for private-sector construction projects that meet a performance level equivalent to a minimum of LEED Silver plus an Energy Star rating of 85. Several current legislative proposals based on this objective are being considered (See HB 46, SB 673.)
- *Energy Audits at Real Estate Transfer*—Energy audit required as part of "seller's disclosure" information in a residential sales transaction.
- *Keystone Home Performance*—Retooling of the Keystone HELP program to offer a greater degree of assistance (much lower loan rates) to homeowners implementing energy-saving measures based on a whole-house energy audit. (See also the Pennsylvania Housing Finance Agency's (PHFA's) Keystone Renovate and Repair program and Maine Home Performance Program)
- *LEED for Homes*—Require that all new homes have an Energy Star rating (15 percent more energy efficient than code-compliant construction). Increase the efficiency requirement every 5 years until all new homes are carbon-neutral.
- Implement a *Pennsylvania Home Climate Champion Collaborative* to provide vision, clarity, and access to human and physical resources so that 100,000 homes will achieve substantial

[2] A zero-carbon house is a building where net carbon dioxide emissions resulting from all energy used in the dwelling are zero or better. This includes the energy consumed in the operation of the space heating/cooling and hot-water systems, ventilation, all internal lighting, cooking and all electrical appliances.

(greater than 60 percent) energy reductions, while maintaining or improving indoor air quality, resilience to storms and power outages, adaptability, comfort, and affordability between now and 2025. Five percent of these demonstration projects should achieve the German PassivHaus energy independence goals of 90 percent energy reduction, with 10 percent met by renewable energy.

- Require energy information to be included in a "seller's disclosure" for residential real estate transfers.
- Require building performance labels that reflect actual utility use.
- Develop energy improvement mortgages or energy-efficient mortgages and promote these products in PA.
- Offer the commonwealth residential sector an incentive for implementing whole-house performance, provide consumer and contractor education, create jobs, spur marketplace development, and significantly improve PA's existing housing stock while reducing energy consumption and associated GHG emissions. Propose blending all existing programs and efforts, applying for federal loan guarantees and special project funding, and seeking partnerships with utilities and others (manufacturers, contractors, nonprofit organizations, etc.).

Supporting Steps to Meet Targeted Goals:

- Support the integrity of UCC as it gets negotiated in the General Assembly.
- Develop an accreditation system for energy auditors.
    - Companies with the appropriate expertise should conduct energy audits. While the requirements for determining expertise exist as guidelines for reputable companies, third-party-verified requirements are ill defined and span a broad spectrum of energy efficiency.
- Educate the mortgage industry on the benefits of recognizing a standardized home rating system and adjust the current mortgage profile to include value realized as a result of increased energy efficiency.
    - Energy audits coupled with energy mortgages could increase the number of families qualified for mortgages. Energy mortgages credit a home's efficiency rating into the loan by proportionately increasing the value of the home. To have a Pennsylvania policy of requiring lenders to provide energy mortgages, it is necessary to adopt a standardized home rating system, like the one adopted by the Residential Energy Services Network (RESNET). Home energy ratings provide a standard measurement of a home's energy efficiency. Ratings can be used for both new and existing homes. An effective rating system will include all information necessary for a lender to judge the worthiness of a home to meet the criteria for an energy mortgage. The program is already established through the mortgage industry and the National Association of State Energy Officials; however, it is not that widespread, with only 19 accredited providers in Pennsylvania.
    - Basing a mortgage on the home efficiency rating allows the buyer to borrow more on the basis that the monthly utility bills will be proportionally less. In cases where the home is

in need of energy-efficient upgrades, an Energy Improvement Mortgage could help finance the upgrades in an existing home by allowing the owner to use a portion of the mortgage payment to pay for the cost of the upgrades.

- Revise GESA/ESCO language to incorporate the equivalent of LEED-EB and Energy Star performance-based requirements. (Could move this to RC-1)
- Require all FY 2009–2010 and future GESA/ESCO projects to adopt the equivalent of LEED-EB and Energy Star performance-based requirements. (Could move this to RC-1)
- Continue working with the U.S. Green Building Council (USGBC) and EPA to streamline work processes and minimize the costs associated with implementing LEED and Energy Star principles and performance requirements into building operational procedures.
- Modify the DGS Architect/Engineer Request for Proposal (RFP)/contract to require a higher standard of competency for design professionals performing state-funded design work.
- Secure an agreement with a developer of rating systems (e.g., USGBC) for acceptance of portfolio standards for the state, reducing costs to register, certify, and commission the projects.
- Require all FY 2009 and future GESA/ESCO projects to adopt the Energy Star performance-based requirements. (Could move this to RC-1)
    - Continue working with EPA to streamline work processes and minimize the costs associated with implementing Energy Star performance requirements into building operational procedures.
    - Ask the PUC to develop and mandate that all PA utilities conform to a uniform billing structure and format to allow automated billing data entry into the Energy Star Portfolio Manager database (based upon California Assembly Bill 1103).
    - Advocate and increase participation in the Build Green Schools initiative and the Green Schools Pledge.

Existing Measures:

- No LEED or high-performance requirements exist in PA. Energy Policy Act (EPAct) 2005 tax credits for certain Energy Star measures do exist.

- The Keystone HELP Program offers reduced-interest unsecured loans for Pennsylvania residents to purchase energy-efficient equipment, such as HVAC, windows, hot water heaters, etc.

- *PHFA*—Keystone Renovate & Repair Loan Program can be used to pay for repairs and improvements that increase the basic livability of the home, including additions and construction, that makes the home safer, more energy efficient, or more accessible to people with disabilities or people who are elderly.

- *EPA and DOE*—The model Home Performance with ENERGY STAR program uses a comprehensive, whole-house approach to improving energy efficiency and comfort at home, while helping to protect the environment.

- *PUC*—As part of the AEPS, PA utilities are required to explore energy efficiency measures prior to applying for capacity increases.

- *DCED*—The department currently runs PA's Weatherization Assistance Program (WAP), and has contractors, auditors, and program administration in place.
- *PA Home Energy*—A nonprofit organization-sponsored residential energy audit and performance evaluation program serving WPP utility customers.
- *ECA (unnamed program)*—This start-up program is similar to PA Home Energy, serving the Philadelphia and Pittsburgh metro areas.
- *Alternative Energy Investment Act*— This Act provides $92.5 million for residential and commercial energy efficiency activities and other initiatives. A portion of this money will be integrated into the Keystone HELP Program and the PHFA.

Key Assumptions:

RC-1 High Performance State and Local Buildings

Other Data, Assumptions, Calculations	2012	2020/all	Units
Total Commercial Floorspace in Pennsylvania (million square feet)	**857**	**928**	
Estimated (see "PA_BLDG_Activities" worksheet in this workbook) based on USDOE EIA CBECS (comercial survey) data for the Mid-Atlantic region, extrapolated using DEP approach.			
Annual demolition of commercial floorspace		**0.58%**	
Taken from analysis by DEP, see PA_Bldg_activities sheet in this workbook. Based on analysis by AIA research corporation for Architecture 2030, national values.			
Est. area of new commercial space per year in PA (million square fee	**13.7**	**14.4**	
Calculated based on annual floorspace estimates above. Note high growth in 2006 and 2007 based on article from American Institute of Architects (see PA_Bldg_Activities page).			
Implied Average Electricity Consumption per Square Foot Commercial Space in Pennsylvania as of 2005		10.60	kWh/yr
Implied Average Natural Gas Consumption per Square Foot Commercial Space in Pennsylvania as of 2005		34.57	kBtu/yr
Estimate based on Reference case forecast, using average intensity of all commercial buildings in PA - REVIEW OF ASSUMPTION NEEDED			
Implied Average Petroleum Consumption per Square Foot Commercial Space in Pennsylvania as of 2005		11.03	kBtu/yr
Estimate based on Reference case forecast, using average intensity of all commercial buildings in PA - REVIEW OF ASSUMPTION NEEDED			

CALCULATION OF SAVINGS

	2012	2020/all	Units
New construction floorspace covered by program, annual	**7**	**14**	million sq ft
Existing building floorspace covered by program, annual	**27**	**44**	million sq ft
Energy consumption, Reference case			
Energy consumption in new commercial buildings			
Electricity	611	664	billion BTU
Natural gas	320	328	billion BTU
Total	931	991	billion BTU
Estimate based on Reference case forecast			
Energy consumption in new commercial buildings, per sq foot			
Electricity	45	46	thousand BTU
Natural gas	23	23	thousand BTU
Total	68	69	thousand BTU
Estimate based on Reference case forecast, using average intensity of all commercial buildings in PA - REVIEW OF ASSUMPTION NEEDED			

RC-2 High Performance Schools

Other Data, Assumptions, Calculations	2012	2020/all	Units
Total School Building Floorspace in Pennsylvania (million square feet)	**720**	**780**	
Estimated (see "PA_BLDG_Activities" worksheet in this workbook) based on USDOE EIA CBECS (comercial survey) data for the Mid-Atlantic region, extrapolated using DEP approach.			
Annual demolition of commercial floorspace		**0.58%**	
Taken from analysis by DEP, see PA_Bldg_activities sheet in this workbook. Based on analysis by AIA research corporation for Architecture 2030, national values.			
Est. area of new school building space per year in PA (million square	**11.5**	**12.1**	
Calculated based on annual floorspace estimates above. Note high growth in 2006 and 2007 based on article from American Institute of Architects (see PA_Bldg_Activities page).			
Implied Average Electricity Consumption per Square Foot school building Space in Pennsylvania as of 2005		10.60	kWh/yr
Implied Average Natural Gas Consumption per Square Foot school building Space in Pennsylvania as of 2005		34.57	kBtu/yr
Estimate based on Reference case forecast, using average intensity of all commercial buildings in PA - REVIEW OF ASSUMPTION NEEDED			
Implied Average Petroleum Consumption per Square Foot Commercial Space in Pennsylvania as of 2005		11.03	kBtu/yr
Estimate based on Reference case forecast, using average intensity of all commercial buildings in PA - REVIEW OF ASSUMPTION NEEDED			

CALCULATION OF SAVINGS

	2012	2020/all	Units
New construction floorspace covered by program, annual	**6**	**12**	million sq ft
Existing building floorspace covered by program, annual	**23**	**37**	million sq ft
Energy consumption, Reference case			
Energy consumption in new school building buildings			
Electricity	514	558	billion BTU
Natural gas	269	275	billion BTU
Total	783	834	billion BTU
Estimate based on Reference case forecast			
Energy consumption in new school building buildings, per sq foot			
Electricity	45	46	thousand BTU
Natural gas	23	23	thousand BTU
Total	68	69	thousand BTU
Estimate based on Reference case forecast, using average intensity of all commercial buildings in PA - REVIEW OF ASSUMPTION NEEDED			

RC-3 High Performance Commercial Buildings (private)

Other Data, Assumptions, Calculations	2012	2020/all	Units
Total Commercial (Private) Floorspace in Pennsylvania (million square feet) *Estimated (see "PA_BLDG_Activities" worksheet in this workbook) based on USDOE EIA CBECS (comercial survey) data for the Mid-Atlantic region, extrapolated using DEP approach.*	**3,597**	**3,895**	
Annual demolition of commercial floorspace *Taken from analysis by DEP, see PA_Bldg_activities sheet in this workbook. Based on analysis by AIA research corporation for Architecture 2030, national values.*		**0.58%**	
Est. area of new commercial (private) space per year in PA (million square feet) *Calculated based on annual floorspace estimates above. Note high growth in 2006 and 2007 based on article from American Institute of Architects (see PA_Bldg_Activities page).*	**57.5**	**60.3**	
Total Residential Housing Units in Pennsylvania *Assumes 2007 number of homes to increase following population through 2020. Based on 2007 PA housing units as provided in U.S Census Bureau annual data, http://www.census.gov/popest/housing/HU-EST2005.html.*	**5,513,044**	**5,570,337**	
Implied persons per housing units in Pennsylvania (for reference only)	**2.26**	**2.26**	
Annual demolition of residential floorspace *Based on average lifespan of home of 70 years, placeholder estimate*		**1.43%**	
Estimated number of new residential units per year *Calculated based on estimates above.*	**85,901**	**85,701**	
Implied Average Electricity Consumption per Square Foot Commercial Space in Pennsylvania as of 2005 (see Note 2)		10.60	kWh/yr
Implied Average Natural Gas Consumption per Square Foot Commercial Space in Pennsylvania as of 2005 (see Note 2)		34.57	kBtu/yr
Implied Average Petroleum Consumption per Square Foot Commercial Space in Pennsylvania as of 2005		11.03	kBtu/yr

	2012	2020/all	Units
New construction floorspace covered by program, annual	**29**	**60**	million sq ft
Existing building floorspace covered by program, annual	**113**	**185**	million sq ft
Energy consumption, Reference case			
Energy consumption in new commercial buildings			
Electricity	3,690	4,008	billion BTU
Natural gas	1,932	1,979	billion BTU
Total	5,622	5,987	billion BTU
Estimate based on Reference case forecast			
Energy consumption in new commercial buildings, per sq foot			
Electricity	45	46	thousand B
Natural gas	23	23	thousand B
Total	68	69	thousand B
Estimate based on Reference case forecast			
Energy consumption in existing commercial buildings, per sq foot		**2005**	
Electricity		36.17	thousand B
Natural gas		34.57	thousand B
Petroleum		11.03	thousand B
Total		82	
Estimate based on Reference case forecast			

RC-4. High-Performance Homes

Other Data, Assumptions, Calculations	2012	2020/all	Units
Total Residential Housing Units in Pennsylvania *Assumes 2007 number of homes to increase following population through 2020. Based on 2007 PA housing units as provided in U.S Census Bureau annual data, http://www.census.gov/popest/housing/HU-EST2005.html.*	**5,513,044**	**5,570,337**	
Implied persons per housing units in Pennsylvania (for reference only)	**2.26**	**2.26**	
Annual demolition of residential floorspace *Based on average lifespan of home of 70 years, placeholder estimate*		**1.43%**	
Estimated number of new residential units per year *Calculated based on estimates above.*	**85,901**	**85,701**	
Implied Average Electricity Consumption per Housing Unit in Pennsylvania as of 2005 (see Note 2)		**9.90**	MWh/yr
Implied Average Natural Gas Consumption per Housing Unit in Pennsylvania as of 2005 (see Note 2)		**46.56**	MMBtu/yr
Implied Average Petroleum Consumption per Housing Unit in Pennsylvania as of 2005 (see Note 2)		**27.88**	MMBtu/yr

CALCULATION OF SAVINGS

	2012	2020/all	Units
New construction housig units covered by program, annual	**42,951**	**85,701**	housing ur
Existing building housing units covered by program, annual	**169,954**	**242,325**	housing ur
Energy consumption, Reference case			
Energy consumption in new residential buildings			
Electricity	5,060	4,783	billion BTU
Natural gas	2,776	2,677	billion BTU
Total	7,836	7,460	billion BTU
Estimate based on Reference case forecast			
Energy consumption in new residential buildings, per housing unit			
Electricity	58.9	55.8	MMBTU/h
Natural gas	32.3	31.2	MMBTU/h
Total	91.2	87.0	MMBTU/h
Estimate based on Reference case forecast			

Energy consumption in existing residential buildings, per housing unit	2005	
Electricity	33.77	MMBTU/h
Natural gas	46.56	MMBTU/h
Petroleum	27.88	MMBTU/h
Total	108	
Estimate based on Reference case forecast		

GHG Reductions:

Table 4-1. Estimated GHG Reductions and Cost-effectiveness

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reduc-tions ($MMtCO_2e$)	Costs (Million $)	Cost-Effective ness ($/t$CO_2e$)	GHG Reduction s ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectivene ss ($/t$CO_2e$)
	High-Performance Buildings						
RC-1	High-Performance State and Local Government Buildings	2.7			11.3		
RC-2	High-Performance School Buildings	1.9			7.8		
RC-3	High-Performance Commercial (Private) Buildings	9.0			37.4		
RC-4	High Performance Homes (Residential)	18.3			83.1		
	Sub-total High Performance Buildings	31.9	-$275.7	-$8.7	139.7	-$1,170	-$8.4

Economic Costs:
See Table 4.1, above.

Potential Overlap:
Overlaps with RC-5 through RC-13.

Other Involved Agencies:

DGS, Labor & Industry, DCED, Department of State's State Real Estate Commission, Public Utility Commission, PA Housing and Finance Authority, Fannie Mae, PA Treasury, EPA and DOE, PDE, All Commonwealth Agencies.

Subcommittee Comments:
Setting high performance goals for new and existing buildings is the most cost effective GHG actions for the State of PA. The subcommittee recommends combining LEED Silver goals with Energy Star goals for non-residential buildings and LEED Silver goals with HERS goals for residential buildings to ensure the highest energy savings in both building systems and in land-use and transportation. The subcommittee further recommends the incorporation of EPA WaterSense goals for all buildings. These savings will be ongoing for with outstanding payback especially for public buildings and schools that intend to be in business for the next ten years as well as strengthening home equity for homeowners and yield substantial GHG savings.

While the market may realize the benefits of energy conservation on its own, this is a policy driven action. The technologies to achieve these goals are available now. The first 30-50 percent savings are easily doable and cost effective with a five year payback. The next 30 percent will be tough unless the market growth ensures manufacturing growth and cost savings, especially for renewables that would be key to the achieving the highest 80 percent reductions.

For non-residential buildings cost effective available technology can achieve the first five year goals. Changes in the market will be important to the next five years, but all signs are that these changes are occurring. The accuracy of cost and savings are somewhat accurate given the track record in LEED and Energy Star, but savings are also dependent on occupant behavior, and costs are often subject to the market and design expertise.

The real challenge in residential standards for new construction is the separation of investor from the benefit, while standards for existing homes will have investment and gain in the same hands. For both of these communities it will be imperative to have a change in financing to reflect mortgage plus energy, and to have clear labels of energy performance at point of sale. Cost effective available technology can achieve the first five year goals. Changes in the market will be important to the next five years, but all signs are that these changes are occurring. The accuracy of cost and savings are somewhat accurate given the track record of HERS, but savings are also dependent on occupant behavior, and costs are often subject to the market and design expertise.

Building renovations are labor intensive activities, with in state economic benefits. The reduction of energy loads and mechanical conditioning operation have definite environmental benefits as well as health benefits through the upgrading of systems that are long overdue for improvements.

The subcommittee puts performance goals as the highest priorities. The first three actions RC1-3 are prioritized based on ease of implementation, with state and local government buildings first, public schools second, and private commercial buildings third. However, both 1 and 2 will require the commitment of public funds, albeit with excellent payback, while 3 is a mandate for private investment. RC will not require the commitment of public funds except for residences of families below the poverty line, albeit with excellent payback.

RC-5. Commissioning and Retro-commissioning

Summary: Promote the common practice of performing commissioning and retro-commissioning processes on newly constructed, renovated, and existing buildings for the purpose of ensuring optimal performance of building systems.

Goals: Commission or retro-commission all non-commonwealth buildings greater than 25,000sq.ft. within 10 years and, commission or retro-commission all commonwealth buildings greater than 25,000 sq.ft. within 5 years.

Possible Vehicles: Promote the common practice of performing commissioning processes on newly constructed and/or renovated buildings for the purpose of ensuring optimal performance of building systems.
Building project teams are currently familiar with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) standards, which cite building commissioning as good practice (Guideline 0-2005).
Expand existing training for building operators to include energy management training. Building operators, such as maintenance technicians, lead custodians, and plant engineers, currently have little formal training in building efficiency.

Implementation Steps: This program may be implemented through stricter municipal/state building codes. Certain tax incentives and/or credits may also be assigned to assist in full implementation. Several mainstream certification standards also promote the practice of performing building commissioning, making the activity seem more attractive.

An example of such a program is the California Governor's Green Building Executive Order and AB 32, which calls for all California state buildings greater than 50,000 square Feet (sq.ft.) be retro-commissioned (RCx) by June 30, 2013, and re-commissioned every 5 years. Nearly 25 RCx buildings are at or near completion. The energy efficiency measures implemented through this program to date have a verified electricity savings of approximately 10 percent.

Key Assumptions:

Key Data and Assumptions	2012	2020	Units
First Year Results Accrue		2010	
Building size threshold		25,000	sq.ft.
Elegibility *% of all commercial buildings*		68.9%	
See Note 1 below			
Deadline			
Commonwealth buildings		2015	
Non-commonwealth buildings		2020	
Avoided Costs			
Avoided Electricity Cost		$84	$/MWh
See "Common Factors" worksheet in this workbook.			
Avoided Natural Gas Cost		$8.4	$/MMBtu
See "Common Factors" worksheet in this workbook.			
Avoided Electricity Emissions Rate	0.46	0.46	tCO_2e / MWh
See "Common Factors" worksheet in this workbook.			
Avoided Natural Gas Emissions Rate	0.05	0.05	tCO_2e / MMBtu
See "Common Factors" worksheet in this workbook.			

Other Data and Assumptions	2012	2020	Units
Eligible non-Commonwealth, commercial floorspace	3,566	3,862	million sq.ft.
Eligible Commonwealth floorspace	131	141	million sq.ft.
Electricity savings	*In 2025*	300	GWh
ACEEE (2009) Potential for Energy Efficiency, Demand Response and Onsite Solar in Pennsylvania - Table B-10		0.24	kWh / sq.ft.
Implied number of square feet recommissioned		1,250,000,000	sq.ft.
Commercial non-Commonwealth			
Number of years to full uptake		10	
Placeholder			
Annual rate of uptake	30%	100%	
Building area recommissioned	1,070	3,862	million sq.ft.
Electricity savings	256,762,489	926,945,655	kWh
Natural gas savings	*In 2025*	6,572,000	MMBtu
ACEEE (2009) Potential for Energy Efficiency, Demand Response and Onsite Solar in Pennsylvania - Table B-13		3.11	MBtu / sq.ft
Implied number of square feet recommissioned		2,113,183,280	sq.ft.
Number of years to full uptake		10	
Placeholder			
Annual rate of uptake	30%	100%	
Building area recommissioned	1,070	3,862	sq.ft.
Natural gas savings	3,327,214	12,011,671	MMBtu
Commonwealth			
Number of years to full uptake		5	
Placeholder			
Annual rate of uptake	60%	100%	
Building area recommissioned	78	141	sq.ft.
Electricity savings	18,801,161	33,937,307	kWh
Natural gas savings	*In 2025*	6,572,000	MMBtu
ACEEE (2009) Potential for Energy Efficiency, Demand Response and Onsite Solar in Pennsylvania - Table B-13		3.11	MBtu / sq.ft
Implied number of square feet recommissioned		2,113,183,280	sq.ft.
Number of years to full uptake		5	
Placeholder			
Annual rate of uptake	60%	100%	
Building area recommissioned	78	141	million sq.ft.
Natural gas savings	243,632	439,771	MMBtu
Levelized cost of recommissioning (electricity) *Calculated from ACEEE (2009) Table B-10*		$0.07	$ / kWh
Levelized cost of recommissioning (natural gas) *Calculated from ACEEE (2009) Table B-13*		$8.34	$ / MMBtu
Gross annual cost	$50	$173	$ million
Annual savings	$54	$190	$ million
Net annual cost	-$5	-$17	$ million

Potential GHG Reduction:

Table 5-1. Estimated GHG Reductions and Cost-effectiveness

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reduc-tions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/t$CO_2$e)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2$e)
RC-5	Commissioning and Retro-commissioning	1.5	-$17	-$11.2	9.6	-$71	-$7.4

Economic Cost: See Table 5-1, above.

Potential Overlap:
Overlaps with RC-1 through RC-4

Other Involved Agencies: ASHRAE; LEED Certification, Building Owners and Manufacturers Association, International Facility Management Association, EPA.

Subcommittee Comments:
Commissioning Existing and New Buildings should be state law, for both the health and comfort of building occupants and for the guaranteed energy savings. HVAC retro-commissioning efforts in existing buildings consistently reveal over 10 percent energy savings with 1-2 year paybacks, given the age and poor maintenance of systems due to consistent maintenance under-funding.

The technologies to achieve these goals are available now, however the commissioning workforce is not. This will be a significant job growth opportunity with excellent payback for both the public and private sector.

The real challenge for commissioning is the trained workforce, especially given the diversity of installed HVAC, lighting and electrical systems. The accuracy of cost and savings are accurate given the track record.

Building commissioning is labor intensive, with in-state job benefits. The reduction of energy loads and mechanical conditioning operation have definite environmental benefits as well as health benefits through the upgrading of systems that are long overdue for improvements.

This Action Plan may be considered redundant with High Performance Building Standards Action Plans, in which commissioning would very likely be undertaken to meet the annual goal increases. However, National energy reduction mandates have not often been met since the building community was unclear on critical steps to undertake in the near term. RC5 is a critical step in achieving timely building energy reductions.

RC-6. Re-Light Pennsylvania

Summary: This initiative is a critical building technology that accelerates replacement of less efficient outdoor and indoor lighting systems, including maximizing use of daylighting in indoor settings. It applies to residential and commercial buildings, as well as parks, streetlights, and parking facilities.

Actively invest in PA manufacturing, sales, green collar jobs, and green building infrastructure by relamping, re-fixturing, and upgrading lighting systems, windows, and control systems. This would also measurably improve the pastoral and remarkable qualities of the state, the quality of light delivered, and the health and safety of residents.

Goals: The following implementation steps could be considered:

Lighting Performance goals

- Lighting power density (LPD) 0.9 watt/sq.ft. connected load as maximum for all workplaces.
- New construction effective immediately; existing construction by 2020, with a linear percentage increase in performance each year.

Fixture Performance

- LOR (lighting output ratio, an index of fixture effectiveness) 70 percent minimum for all new construction, all building types, and all fixture replacements.

Lamp Performance (for all new lamp purchases, for all points of sale by 2015)

- 90 mean lumens/watt lamps.
- Mercury not to exceed 80 picograms per lumen-hour, 5 milligrams of mercury per lamp.
- CRI (color rendering index) of 85 minimum.
- 92 percent luminance maintenance (lamp depreciation) over rated life.

Controls and System Performance (new and existing construction by 2015)

- Individual lighting controls for 90 percent of occupants.
- Occupancy sensors in single-occupancy rooms or short time-of-use rooms.
- Commissioning of installed lighting system, including controls.

Daylight (all non-residential buildings)

- 25 foot candle (fc) of daylight to 90 percent of occupied spaces (new construction and historic buildings).
- Seated daylight access for 90 percent of occupants (new construction and historic buildings).
- Glazing with visible transmission over 50 percent, solar heat gain coefficient (SHGC) under 50 percent or 1.5 ratio of visible light divided by SHGC in summer (whenever replacements are made).
- Window blinds/shades to ensure daylighting and view without glare and overheating (all buildings 2015).

- Daylight-responsive controls for all fixtures within 15 feet of window (all buildings 2012).

Exit Lighting (all new construction, 2012 existing)

- Maximum 5 watts per fixture or "face."

Site Lighting (all new construction, 2012 existing)

- LPD 0.15 watt/sq.ft. max
- No night sky pollution (0 percent above 90° cutoff)
- Zone-occupancy controls in large parking lots.
- Light-emitting diode (LED) traffic lights.
- No LED billboard faces.

No- or Low-Cost Education Campaign

- Wash reflectors, lenses to maximize light output.
- Install occupancy and daylight sensors.
- Promote the Turn It Off campaign.
- Delamp where light levels are not needed.
- Raise or tilt the blinds and use daylight.

Key Assumptions:

Assumptions and Calculations	2012	2020	Units
Residential			
Number of housing units	5,513,044	5,570,337	
Single-family	4,222,992	4,266,878	
http://pasdc.hbg.psu.edu/pasdc/whats_new/2008factsfortheweb.pdf			
Multi-family	1,290,052	1,303,459	
Fraction of Residential Electricity Consumption as Lighting		8.8%	
National average based on Residential Energy Consumption Survey data from 2001 survey (http://www.eia.doe.gov/emeu/recs/recs2001/enduse2001/enduse2001.html).			
Residential electricity consumption as lighting	5,075	5,762	GWh
Power demand of existing lamps		60.0	W
Power demand of new lamps		15.0	W
Difference between old lamp and new lamp		45.0	W
Daily hours of operation		6.0	h
Rate of uptake of high-efficiency lamps	60%	100%	
Assumed			
Lifetime		5.0	yr

Existing power intensity of lighting		14.5	lm/W
Assume incadescent bulbs http://www.ccri.edu/physics/keefe/light.htm		0.069	W/lm
New power intensity of lighting		90.0	lm/W
From workplan goals		0.011	W/lm
Energy savings	2,234	4,002	GWh
Number of high-efficiency lamps in use	22,670,292	40,607,603	lamps
Number of lamps replaced annually	10,408,587	8,485,363	lamps
Cost premium		$3.44	one-time
Placeholder from www.homedepot.com		$0.79	$ / lamp / year
Gross annual cost	$36	$29	$ million

Commercial

Lighting Performance Goals

Existing lighting power density		2.0	W / sq.ft.
Based on conversation with Vivian Loftness			
Proposed lighting power density		0.9	W / sq.ft.
Proposed From workplan goals			
Rate of update in existing buildings	20%	100%	
Cost premium		$0.36	$/sq ft

US DOE Energy efficiency and renewable energy website, The Business Case for Sustainable Design in Federal Facilities http://www1.eere.energy.gov/femp/sustainable/sustainable_federalfacilities.html www1.eere.energy.gov/femp/pdfs/buscase_appendixb.pdf

Fixture Performance Goals

Existing power intensity of lighting		60.0	lm/W
Assume incadescent bulbs http://www.ccri.edu/physics/keefe/light.htm		0.017	W/lm
New power intensity of lighting		90.0	lm/W
From workplan goals		0.011	W/lm
Rate of uptake of high-efficiency lamps in existing buildings	60%	100%	
Assumed			
Cost premium (4-ft. 32 W T8)	*one-time*	$2.99	$ / lamp
From www.homedepot.com		$0.69	$ / lamp / year
Lifetime		5.0	yr
Difference between old lamp and new lamp		19	W
Daily hours of operation		10	h / d
Number of days in use annually		261	d / yr
Existing power per lamp	*Assumed*	44	W / lamp
Existing lighting power density	*Assumed*	1.1	W / sq.ft.
Estimate of lamps in PA	125,363,629	125,363,629	lamps
Number of lamps replaced annually	25,072,726	25,072,726	lamps

Daylighting

Reduction in lighting energy consumption		44%	
Attachment in email from Vivian Loftness - e-BIDS Guidelines for High Performance Buidlings 2005			
Percentage of existing buildings that are historic		0.5%	by floorspace
Placeholder, pending input from PA Bureau for Historic Preservation			
Applicable floorspace (new construction and historic)	77.0	76.4	million sq.ft. / yr
Cost premium - levelized		$0.22	$ / sq.ft.
Attachment in email from Vivian Loftness - e-BIDS Guidelines for High Performance Buidlings 2005			

Controls and System Performance

Reduction in lighting energy consumption		19%	
Attachment in email from Vivian Loftness - Architects of the Capital Interior Lighting			
Rate of uptake in existing buildings	20%	100%	
Cost premium for new construction		$0.25	$ / sq.ft.
e-BIDS Guidelines for High Performance Buildings 2005			
Estimate in document includes ballasts, lamps, etc. Assume 25% of cost is for controls.			
Life of measure (life of building)		50	yrs
Levelized incremental cost		$0.01	$ / sq.ft. / yr.
Cost of retrofit		$0.90	$ / sq.ft.
e-BIDS Guidelines for High Performance Buildings 2005			
Estimate in document includes ballasts, lamps, etc. Assume 25% of cost is for controls.			
Life of measure (remaining life of building)		25	yrs
Levelized cost of retrofit		$0.06	$ / sq.ft. / yr.

Site Lighting

Number of vehicles in Pennsylvania		9,598,142	9,697,888	vehicles
Bureau of Transportation Statistics http://www.bts.gov/publications/state_transportation_statistics/pennsylvania/html/table_05_01.html				
Ratio of parking spaces to vehicles			9	spaces / vehicle
Subcommittee input				
Area of parking lots			150	sq.ft. / space
Existing lighting intensity in parking lots	*See Note 3*		0.29	W / sq.ft.
Proposed lighting intensity in parking lots			0.15	W / sq.ft.
Annual hours in operation	*Assumed*		2,920	h / yr
Rate of participation		100%	100%	
Area of parking lot with efficient lighting		12,957	13,092	million sq.ft.
Area of parking lot with efficient lighting (new)		11,016	14	million sq.ft.
Energy savings		5,220	5,275	GWh / yr
Cost premium - levelized			$0.05	$ / sq.ft.
Email from Vivian Loftness				
Gross cost		$550.82	$0.72	$ million

Exit sign - 5 W / face

Annual savings per sign			114	kWh / sign / yr
http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/waensati/waensati_039.cfm				
Density of signs			0.00013	signs / sq.ft.
Attachment in email from Vivian Loftness - Architect of the Capital - Emergency Lighting and http://www.aoc.gov/cc/cobs/rhob.cfm				
Rate of uptake in existing buildings		100%	100%	
Number of signs		155,072	155,121	signs
Cost of unit retrofit	*Annualized*		$4	$ / sign / yr
http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/waensati/waensati_039.cfm				
Total cost of retrofit		$0.61	$0.61	$ million

GHG Reductions:

Table 6-1. Estimated GHG Reductions and Cost-effectiveness

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reduc-tions ($MMtCO_2e$)	Costs (Million $)	Cost-Effective ness ($/tCO_2e$)	GHG Reduction s ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectivene ss ($/tCO_2e$)
RC-6	Re-Light Pennsylvania	12.9	-$823	-$64	103.2	-$4,020	-$39

Economic Cost: See Table 6.1, above.

Potential Overlap: Overlaps with RC-1 through RC-4.

Subcommittee Recommendations

This Action Plan has 7 key assumptions and each action has outstanding GHG reduction potential and economic potential. Lighting energy is 10 percent of all national and state electricity use, and conservation often with improved lighting quality is technically straightforward and economically viable.

The technologies to achieve these goals are available now; however replacing lighting in commercial buildings often suggests ceiling replacement as well, and the effective use of daylight must be accomplished without glare or overheating.

The State of PA has a manufacturing community that will benefit from this action (fixtures, blinds, controllers, ceilings) and the potential for industrial growth; building engineering and unions will also benefit from this action plan. The payback is typically 3-5 years for the building owner, with immediate energy benefits to the State.

Existing lighting is often too bright for computer work, too dim in areas of safety, and old enough to still contain magnetic ballasts that buzz and contain PCBs, both health concerns. Relighting PA will measurably improve these conditions for productivity, safety and health benefits.

This Action Plan may be considered redundant with High Performance Building Standards Action Plans, in which lighting retrofits would very likely be undertaken to meet the annual goal increases. However, National energy reduction mandates have not often been met since the building community was unclear on critical steps to undertake in the near term. RC6 is a critical step in achieving timely building energy reductions.

RC-7. Re-Roof Pennsylvania

Summary: This initiative mandates standards of thermal resistance for all new roofing projects.

Goals: Replace 75 percent of commercial building roofs with more energy-efficient roofing at the time of regular replacement. (See Table 7.1 for roof types.)

Table 7.1. Portfolio of Roof Replacements for Commercial Buildings

Types of Roofs	2012	2020
Light colored, super insulated	90%	50%
Green roofs with super insulation	0%	20%
Solar PV roofs with super insulation	10%	30%

Possible Vehicles:

- High reflectivity should be mandatory for all commercial buildings to minimize cooling loads.
- Thermal resistance standards (R/U factors) should be raised to minimize both cooling and heating loads.
- Green roofs should be promoted with incentives for benefits to cooling, carbon sequestration, and stormwater management.
- Skylights for daylighting should be mandatory for roof replacements in buildings lower than four stories, with deep sections that result in windowless spaces for occupants.
- Shading or insulation from renewable energy systems as secondary goals should be explored.

Assumptions:

- Only commercial buildings.
- All public and private.
- 75 percent are less than 4 stories; roof is 25 percent of floor space.
- 20–25-year roof replacement on commercial buildings but many roofs in PA have not been replaced regularly recently to there is pent-up need for replacement; assume 5 percent roof replacement a year until 2030.
- Replace with light-colored (75 percent dark now, 15 percent cooling energy savings with light colored roofs, no cost delta).
- Replace with light-colored and super-insulated R40 (10 percent heating energy savings and 20 percent cooling energy savings).
- Introduce green roofs with super insulation.
- Equip solar photovoltaic (PV) roofs with super insulation (10 percent heating and cooling energy savings, distributed power generation PA GHG savings)

Incremental Cost of roof replacement (relative to regular roof replacement)		
Upgrade from R-11 to R-30 roof insulation	**$0.07**	$/sq ft roof
ACEEE (2009) Table B-10		
Light coloured, super insulated	**$0.96**	$/sq ft roof
e-BIDS Guidelines for High Performance Buildings 2005 cites $0.89/sq.ft. for light-coloured membrane; no reference to super insulation		
Green roofs with super insulation	**$10.07**	$/sq ft roof
Dirksen (email from Vivian Loftness) and ACEEE (2009)		
Solar PV roofs with super insulation	**$38**	$/sq ft roof
Implied from ACEEE (2009) p. 227		
Energy savings from roof replacement		
Light coloured, super insulated		
Heating	**10.00%**	
Placeholder - no basis		
Cooling	**11.30%**	
e-BIDS Guidelines for High Performance Buildings 2005; not PA-specific		
Green roofs with super insulation		
Heating	**10.00%**	
Placeholder - consistent with e-BIDS Guidelines for High Performance Buildings		
Cooling	**48.00%**	
e-BIDS Guidelines for High Performance Buildings 2005; not PA-specific		
Solar PV roofs with super insulation		
Heating	**10.00%**	
Placeholder - no basis		
Cooling	**11.30%**	
Assume same as light coloured		
Electricity capacity	**12.00**	W/sq.ft. roof
Email from solar design firm - reference Vivian Loftness		
Capacity factor	25%	
Assumed		
Electricity generation	**26.28**	kWh/sq.ft. roof
Email from solar design firm - reference Vivian Loftness		
Avoided Electricity Cost	**$89**	$/MWh
See "Common Factors" worksheet in this workbook.		
Avoided Natural Gas Cost	**$8.4**	$/MMBtu
See "NG prices aeo2006" and "Common Factors" worksheets in this workbook.		

Potential GHG Reduction:

Table 7-2. Estimated GHG Reductions and Cost-effectiveness

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reduc-tions ($MMtCO_2e$)	Costs (Million $)	Cost-Effective ness ($/tCO_2e$)	GHG Reduction s ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectivene ss ($/tCO_2e$)
RC-7	Re-Roof Pennsylvania	1.4	$633	$438	4.3	$1,412	$327
	Light-colored materials	0.2	-$4	-$18	0.8	$13	$17
	Green roofs	0.1	$77	$614	0.3	$147	$462
	PV roof	1.1	$399	$359	3.2	$903	$282

Economic Cost: See table above

Potential Overlap: Overlaps with RC-1 to RC-4

Subcommittee Recommendations

This action plan has three alternative considerations - light colored highly insulated roofs with excellent payback and very manageable costs; green roofs with high costs but measurable benefits in reducing heat island effect and offering carbon sequestration as well as major aesthetic advantages; and photovoltaic roofs with the highest cost but obvious benefits as a distributed energy source. All three should be considered, in addition to solar hot water systems, to advance the States competitiveness.

Buildings have a natural cycle for re-roofing in the order of 20-25 years, meaning that 4-5 percent of PA roofs are in the process of selecting new roof materials. This Action Plan has three alternative considerations - light colored highly insulated roofs with excellent payback and very manageable costs; green roofs with high costs but measurable benefits in reducing heat island effect and offering carbon sequestration as well as major aesthetic advantages; and photovoltaic roofs with the highest cost but obvious benefits as a distributed energy source. The differences in these three alternatives make the selection of a single score difficult.

Roofs have a natural cycle of replacement and hence are excellent opportunities for innovation that achieves GHG gains or new energy sources.

The opportunity to replace roofs with integral solar photovoltaic and solar domestic hot water systems is a growth area for both manufacturing and installers. PA should take a lead in this area. At a very minimum, well-insulated, highly reflective roofs (need not be light colored) should be mandated.

RC-8. PA buys Energy Efficient (EE) Appliances

Summary: This initiative promotes accelerated adoption of energy-efficient appliances that meet current and proposed federal standards. It also proposes that Pennsylvania adopt its own efficiency standards for products that are not sufficiently covered in the joint DOE and EPA ENERGY STAR specifications.

In developing this initiative, PA should consider the following criteria proposed by the American Council of Energy Efficiency Engineers (ACEEE)[3]:

- The standard would achieve significant energy savings.
- The standard would be cost-effective for the purchaser.
- Products that meet the standard are readily available.
- The state can implement the standard at low cost.
- Federal preemptions do not apply.

Another resource for identifying which appliance standards to adopt is the Appliance Standards Awareness Project, which summarizes what other states have developed: www.standardsasap.org/state/index.htm. Pennsylvania also should consider joining the Multistate Appliance Standards Collaborative: http://appliancestandards.org/.

Goals (Actions)

- Pennsylvania should support all federal efforts to develop and adopt high-efficiency and ENERGY STAR standards for appliances and to accelerate the rulemaking for additional products.
- Pennsylvania should adopt existing ENERGY STAR and federal appliance standards for all state-owned buildings, and projects receiving state funding.
- Through incentives and financing, the state should encourage local government and municipalities to adopt similar standards for their own buildings and for public housing in their jurisdiction by 2015 (possibly require this by 2020).
- Pennsylvania should monitor and encourage or require public utilities to include ENERGY STAR qualified appliances in their Act 129 implementation, and in all low-income programs they administer.
- The state should require that all appliances sold in the state meet the existing federal standards by 2015, or adopt federal requirements as they are promulgated, unless market forces achieve earlier adoption of efficient appliances.

Per ACEEE (2009),[4] Pennsylvania should set standards for the following appliances:

- furnace fans,
- fluorescent lighting fixtures,
- DVD players,

[3] ACEEE (2006) Leading the Way: Continued Opportunities for New State Appliance and Equipment Efficiency Standards www.aceee.org/pubs/a062.htm
[4] ACEEE (2009.04) Potential for Energy Efficient, Demand Response, and Onsite Solar Energy in Pennsylvania http://www.aceee.org/pubs/e093.htm

- compact audio equipment,
- portable electric spas,
- water dispensers,
- hot food holding cabinets,
- TVs, and
- portable lighting fixtures.

The Multi-State Collaborative has outlined the following products, which have similar state standards, primarily based on the California State Appliance Energy Efficiency Standards, Title 2. Pennsylvania should review and consider adopting its own standards for these products.

- commercial ice makers,
- compact audio players,
- distribution transformers,
- DVD players and recorders,
- hot food holding cabinets,
- metal halide lamp fixtures,
- pool heaters,
- portable electrics spas,
- refrigerators and freezers,
- unit heaters and duct furnaces, and
- water dispensers.

Information Sources:

- ACEEE (2009) is the primary information source for this quantification.
- Also check the data on the Multi-State Appliance Standards Collaborative.
- DOE Appliance Standards :www1.eere.energy.gov/buildings/appliance_standards/
- EPA ENERGY STAR for Appliances: www.energystar.gov/index.cfm?c=appliances.pr_appliances

Key Assumptions:

Other Data and Assumptions	2012	2020	Units
Average annual cost for state appliance efficiency standards *ACEEE (2009) Table 18*		$92.54	$ million
Number of years before full penetration		10	yr
Percent penetration by year	30%	100%	
Percent replacement	100%	10%	
Annual gross cost	$39	$129	$ million
Annual cost savings	$55	$184	$ million
Net cost of program	-$17	-$55	$ million
Energy savings			
Electricity	660	2,200	GWh / yr
Average annual electricity savings for state appliance efficiency standards *ACEEE (2009) Table 16*		1,581	GWh / yr

GHG Reductions:

Table 8-1. Estimated GHG Reductions and Cost-effectiveness

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/t$CO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2e$)
RC-8	Appliance Standards	1.9	-$68	-$36	12.4	-$291	-$24

Economic Cost: See above.

Possible Overlap:

RC-1 through RC-4 High Performance Building Standards.

Additional information:

One of the authors of the ACEEE report states the following regarding federal preemption, "Federal standards now cover about 45 products. Nearly all of these 45 products, including all major home appliances, also have and Energy Star spec. States are preempted from setting standards on these products. A waiver process exists, but the hurdle to gain waivers is very high, and the process is very drawn out. Plus, the Obama administration is working on updating most of the key standards."

Similarly, the author of the ACEEE report states the following with regards to ENERGY STAR: "Energy Star specs are not designed to be mandatory: Energy Star is a voluntary program meant to help consumers distinguish efficient choices; it is not designed to be mandatory. Every time a given Energy Star spec is considered for a mandatory standard, we need to think through whether it is appropriate. For example, we need to be careful not to ban products that meet a specific need, but can't or don't meet the spec. We carefully consider ENERGY STAR specs when updating our model standards, but it would be a mistake to adopt it across the board for all products as a mandatory level."

Subcommittee Recommendations

This Action Plan fills the gap between appliances and equipment that is covered under Energy Star and other appliances that consume substantial amounts of electricity for which quality differences matter. Appliance Standards are cost effective ways to achieve GHG and energy savings for consumers. Often first cost is not affected for the consumer, while long term running costs are reduced. PA should adopt all CA appliance standards that are issued above and beyond Energy Star. In addition, the State should consider further incentives to urge consumers to buy the most energy efficient appliances (significant delta even within energy star rated appliances).

This has some impact on retail choices, especially at the low cost end, but national commitments are emerging and PA should be in the forefront of demand for these appliances and equipment.

Appliances have a natural cycle of replacement and hence are excellent opportunities for innovation that achieves GHG gains and consumer energy savings.

Appliance replacement with energy efficient and long life choices will reduce waste.

Appliance and Equipment Standards are cost effective ways to achieve GHG and energy savings for consumers. PA should adopt all CA appliance standards that are issued above and beyond Energy Star. In addition, the State should consider further incentives to urge consumers to buy the most energy efficient appliances and equipment (significant delta even within energy star rated appliances).

RC-9. Geothermal Heating and Cooling

Summary: This strategy capitalizes on the energy-effectiveness of geothermal or ground source heat pumps (GSHPs) in Pennsylvania's climate, and the accompanying reductions in carbon emissions and in demand for peak generation and transmission. Pennsylvania is already ranked as one of the top-tier states for experienced and competitive installation of GSHPs in its urban centers. This strategy would build on that strength, expanding the network of trained drillers and installers throughout the state. This strategy advocates GSHP installations for individual buildings and in district systems. Warren, PA, hosts one of the few district GSHP systems in the United States, and this strategy supports further development of such systems for their energy and environmental benefits and for economic revitalization.

Additional benefits of GSHPs include:

- Levels seasonal electrical demand and 42 percent-48 percent reduced demand for new capacity.[5] (DOE/ORNL, 12/08).
- Widely applicable.
- Elimination of bulky and noisy exterior equipment, such as cooling towers or condensing units and heating plants.
- Atmosphere not used as a heat sink.
- Economical operating costs due to high coefficient of performance (metered Department of Defense installations in Pennsylvania achieve mean Coefficient of Performance of 4.0 and energy efficiency ratio of 20.83)
- Water heating integrated at low cost (can be scavenged whenever compressors are running).
- The fossil fuel used is burned at a large, industrial generating facility where air scrubbers and other anti-pollution equipment can be installed due to the economy of scale.
- Excellent part-load performance.
- Maintenance simpler and less costly than conventional fossil fuel and cooling tower systems.
- Frees peak transmission and generation capacity for other purposes.
- Reduces the use of natural gas as a heating fuel.
- Reduces water consumption by power plants

The calculations here are based on GSHP installations for individual buildings. District systems can offer economies of scale in the exterior infrastructure, but data on this are limited.

[5] Hughes, Patrick (2008). Geothermal (Ground-Source) Heat Pumps: Market Status, Barriers to Adoption, and Actions to Overcome Barriers. Oak Ridge National Laboratory. www1.eere.energy.gov/geothermal/pdfs/ornl_ghp_study.pdf

Goals:

Residential

Each year, 20 percent of new dwellings and 2 percent of existing dwellings will install GSHPs for heating and cooling, either on a building-by-building basis, or in district systems, serving multiple dwellings.

[Optional: 10 percent of new installations and 1 percent of replacement systems will be metered to support system maintenance and improvement.]

Commercial

By 2020, 40 percent of existing commercial buildings and 12.5 percent of new commercial buildings will be heated and cooled with GSHPs serving individual buildings or serving multiple buildings in district systems.

[Optional: 100 percent of new installations and 50 percent of replacement systems will be metered to support system maintenance and improvement.]

Possible Vehicles:

1. Require the DGS to do comprehensive life-cycle cost analysis for new buildings and building upgrades and advocate/support use of life-cycle cost analysis for all new and retrofit projects in the public and private sectors.

2. Educate designers/contractors/consumers about geothermal heat pump efficiency ratings (COP/EER), different from conventional gas furnace and air conditioner ratings, and highlight currently achievable efficiencies in PA climate, which are significantly higher than the ENERGY STAR standard.

3. Encourage the use of ESCOs to address first-cost hurdles.

4. To address the potential environmental impacts of ground loop, establish a mechanism for verifying the competence of drillers and external loop/well installers, and require that only state-approved drillers/installers are used (Oregon has such a policy).

5. Establish policies that will give utilities an incentive to install the external loop infrastructure and lease them on per-ton basis:
   a. Allow utilities to count the energy savings from GSHPs toward a renewable portfolio standard (RPS) target.
   b. Allow aggregated savings from GSHPs to be proxy for carbon-trading contracts.

   With these strategies, utilities will lose energy sales revenue, but will recoup some of it on loop leases and rate-based infrastructure. They'll also lose money on demand charges, but can get RPS credit and look good for doing so. Consumers get some efficiency benefits.

Reduction in peak demand reduces the need for new power plants and carbon emissions are reduced.

Other Involved Agencies:

DCED.

Implementation Steps: see *Vehicles* above

Potential Overlap:
DCED Renewable Energy Program: Geothermal and Wind Projects (January 2009); RC-1 through RC-4

Potential Complementarity: Potential integration with DOE/Oak Ridge National Laboratory's (ORNL's) interest in extending/funding infrastructure for geothermal heating and cooling. December 2008 report available at www1.eere.energy.gov/geothermal/pdfs/ornl_ghp_study.pdf

Key Assumptions:

Incremental Cost of Geothermal system			
Resdiential, household without central cooling		**$3,000**	$/housing unit
Residential, household with heating and central cooling		**$0**	$/housing unit
Input from V. Loftness & N.Baird. Because the ground infrastructure is warrantied for 50 years, assumption here is that the cost of installing ground source heat pumps is no greater than cost of conventional equipment. Cost here reflects 2-ton exterior heat exchange per unit.			
Cost of Geothermal system			
Commercial, existing buildings		**$14.4**	$/sq ft
G. Mattern, P.E., Adjunct Professor & geothermal specialist, Carnegie Mellon Univ., estimates $19.60/sf f			
Commercial, new buildings		**$12.5**	$/sq ft
G. Mattern, P.E., Adjunct Professor & geothermal specialist, Carnegie Mellon Univ., estimates $17.00/sf for new installation, bu ground infrastructure is warrantied for 50 years, assumption here is that the cost of installing ground source heat pumps is no g cost of conventional equipment. May be less.			
Cost of NG+AC VAV system (base case system)			
Commercial, existing buildings		**$14.4**	$/sq ft
Commercial, new buildings		**$12.5**	$/sq ft
Input from G, Mattern, P.E., Adjunct Professor, Carnegie Mellon Univ.			
Avoided Electricity Cost		**$89**	$/MWh
See "Common Factors" worksheet in this workbook.			
Avoided Natural Gas Cost		**$8.4**	$ / million Btu
See "NG prices aeo2006" and "Common Factors" worksheets in this workbook.			
Avoided Fuel Oil Cost	**$15.8**	**$13.6**	$ / million Btu
See "Common Factors" worksheets in this workbook.			
Emissions from additional Electricity Use		**0**	tCO_2/MWh
Assume that all new electricity for geothermal heatpump use is supplied by green electricity			
Green Electricity Premium		**12**	$/MWh
Based on BeGreen cost of $288 for 24 MWh of renewable energy, http://www.begreennow.com/ accessed on June 22, 2009			

Note: analysis assumes that electricity for heatpumps will be provided by "green electricity" with zero GHG emissions/MWh.

Energy savings due to ground source heatpumps	
Residential	45%
Commercial	30%
P Hughes, ORNL, 12/ 2008, p. 26	

Residential

- 50 percent of existing homes have HVAC systems that will need to be replaced before 2020.
- 30 percent of existing homes will decide to add air conditioning when this replacement is necessary.
- For the 20 percent replacement without air conditioning, the first cost differential of geothermal over conventional will be $3,000. Without cooling, the use of geothermal may not be as strategic as high-performance boilers and furnaces, especially integrated with domestic hot water (DHW) which would be a technology identified in the RC-8 Appliance Standards and RC-10 demand-side management (DSM)-Gas workplans.
- For the 30 percent with both heating replacement and air conditioning addition, the differential cost for geothermal over conventional will be $0. Energy savings will be substantial with two-season use.
- 45 percent savings relative to new heating and cooling equipment (Hughes, 2008).

Potential GHG Reductions:

Table 9-1. Estimated GHG Reductions and Cost-effectiveness

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reduc-tions ($MMtCO_2e$)	Costs (Million $)	Cost-Effective-ness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)
RC-9	Geothermal Heating and Cooling	1.4	$224	$158	8.0	$879	$109

Economic Cost: See Table 9-1, above.

Subcommittee Recommendations

This Action Plan addresses two approaches to geothermal heating and cooling: ground source heat pumps that would provide adequate conditioned water for heating and cooling individual residential and commercial buildings; and geothermal loops that would provide infrastructures for entire communities of heating and cooling requirements including load balancing benefits. Both of these offer significant commercial potential for the State of PA.

PA is a prime state for using geothermal energies for heating and cooling both with GSHP and with geothermal loops; however industry and labor growth is needed.

First cost intensive compared to the alternative, however GSHPs provide good alternatives to the addition of new AC in homes, changing the economics.

New industry growth area for PA. Economic benefit for building owners in reduced energy costs if first cost incentives exist, or reductions in installer costs.

RC-10. Demand Side Management (DSM)—Natural Gas

Summary: This initiative replaces or upgrades inefficient household appliances that utilize natural gas with more energy-efficient models.

Goals:
Residential sector: Achieve 36 percent reductions from reference case natural gas demand in 2025.
Commercial sector: Achieve 28 percent reductions from reference case natural gas demand in 2025.

Value from Pennsylvania: *Potential for Energy Efficiency, Demand Response, and Onsite Solar Energy in Pennsylvania* (ACEEE, 2009). See page 19 for residential and page 26 for commercial. This represents the cost-effective potential. Note that these savings are greater than the amount identified by ACEEE analysis as achievable by the set of policies analyzed. The policy analysis led to savings of 15 percent natural gas in 2025, for residential and commercial combined (see page 46). This work plan's assumptions imply stronger policies than those identified by ACEEE (mostly standards and utility programs)

Possible Vehicles:

1. Air Sealing and Insulation (10 percent–40 percent annual energy savings)
   - Pennsylvanians using natural gas for heating use about 600 therms per household.
   - By air sealing & insulation, consumers could probably easily save 25 percent of this.

2. Increased furnace and boiler efficiency to >95 AFUE .
   - Nationwide and in PA, about 50 percent of homes use natural gas for heating.
   - The minimum allowed annual fuel utilization efficiency (AFUE) rating for a non-condensing, fossil-fueled, warm-air furnace is 78 percent; the minimum rating for a fossil-fueled boiler is 80 percent; and the minimum rating for a gas-fueled steam boiler is 75 percent.
   - Although older furnace and boiler systems had efficiencies in the range of 56 percent-70 percent, modern conventional heating systems can achieve efficiencies as high as 97 percent, converting nearly all the fuel to useful heat for the home. Energy efficiency upgrades and a new high-efficiency heating system can often cut fuel bills and a furnace's pollution output in half. Upgrading a furnace or boiler from 56 percent to 90 percent efficiency in an average cold-climate house will save 1.5 tCO_2 emissions each year if heated with gas, or 2.5 tCO_2 if heated with oil (DOE, Energy Savers).
   - Therefore consumers could expect to see a 15 percent–50 percent range in energy savings from "heating season" improvements (depending on age and efficiency of equipment being replaced).

3. Solar domestic hot water heaters
   - Heating water accounts for 14 percent–25 percent of total household energy consumption. Solar water heaters can provide 85 percent of DHW needs.

4. Instantaneous hot water heaters with an energy factor >0.80

- For homes that use 41 gallons or less of hot water daily, demand water heaters can be 24 percent–34 percent more energy efficient than conventional storage tank water heaters.
- They can be 8 percent–14 percent more energy efficient for homes that use a lot of hot water—around 86 gallons per day. You can achieve even greater energy savings of 27 percent—50 percent if you install a demand water heater at each hot water outlet.

5. ENERGY STAR front-loading washing machines.

- Most ENERGY STAR-qualified clothes washers extract more water from clothes during the spin cycle. This reduces the drying time and saves energy and wear and tear on your clothes.
- ENERGY STAR-qualified clothes washers clean clothes using 50 percent less energy than standard washers (including energy used in the washing process, including machine energy, water heating energy, and dryer energy).

6. Pilot lights.

- Standing pilot lights may use over 7 therms (700,000 British thermal units) of gas per appliance, if left on year round.
- Replacing old appliances that have pilot lights on full time with appliances that have electronic (intermittent) ignitions could create savings.
- Some people feel that standing pilot lights on appliances are gradually becoming the exception, instead of the rule, with new appliances on the market using electronic ignitions. However, even though electronic ignition pilot lights are becoming increasingly common, without legislation, standing pilots may not disappear by 2025 because they are cheaper to manufacturer, and the appliance is sometimes viewed as solution to emergency heat when the electricity fails, because they do not need electric power to start.
- This initiative would institute public benefit funds for investment in residential, commercial, and industrial energy efficiency and renewable energy programs through third-party administrators.

Implementation Steps:

- Market driven.
- Encourage natural gas utilities to engage in consumer education initiatives regarding these efficient technologies.
- Potential opportunity for appliance efficiency legislation.

Key Assumptions:

Key Data and Assumptions	2012	2020	Units
Savings Targets			
Natural Gas			
Achievable cost-effective savings in natural gas use as a fraction of total gas demand:			
Residential		**36.00%**	
Commercial		**28.00%**	
Value from Pennsylvania: Energy Efficiency, Demand Response and On-Site Solar Potenial. ACEEE 2009. See page 19 for residential and page 26 for commercial. This represents the cost-effective potential. Note that these savings are greater than the amount identified as ACEEE analysis as achievable by the set of policies analysed. The policy analysis led to savings of 15% natural gas in 2025, for residential and commercial combined (see page 46). This workplan assumptions imply stronger policies than those identified by ACEEE (mostly standards and utility programs`			
Fraction of achievable savings reached under program		**100%**	Option Goal
Year in which target fraction reached		**2025**	Option Goal
Year in which programs fully "ramped in"		**2012**	Assumption
Fraction of full program savings by year	100%	100%	
Implied fractional annual gas demand savings, residential	3.6%	3.6%	
Implied fractional annual gas demand savings, commercial	2.8%	2.8%	
Analysis			
RCI Gas Sales Covered *(from inventory)*	414,382	415,519	Billion Btu
Residential	254,778	247,865	Billion Btu
Commercial	159,604	167,655	Billion Btu
Industrial	0	0	Billion Btu
Conversion Factor: Million Btu per Thousand Cubic feet		1.03	MMBtu/Mcf

Additional Results	2012	2020	Units
Investments to Meet RC-7 Savings Target--Natural Gas			
Reduction in Gas Use (Cumulative)	4,549	136,308	Billion Btu
as % of overall projected sales in that year	1.10%	32.80%	

Cost of Saved Energy:
Residential Sector: $5.29/MMBtu
Commercial Sector: $3.28/MMBtu
Source: ACEEE 2009 report, see above

Table 10-1. Residential Natural Gas Efficiency Potential and Costs by End-Use (2025)

End-Use	Savings (MMBtu)	Savings relative to Reference Case (%)	% of Total Efficiency Potential	Levelized Cost of Saved Energy ($/MMBtu)
Single Family Gas	**74,070**	**35%**	**100%**	**$5.01**
Space Heating	47,540	22%	64%	$3.70
Water Heating	16,840	8%	23%	$7.90
Cooking	920	0.4%	1%	$9.34
Existing	65,300	30%	88%	$4.86
New Homes	8,770	4%	12%	$4.82
Multifamily Gas	**9,620**	**46%**	**100%**	**$7.47**
Space Heating	4,350	20%	45%	$6.86
Water Heating	3,360	16%	35%	$3.04
Cooking	100	0.5%	1%	$11.71
Existing	7,810	37%	81%	$5.28
New Homes	1,810	9%	19%	$9.40
All Residential Gas	**83,690**	**36%**	**100%**	**$5.29**
Space Heating	51,890	22%	62%	$3.96
Water Heating	20,200	9%	24%	$7.09
Cooking	1,010	0.4%	1%	$9.57
Existing	73,10	31%	87%	$4.91
New Homes	10,590	5%	13%	$5.61

Table 10-2. Commercial Natural Gas Efficiency Potential and Costs by End-Use (2025)

End-Use	Savings (MMBtu)	Savings over Reference Case (%)	% of Efficiency Potential	Weighted Levelized Cost of Saved Energy ($/MMBtu)
HVAC equipment & controls	26,200,000	15%	54%	$ 2.39
Building shell	2,000,000	1%	4%	$ 0.30
Water Heating	5,400,000	3%	11%	$ 6.27
Cooking	4,000,000	2%	8%	$ 1.11
Other	7,200,000	4%	15%	$ 8.43
Existing Buildings	44,700,000	26%	93%	$ 3.19
New Buildings	3,500,000	2%	7%	$ 2.45
Total Gas	48,200,000	28%	100%	$ 3.28

Source: ACEEE 2009

Avoided Cost of Natural Gas:

All sectors: $8.40/MMBtu

GHG Reductions and Economic Costs:

Table 10-3. Estimated GHG Reductions and Cost-effectiveness

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)
10	DSM - Natural Gas	7.3	-$51	-$7	40.5	-$357	-$9

Economic Cost: See table 10-3 above.

Potential Overlap:

- Reduced Load Growth Work Plan
- HB 2200 Work Plan
- Appliance Standards Work Plan
- Alternative Energy Investment Act Work Plan
- RC-1 through RC-4

Other Involved Agencies: PUC.

Subcommittee Recommendations

Demand side management of natural gas appliances and equipment in residential and commercial buildings offer excellent GHG reduction potential and excellent cost savings. This is especially important since aging equipment may be subject to replacement by electric alternatives which would increase PA electricity use and commensurate GHGs.

The technologies to achieve these goals are available now.

The real challenge for demand-side management (DSM) of gas equipment is upfront cost to the building owners. Federal and state incentives may significantly reduce this challenge, although many home owners do not have the ready cash. It may be imperative for utility sponsored retrofits with pre-certified installers and constant fuel bills until the DSM is paid for.

Replacement of gas appliances and equipment have health benefits as well since older equipment is more subject to fumes and leakage in occupied spaces. Homes may also benefit from appropriately matched equipment sizing to the load, ensuring adequate temperatures are met, and reducing 'cycling'.

The GHG and energy cost savings benefits are excellent, but the upfront cost implications must be addressed through utility programs.

RC-11. Oil Conservation and Fuel Switching for Heating Oil

Summary:

Oil conservation
This initiative replaces or upgrades inefficient household appliances that utilize fuel oil with more energy-efficient models.

Biofuel
This initiative aims to blend all heating oil sold in PA with a 5 percent blend of biodiesel. Bioheat is the industry term for heating oil that is blended with biodiesel. Heating oil is essentially the same as diesel, with some difference in sulfur content and a colorant added to deter tax evasion through its potential use as a transportation fuel. The use of bioheat has been proven to reduce maintenance concerns and burns cleaner than conventional heating oil. Significant, positive experience utilizing bioheat exists. Numerous customers throughout south central and southeastern PA have been using bioheat in their furnaces and boilers for the past few years. The DGS also has bioheat on contract for state agencies.

Goal:

Oil conservation
Residential sector: Achieve 37 percent reductions from reference case oil consumption in 2025.
Commercial sector: Achieve 26 percent reductions from reference case oil consumption in 2025.

Biofuel
Replace 5 percent of heating oil with biodiesel.

Implementation Steps: Representatives from the Northeast Regional Biomass Program, including PA, have been working in association with oil heat industry representatives to promote greater awareness and acceptance of bioheat among both customers and distributors. Further discussions should occur between the Departments of Public Welfare, the Office of Consumer Advocate, and the DEP so that all are aware of potential economic considerations in implementing such an initiative. Implementation would require legislative action. Adequate injection-blending facilities would need to be in place around the state to support this measure.

Assumptions: Values from Pennsylvania: Potential for Energy Efficiency, Demand Response, and Onsite Solar Energy (ACEEE 2009). See page 21 for residential and page 27 for commercial. This represents the cost-effective potential. Note that these savings are greater than the amount identified by ACEEE analysis as achievable by the set of policies analyzed. The policy analysis led to savings of 11 percent fuel oil in 2025, for residential and commercial combined (see page 46). The assumptions in this work plan imply stronger policies than those identified by ACEEE (mostly standards and utility programs)

Heating Oil

Achievable cost-effective savings in heating oil use as a fraction of total gas demand:			
Residential		37%	
Commercial		26%	

Value from Pennsylvania: Energy Efficiency, Demand Response and On-Site Solar Potenial. ACEEE 2009. See page 21 for residential and page 27 for commercial. This represents the cost-effective potential. Note that these savings are greater than the amount identified as ACEEE analysis as achievable by the set of policies analysed. The policy analysis led to savings of 11% fuel oil in 2025, for residential and commercial combined (see page 46). This workplan assumptions imply stronger policies than those identified by ACEEE (mostly standards and utility programs)

Fraction of achievable savings reached under program		100%	Option Goal
Year in which target fraction reached		2025	Option Goal
Year in which programs fully "ramped in"		2012	Assumption
Fraction of full program savings by year	100%	100%	
Implied fractional new annual oil demand savings, residential	3.7%	3.7%	
Implied fractional new annual oil demand savings, commercial	2.6%	2.6%	
Biofuel for heating		5%	
Lifecycle emissions factor for biofuel	*Y/N*	Y	*1*

Weighted Levelized Cost of Saved Energy

Residential		$0.63	$/gal
Commercial		$0.98	$/gal

Value from Pennsylvania: Energy Efficiency, Demand Response and On-Site Solar Potenial. ACEEE 2009. See page 21 for residential and page 27 for commercial.

Assumed average measure lifetime		8	years
Avoided Delivered Heating Oil Cost		$14.0	$/MMBtu
See common assumptions		$1.9	$/gal
Cost of biofuel for heat	$28.73	$24.75	$ / MMBtu
See "Common Factors" worksheet in this workbook			
Avoided Heating Oil Emissions Rate		0.07	tCO_2e / MMBtu
See "Common Factors" worksheet in this workbook.			

Analysis

RCI Oil Sales Covered	*(from inventory)*	208,860	209,113	Billion Btu
Residential		155,241	150,678	Billion Btu
Commercial		53,619	58,434	Billion Btu
Industrial		0	0	Billion Btu
Conversion Factor: Million Btu per Thousand Cubic feet			1.03	MMBtu/Mcf

Potential GHG Reduction:

Table 11-1. Estimated GHG Reductions and Cost-effectiveness

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reduc-tions ($MMtCO_2e$)	Costs (Million $)	Cost-Effective ness ($\$/tCO_2e$)	GHG Reduction s ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectivene ss ($\$/tCO_2e$)
RC-11	Oil conservation and Fuel Switching for Fuel Oil	5.7	-$21	-$4	35.8	$140	$4

Economic Cost: See Table 11-1 above.

Potential Overlap:

- Biofuels Investment and In-State Production Act
- RC-1 through RC-4

Other Involved Agencies: Department of Welfare.

Subcommittee Recommendations

Demand side management of heating oil appliances and equipment in residential and commercial buildings offer excellent GHG reduction potential and excellent cost savings. This is especially important since aging equipment may be subject to replacement by electric alternatives which would increase PA electricity use and commensurate GHGs.

The technologies to achieve these goals are available now.

The real challenge for demand-side management (DSM) of heating oil equipment is upfront cost to the building owners. Federal and state incentives may significantly reduce this challenge, although many home owners do not have the ready cash. It may be imperative for utility sponsored retrofits with pre-certified installers and constant fuel bills until the DSM is paid for.

Replacement of heating oil appliances and equipment have health benefits as well since older equipment is more subject to fumes and leakage in occupied spaces. Homes may also benefit from appropriately matched equipment sizing to the load, ensuring adequate temperatures are met, and reducing 'cycling'.

The GHG and energy cost savings benefits are excellent, but the upfront cost implications must be addressed through utility programs.

Information sources:

Table 11.2. Projected Heating Oil Consumption and Associated B5 Bioheat Requirements

Projected Heating Oil Consumption and Associated B5 Bioheat Requirements							
Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	
#2 Heating Oil	929,363,000	909,673,787	890,401,704	871,537,914	853,073,766	835,000,795	
Biodiesel for B5 Bioheat	46,468,150	45,483,689	44,520,085	43,576,896	42,653,688	41,750,040	
Year	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	
#2 Heating Oil	817,310,712	799,995,406	783,046,937	766,457,534	750,219,588	734,325,655	
Biodiesel for B5 Bioheat	40,865,536	39,999,770	39,152,347	38,322,877	37,510,979	36,716,283	
Year	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**
#2 Heating Oil	718,768,446	703,540,828	688,635,818	674,046,581	659,766,427	645,788,808	632,107,315
Biodiesel for B5 Bioheat	35,938,422	35,177,041	34,431,791	33,702,329	32,988,321	32,289,440	31,605,366

Baseline consumption data for PA is from EIA's Petroleum Navigator (http://tonto.eia.doe.gov/dnav/pet/pet_cons_prim_dcu_SPA_a.htm).

Table 11.3. Diesel Production GHG Lifecycle Assessment

Diesel* Production GHG Lifecycle Assessment (LCA) (Includes Production-Related GHGs & Finished Fuel Carbon Content, Expressed as CO_2e/Gallon)						
	CO_2	CH_4	N_2O	Total CO_2e	Carbon Content (Lbs CO_2/Gal.)	Total LCA (Lbs. CO_2e/Gal.)
G/MMBtu	20,142	109.1	0.343			
MMBtu per Gallon	0.1284	0.1284	0.1284			
GWP	1	23	296			
CO_2e	2586.23	322.19	13.04	6.44	22.38	28.82

"Biomass-based diesel" means renewable fuel that is biodiesel as defined in section 312(f) of the Energy Policy Act of 1992 (42 U.S.C. 13220(f)) and that has life-cycle greenhouse gas emissions, as determined by the Administrator, after notice and opportunity for comment, that are at least 50 percent less than the baseline life-cycle emissions. Notwithstanding the preceding sentence, renewable fuel derived from co-processing biomass with a petroleum feedstock shall be advanced biofuel if it meets the requirements of subparagraph (B), but is not biomass-based diesel.

RC-12. Demand-Side Management (DSM)—Electricity

Summary: Electric energy conservation in buildings is the most affordable strategy for achieving major GHG reductions as well as providing substantial energy cost savings for consumers. This work plan is focused on delivering a diverse portfolio of cost-effective energy-conserving retrofits to existing residential and commercial buildings through the creation of utility ESCOs (UESCOs) or independently led ESCOs that ensure expertise, installed performance and warranty, as well as finance. It is anticipated the funds needed for these efforts will be secured through a systems benefit charge.

Other Involved Agencies: PUC, PA Department of Commerce.

Work Plan: This strategy builds upon the energy efficiency and conservation program of Act 129, HB 2200, which mandates the introduction of utility demand-side management (DSM) programs. While an Energy Subcommittee work plan addresses both performance incentives as well as rate decoupling (see Appendix A of Energy Subcommittee Work Plan), this work plan is focused on the need for education, adding expertise with trained labor, and financing opportunities to the building sector.

Education

The first level of electric energy savings can be achieved through consumer education. Consumers determine both peak and annual energy use through product selection and use, such that a dedicated education program in concert with state commitments to the energy quality of products for purchase can reduce energy use in PA. All appliances, light fixtures, desktop technology, and entertainment technology have measurable energy differences in operation and in standby modes. In addition to product selection and standby power demands, a "Turn it off PA" program is described at the end of this work plan.

Trained Workforce

The second level of electric energy savings must be achieved through a trained "green collar" workforce ensuring the installed performance of more significant building components: replacement furnaces, boilers and air conditioners, roof and window replacements, building insulation, shade trees, and green roofs (for cooling load reductions). In other states, these retrofits—with sustained energy savings—have been delivered by ESCOs and UESCOs. A critical factor for the building owner will be one-stop-shopping with finance, trained labor, and performance guarantees.

Finance

The third element in this work plan is funding. While ESCOs have a track record of shared economic benefits supporting ongoing investments, the lack of widespread action for either commercial or residential buildings in PA suggests that other funding must be secured. One alternative to financing electricity DSM is to mandate utility electricity load reductions of 5 percent by 2015 and 10 percent by 2010, and allow utilities to negotiate costs and savings with the customer base. A second alternative is to establish system benefit charges ranging from $.001 to $.004 per kWh linked to statewide energy savings. As demonstrated in California—the leading state for electricity DSM—system benefit charges alongside mandated electricity savings by utilities will ensure measurable GHG savings and measurable citizen benefits.

Possible Vehicles:
Turn it Off PA! Campaign
Consumer Education and Feedback

Goal:. A campaign to eliminate unnecessary equipment operating hours and appliance loads can reduce residential and commercial energy consumption by 5 percent to 15 percent (without any loss in quality of life).[6] The limitations are awareness and easy hardware for controlling equipment and appliances, which can be overcome with a concerted state work plan.

Possible New Measure(s):

The *Turn it off PA! Campaign 1* will address unnecessary heating, cooling, and lighting conditioning energy use during periods when no one is in the building, or when natural conditioning would be equally effective.

User-friendly setback thermostats to replace manual thermostats in homes and commercial buildings without building automation systems would reduce heating and cooling during unoccupied periods by an average of 20 percent (for homes daytime for dual working parents for example). To further address heating loads in homes and small commercial buildings, education and policy would emphasize the value of increasing south-facing windows and living spaces, maintaining high solar transmission glass on the south, so passive solar heat can meet an additional 20 percent of the heating load. To further address cooling loads, the promotion of internal and external shading devices for windows in all building types, alongside a shade tree program will reduce air conditioning by at least 20 percent.

Education and policy would promote the use of natural ventilation as a cooling and ventilation system for a majority of the year whenever outside conditions are not too hot, humid, or polluted. A statewide policy to mandate operable windows for all long-term occupancy spaces would ensure that natural ventilation (and daylighting) remains viable if not central solutions to reducing conditioning energy loads.

Finally, policy and education would guarantee the maximum use of daylighting for both task and ambient lighting in commercial buildings. Policies would include: mandates for high-visible transmission glass (independent of shading or heat gain coefficients) in all new and retrofit projects, the design and/or specification of light-redirection devices (light shelves and horizontal blinds) that maintain views while improving daylight distribution, the renovation of historic academic and municipal buildings to re-activate their effective daylighting systems, and the introduction of daylight or time-of-day responsive controls.

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[6] Darby, Sarah. 2006. *The Effectiveness of Feedback on Energy Consumption: A Review for DEFRA of the literature on metering, billing and direct displays.* Environmental Change Institute, University of Oxford. http://www.defra.gov.uk/environment/climatechange/uk/energy/research/pdf/energyconsump-feedback.pdf

The *Turn it off PA! Campaign 2* will address unnecessary appliance loads caused by equipment left on in unoccupied spaces and by parasitic or vampire loads caused by transformers and stand-by modes of equipment that is turned off.

Simple household energy software introduced in elementary schools can help families recognize the unnecessary energy being used by everyday appliances in on, standby, sleep, and off positions. Education should be supported by mandated or subsidized meters that give residents feedback for turning equipment off in daily, monthly, and annual benefits. All legislation that limits low-energy living would be modified, from clothes line ordinances to mandated air conditioning.

In a mini campaign focused on *PA kills vampire loads!,* standards would be set for all Pennsylvania transformers and set-top boxes; subsidies could be considered for switchable power strips that enable residents to turn off banks of equipment when leaving, with timers or occupancy sensors; and electricity counters could be integrated into power strips. The Prius effect, by which drivers continuously learn which actions improve the mile-per-gallon performance of their car, would be brought to residential and commercial appliances.

Assumptions:

Cost of measure — 3% premium

Geller (2002) Utility Energy Efficiency Programs and Systems Benefit Charges in the Southwest p.4
http://www.swenergy.org/pubs/system_benefit_charges.pdf

	2017	2027
Electricity savings	6.7%	10.2%

Darby, Sarah. 2006. *The Effectiveness of Feedback on Energy Consumption: A Review for DEFRA of the literature on metering, billing and direct displays.* Environmental Change Institute, University of Oxford.
http://www.defra.gov.uk/environment/climatechange/uk/energy/research/pdf/energyconsump-feedback.pdf

The analysis indicates that "The norm is for savings from direct feedback (immediate, from the meter or an associated display monitor) to range from 5-15%." We assume this could be achieved over time for the majority of homes and businesses, approaching an average of 10% by 2027.

Potential GHG Reduction:

Table 12-1. Estimated GHG Reductions and Cost-effectiveness

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/$tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/$tCO_2e$)
RC-12	DSM—Electricity	10.1	$31	$3	66.2	$136	$2

Economic Cost: The literature indicates a range of costs for the education programs from net savings to low net costs. The costs here reflect the costs reported for electricity savings programs in south western states. Costs will depend on the decisions for programs, education and financing.

Potential Overlap:

- None (utilities required to prove no overlap)

Subcommittee Recommendations

Demand side management of electric appliances and equipment in residential and commercial buildings offer excellent GHG reduction potential and excellent cost savings.

The technologies to achieve these goals are available now.

In addition to behavioral changes and technology to reduce standby loads with only educational costs, aging equipment due for replacement ensures the economic viability of DSM efforts.

There may not be significant externalities for electric DSM.

DSM of electric appliances and equipment, behavioral changes and technology improvements to reduce stand by and parasitic loads makes excellent economic and environmental sense.

RC-13. Demand-Side Management (DSM) – Water

Summary: This initiative supports water conservation and yields energy savings. To achieve 25 percent potable water conservation, enact new utility incentives, conservation credits, smart metering, and education programs. The energy impact of water use is estimated at 4 percent of all electricity consumption nationwide.

Most homeowners in PA have water bills that exceed electric bills, with little awareness of where those costs are generated. Landscaping, toilet flushing, showers and sinks and washing machines are the most significant contributors to building water loads. These water costs have measurable GHG implications (4 percent of all energy use) because of the processing energy costs and the pumping energy costs. Faucets and washing machines also have hot water loads, gas or electric, with GHG implications.

As a result, water conserving alternatives benefit building owners both in water cost savings and in DHW heating cost savings.

Conservation can be achieved through State efforts to promote rain capture for landscaping, dual flush toilets, low flow faucets and shower heads, and water efficient/ front loading washing machines. This can be achieved by: point of sale education and Watersense product performance standards; elimination of code barriers; and utility managed programs that combine certified installers with equitable utility rate financing.

Goals:

- Reduce per-capita water use by 20 percent statewide by 2015.
- Achieve a 10 percent overall water savings by 2025.
- Install WaterSense fixtures for all new construction.

Possible Vehicles:

- Low-water landscaping:
  - Irrigation (low-water landscaping, rain capture).
- Low-water plumbing:
  - Toilets (WaterSense uses 1.28–1.6 gallons per flush).
  - Faucets.
  - Washing machines.

Assumptions:

Other Data, Assumptions, Calculations		2012	2020	Units
Population		12,439,741	12,569,017	persons
Population (2005)			12,328,348	persons
Baseline (2005) per capita water use *Assumes no change in per capita use from 1995 to 2005*			30,081	gal/person/yr
Baseline (2005) total water use *Assumes no change in per capita use from 1995 to 2005*			370,847	million gal / yr
Energy Intensity (excluding heating) *Griffiths-Satenspiel and Wilson (2009.04) The Carbon Footprint of Water,* *provided by Mary Ann Dickinson, Alliance for Water Efficiency* *Savings from water heating included under RC-8 Appliances*			4	MWh / million gal
Goals				
Water use avoided (per capita)		10.0%	20.0%	
		37,420	75,617	million gal
Water use avoided (absolute)		1.9%	6.9%	
		6,953	25,496	million gal
Water use avoided (greater of per capita and absolute)		37,420	75,617	million gal
Costs				
Levelized cost of measure - landscaping *See Note 2 on this sheet*			$4.84	$ / thousand gal
Levelized cost of measure - fixtures *See Note 2 on this sheet*			$0.34	$ / thousand gal
Levelized cost of measure - washing machine *See Note 2 on this sheet*			$0.01	$ / thousand gal
Levelized cost of measure - toilet *See Note 2 on this sheet*			$1.74	$ / thousand gal
Avoided cost of water	*Residential*		$7.50	$ / thousand gal
Pittsburgh water and sewer authority http://www.pgh2o.com/fees.htm	*Commercial*		$7.19	$ / thousand gal
	Weighted average		$7.42	$ / thousand gal
Buildings undergoing irrigation retrofits annually			10,000	buildings
Washing machines replaced annually			50,000	machines
Homes retrofitting fixtures annually			250,000	housing units
Toilets replaced annually			250,000	toilets

Additional Results	2012	2020	Units
Overall			
Avoided water use	10,679	39,156	million gal

Note: the measures assumed are not sufficient to meet the overall goals of the workplan

Potential GHG Reduction:

Table 13-1. Estimated GHG Reductions and Cost-effectiveness

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/t$CO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/t$CO_2e$)
13	Demand Side Management (DSM) – Water	0.1	-$255	-$1,944	0.8	-$1,011	-$1,285
	Irrigation at commercial buildings	0.0	-$4	-$804	0.0	-$18	-$558
	Replace fixtures	0.0	-$89	-$2,242	0.2	-$372	-$1,556
	Replace clothes washing machines	0.0	-$22	-$2,340	0.1	-$91	-$1,624
	Replace toilets	0.1	-$140	-$1,822	0.5	-$582	-$1,264

Economic Cost: See Table 13-1, above.

Potential Overlap: None

Other Involved Agencies: None identified

Subcommittee Recommendations

Water use contributes 4 percent of all electric demand, for processing and pumping energy. Water conservation in the areas of greatest use - landscape irrigation, toilets, faucets and washing machines, offers measurable GHG benefits at low costs especially given the natural cycles of replacement.

Between 1950 and 2000, the U.S. population nearly doubled. However, in that same period, public demand for water more than tripled. American public water supply and treatment consume approximately 56 billion kilowatt-hours per year. If one out of every 100 American homes retrofitted with water-efficient fixtures, 100 million kilowatt-hours of electricity would be saved each year. (Source: EPA WaterSense Program - website accessed 06/10/09)

The technologies to achieve these goals are available now. Water conservation and water reuse technologies have infiltrated the market, public perspective, and government policy. While the products marketed to the public are recognizable, technologies are strongly supported by policy across all levels of government.

The major barrier to water conservation is the upfront cost of replacing fixtures. While low-flow faucets have very low costs, low water consumption toilets and washers, as well as rain barrels have first costs and installation costs that are often prohibitive for building owners and renters. Utility-based programs are needed to ensure certified installers, carefully specified fixtures, and financing, with water cost savings to pay for the program. Dry states such as California offer excellent precedent.

The average household spends as much as $500 per year on its water and sewer bill. If all U.S. households installed water-efficient appliances, the U. S. could save more than 3 trillion gallons of water and more than $18 billion dollars per year. (Source: EPA WaterSense Program - website accessed 06/10/09) While a significant portion of water conservation and reuse technologies are affordable to most, legislation could provide financial assistance and incentives.

While water is not scarce in PA, there are periods of drought and significant processing costs to providing potable water. Water conservation will ensure that water is available for the highest and best use. Water conservation and water reuse encourages economic development and benefits the environment. Water conservation reduces water costs for building owners and renters; benefits that can pay for the retrofit actions. The cost savings borne out of water conservation and reuse frees up opportunity costs and may provide a higher quality of life for some individuals. In addition, reusing water where potable is not needed reduces demand and the associated energy needs.

WORKPLANS THAT ARE NOT QUANTIFIED IN THIS ANALYSIS

RC-14. PA Values Embodied Energy in Building Materials, Including Historic Structures

Summary: This work plan promotes the use of regionally sourced and manufactured building products, as well as historic/existing structures.

Other Involved Agencies: DCED, U.S. Small Business Administration, local/regional economic development companies, Pennsylvania Technical Assistance Program, Industrial Resource Centers, DGS COSTAR, PA Historic and Museum Commission, county historic societies, PA Historic Landmark Foundation, Young Preservationists of Pittsburgh/PA.

Possible Vehicles: Promotion of the use of regionally sourced and manufactured building products as well as historic/existing structures.

The notion of supporting regional communities and economies is becoming widespread in "buy-local" campaigns. Included in that notion is the procurement of building product materials within one's own region. This practice supports local businesses and manufacturers by strengthening demand for local industries instead of relying on shipping from other regions. The buy-local ideology can also reduce the amount of embodied energy in building materials by reducing the distance of travel for those materials. Locally sourced building materials are also a major component of the LEED Rating System.

Included with the concept of embodied energy is the practice of reusing existing structures, such as historic buildings. By repurposing buildings, builders are reducing GHGs and embodied energy by reducing new infrastructure, landfill waste, and the use of many new materials typically consumed in the new building construction.

Many state and municipal governments are already promoting the practice of utilizing regional materials within public buildings through legislation.

Potential GHG Reduction: Unknown at this time. Can be determined from shipping emission reductions and the reduced amount of daily commuters due to urban density.

Economic Cost: The economic cost of such a program would be easily obtainable through past and present purchasing orders/shipping orders related to the building industry. The great economic impact would be more obvious in the amount of revenue earned through regional sales by Pennsylvania manufacturers. A cost may also be associated with a PA preferred product label/database to be administered by staff.

Implementation Steps: Implementation of this program includes state and municipal legislation, such as that outlined above. Certain tax credits may also be structured and applied to building projects that strive to utilize regionally sourced materials and historic/existing structures.

Potential Overlap:

- Building Performance Labels That Reflect Actual Utility Usage
- High-Performance Pennsylvania Building Standards
- High-Performance Building Standards for Existing Commonwealth of PA Buildings

RC-15. Sustainability Education Programs

Summary: This initiative supports sustainable education programs in primary and secondary schools and post-secondary, college, and university programs.

- Introduce or augment environmental/energy curricula in schools.
- Introduce energy efficiency at community colleges and trade schools.
- Provide training and certification for builders and contractors and building code officials working in energy code enforcement.
- Provide continuing education for design professionals, including architects, engineers, developers, contractors, urban planners and realtors.
- Educate consumers with information programs on efficiency and conservation targeted to reduction and wise use of energy.
- Ensure municipalities coordinate and share resources.

Possible Vehicles:
The establishment of the Turn it off PA! campaign eliminates unnecessary equipment operating hours and appliance loads. This can reduce residential and commercial energy consumption by 25 percent without loss in quality of life. The limitations are education and needed hardware for equipment. Heating, cooling, lighting, and appliance energy conservation and plug loads would be the focus of a multistage statewide campaign.

RC-16. Adaptive Building Reuse

Summary: This initiative encourages adaptive building reuse and sourcing of regionally available building materials.

Possible New Measure(s):

By promoting the reuse of historic and existing buildings, the following reductions occur: GHG, landfill waste, new building materials, and new infrastructure. The sourcing of regionally available building materials results in similar reductions.

APPENDIX G
Land Use and Transportation Work Plans

Summary of Work Plan Recommendations and Recent Actions (noted at bottom of table)

Work Plan No.	Work Plan Name		Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $)	Annual Results (2020) Cost-Effectiveness ($/$tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $)	Cumulative Results (2009-2020) Cost-Effectiveness ($/$tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)[1]
3	Low-Rolling-Resistance Tires		0.68	-$212	-$310	4.1	-$1,244	-$300	16 / 5 / 0
5	Eco-Driving	PAYD	0.43	-$277	-$651	1.76	-$1,065	-$605	13 / 8 / 0
		Feebates	0.41	-$133	-$320	2.74	-$810	-$296	13 / 8 / 0
		Driver Training	0.62	-$129	-$206	4.53	-$605	-$134	13 / 8 / 0
		Tire Inflation	0.09	-$27	-$282	0.58	-$137	-$238	13 / 8 / 0
		Speed Reduction	1.96	$185	$94	23.0	$4,153	$181	13 / 8 / 0
6	Utilizing Existing Public Transportation Systems		0.05	$300	$6,000	0.55	$3,000	$5,454	13 / 8 / 0
7	Increasing Participation in Efficient Passenger Transit		0.12	<$0	<$0	2.02	<$0	<$0	21 / 0 / 0
8	Cutting Emissions From Freight Transportation		0.99	-$293	-$295	6.67	-$1,495	-$224	15 / 6 / 0
9	Increasing Federal Support for Efficient Transit and Freight Transport in PA		1.17	$92	$78	12.87	$1,008[2]	$78	20 / 1 / 0
10	Enhanced Support for Existing Smart Growth/Transportation and Land-Use Policies		0.76-1.84	<$0	<$0	3.79-9.18	<$0	<$0	13 / 8 / 0
11	Transit-Oriented Design, Smart Growth Communities, & Land-Use Solutions		Included in T-10	<$0	<$0	Included in T-10	<$0	<$0	13 / 8 / 0
Sector Total After Adjusting for Overlaps			6.6	-$494	-$75	60.1	$2,805	$47	
Reductions From Recent State and Federal Actions			15.7	-$109[3]	-$31[3]	72.0	-$380[3]	-$25[3]	
1	Pennsylvania Clean Vehicles (PCV) Program		0.095	0.0	0.0	1.27	0.0	0.0	NA
	Federal Vehicle GHG Emissions and CAFE Standards		12.2	NQ	NQ	57.3	NQ	NQ	NA
2	Biofuel Development and In-State Production Incentive Act		3.47	-$89	-$26	14.8	-$203	-$14	NA
4	Diesel Anti-Idling Program		0.07	-$20	-$273	0.7	-$177	-$238	NA
Sector Total Plus Recent Actions			22.3	-$603	-$27	132	$2,425	$18	

[1] NA in this column means "not applicable." Work plan numbers 1, 2, and 4 are recent state actions that are being implemented by the state; and the federal government will be implementing national vehicle GHG emissions and corporate average fuel economy (CAFÉ) standards starting in 2012.

[2] Because T-9 uses federal dollars exclusively, it should be noted that the cost figures for T-9 are calculations of how many federal dollars—not state dollars—would be required to implement the work plan.

[3] This cost per ton value excludes the emission reductions associated with the “Federal Vehicle GHG Emissions and CAFE Standards” since costs (savings) were not quantified for this recent federal action.

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; NQ = not quantified; PA = Pennsylvania; PAYD = Pay-As-You-Drive; CAFE = Corporate Average Fuel Economy.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

Transportation 1. Pennsylvania Clean Vehicles (PCV) Program

Summary: Adoption of the California Air Resources Board (CARB) certification standards for all vehicles registered in PA.

Other Involved Agencies: Pennsylvania Department of Transportation (PennDOT), Department of Environmental Protection (DEP).

Possible New Measure(s): Implementation of the existing Clean Vehicles Program, starting with model year 2008. Under this program, passenger cars and light-duty trucks (8,500 pounds gross vehicle weight or less) sold or leased and titled in Pennsylvania must be certified by CARB for use either in California or for all 50 states.

CARB recently added a greenhouse gas (GHG) fleet average requirement to its low-emission vehicle (LEV) II program beginning with model year 2009. The GHG fleet average will have to be met in California to obtain CARB certification. Once the U.S. Environmental Protection Agency (EPA) grants California a waiver of federal preemption under the Clean Air Act, Pennsylvania will begin to realize the benefits of California's GHG-certified vehicles through the existing requirement that new vehicles have CARB certification.

On December 19, 2007, President Bush signed the Energy Independence and Security Act of 2007. This Act included a provision to raise the Corporate Average Fuel Economy (CAFE) standard to 35 miles per gallon (mpg) by 2020. If the CAFE standard were to be in effect, Pennsylvania would realize GHG emission reductions of 5.0 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) in 2020 and 7.8 $MMtCO_2e$ in 2025.

On May 19, 2009, President Obama announced that new federal fuel economy standards for new light-duty vehicles will be established through a joint rulemaking process between the EPA and the U.S. Department of Transportation (DOT). Under the agreement, CARB would be granted its 2005 waiver request, which would allow CARB to set a state vehicle standard for GHGs that is more stringent than the federal standard. CARB has also agreed to set vehicle standards that are identical to federal standards for model years 2012–2016, if CARB receives a waiver that allows it to set vehicle standards after 2016. It is most likely that the agreement announced by President Obama will go into effect.

On June 30, 2009, EPA granted California’s request for a waiver of Clean Air Act preemption for California’s emission standards for 2009 and later model years, adopted by the California Air Resources Board on September 24, 2004. This decision withdraws and replaces EPA’s previous March 6, 2008 denial. A newly implemented federal program would greatly reduce the GHG emission reductions benefit that Pennsylvania derives from adoption of the CARB standards. New light-duty vehicles titled in Pennsylvania would produce less GHG emissions for model years 2009, 2010, and 2011 as a result of EPA granting CARB’s waiver request, but the federal program and CARB’s program would become identical between 2012 and 2016. Therefore, the PCV Program would generate no emission reductions between those years. By the target year 2020, the vehicles for model years 2009, 2010, and 2011 would comprise only about 17 percent of the Pennsylvania fleet. Also, these three model years would contribute the least amount of GHG emission reductions of all the years of the PCV Program. It is only starting in 2013 when new vehicles will demonstrate a significant increase in fuel economy and, consequently, lower emissions of GHGs. The overall effect of a new federal program is to reduce the emissions benefit from the PCV Program to only 0.095 $MMtCO_2e$ in 2020.

Potential GHG Reductions and Economic Costs:[1]

Table 1-1. Estimated GHG Reductions and Cost-effectiveness

GHG emission savings (2020)	0.095	$MMtCO_2e$
Net present value (2009–2020)	NQ	$million
Cumulative emission reductions (2009–2020)	1.27	$MMtCO_2e$
Cost-effectiveness (2009–2020)	NQ	$/tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.

Estimated Reduction: 0.095 MMt. Using an EPA-approved highway vehicle emissions model (MOBILE6), combined with Pennsylvania-specific highway vehicle registration and traffic data, potential baseline (i.e., without the PCV Program) CO_2 emissions in 2025 can be estimated. Assuming reductions similar to CARB's predictions and adjusted to account for (1) Pennsylvania fleet composition, (2) a lack of a zero-emissions vehicle sales percentage mandate, and (3) a small "rebound effect,"[2] Pennsylvania can experience a small overall emissions reduction in 2020.

This estimate assumes that the vehicle miles traveled (VMT) by subject vehicles would be 128 billion miles annually in 2025, based on a PennDOT-approved highway vehicle growth methodology.[3] The estimate assumes current mpg estimates for subject vehicle classes would be increased to 32.9 mpg (average of both passenger vehicles and trucks) by 2012 from current mpg estimates of 26.3 and 21.9 for passenger vehicles and trucks, respectively. It is also assumed that 99 percent of all fuel used would be combusted to CO_2.

Economic Cost: There currently is no appreciable retail price difference between CARB-certified and non-CARB-certified vehicles. CARB estimated that its new GHG provisions (beginning in the 2009 model year) could add $1,000 to the price of larger subject vehicles (sport utility vehicle [SUV] or small truck) in 2014. CARB further estimated that the money the motorist saves due to increased operational efficiency will more than offset the additional cost over a 5-year life of the vehicle. In addition, as the existing GHG-reducing vehicle technologies are used more by automakers, there is an increased likelihood these potential additional costs will not be passed on to the consumer, but will be absorbed into the overall price of the vehicle, as appears to happen now.

[1] The 2020 GHG emission reduction benefits of the California GHG standards are as estimated in the MS Excel workbook: PCV GHG Benefits-Baker Analysis-6-12-08.xls. Personal Communication, Dan Szekeres at Michael Baker, Inc, email received by Jackson Schreiber on 5/4/09.
[2] The "rebound effect" can be described as the cumulative effect of drivers potentially increasing their individual vehicle miles traveled (VMT) as the fuel efficiency of their vehicles improves. This effect is difficult to model using conventional models, and the magnitude of the effect (estimated from 0% to 17%) is currently being debated. Many other variables, besides vehicle fuel efficiency, also influence VMT.
[3] This methodology employs a regression-based forecasting model that uses PA county-level socioeconomic factors (e.g., population, household data, employment, land use, education, retail sales, etc.) to estimate future VMT on the PA highway network.

No additional significant costs to DEP or PennDOT will occur for the implementation and operation of this program, since the program is already in effect for the purpose of reducing emissions that relate to criteria pollutions.

Implementation Steps: The PCV Program is currently being implemented. The GHG benefits of this program will not be realized until the EPA grants California a waiver of federal preemption under the Clean Air Act. This occurred June 30, 2009. The most likely scenario is that EPA will grant CARB a waiver in order to secure a national low-emissions vehicle program.

Key Assumptions: An agreement between the federal government and the automobile manufacturers will be finalized and will result in the harmonization of California and federal light-duty vehicle GHG emission standards.

Key Uncertainties: Model year 2009 benefits are uncertain because the CA waiver request was not granted until June 30, 2009. To limit potential manufacturer concerns over their reliance on EPA's previous waiver denial, EPA's decision provides that CARB may not hold a manufacturer liable or responsible for any noncompliance civil penalty action caused by emissions debits generated by a manufacturer for the 2009 model year.

Additional Benefits and Costs: The PCV Program was adopted to reduce emissions from light-duty vehicles—particularly concentrations of criteria pollutants in the ambient air—which would allow areas of Pennsylvania to meet the National Ambient Air Quality Standards (NAAQS). The PCV Program lowers emissions of oxides of nitrogen (NO_x) and volatile organic compounds (VOCs), which are both precursors of the formation of ground-level ozone. By 2025, the program will lower emissions of NO_x by 3,540 short tons per year, VOCs by up to 6,170 short tons per year, and air toxics from light-duty vehicles by 5 percent–11 percent.

For model years 2009, 2010, and 2011, a projected small increase for the cost of the vehicle is expected, but the fuel economy benefits will more than offset that cost over the life of the vehicle.

Potential Overlap: There is a potential overlap between the PCV Program, the Biofuel Incentive and In-State Production Act, Pay-As-You-Drive (PAYD), feebates, and other VMT-reducing or highway vehicle fuel programs. The estimated 2025 reductions for the PCV Program assume no changes in fuel or the implementation of any additional VMT-reduction strategy.

References:

EPA, 2009: California State Motor Vehicle Pollution Control Standards; Notice of Decision Granting a Waiver of Clean Air Act Preemption for California's 2009 and Subsequent Model Year Greenhouse Gas Emissions Standards for New Motor Vehicles, June 30, 2009.

EPA and DOT, 2009: Notice of Upcoming Joint Rulemaking to Establish Vehicle GHG Emissions and CAFE Standards, May 19, 2009.

ARB, 2008: California Air Resources Board, Comparison of Greenhouse Gas Emission Reductions for the United States and Canada under U.S. CAFE Standards and California Air Resources Board Greenhouse Gas Regulations, February 25, 2008.

Transportation 2. Biofuel Development and In-State Production Incentive Act and the Regional Low Carbon Fuel Standard

Summary: The Biofuel Development and In-State Production Incentive Act (Act 78 of 2008, previously referred to as the PennSecurity Fuels Initiative) requires minimum volumes of cellulosic ethanol and biodiesel to be blended into gasoline and diesel fuel, commensurate with specified in-state production levels of these biofuels. Pennsylvania will also be working with ten other states in the Northeast and Mid-Atlantic States Low-Carbon Fuel Standard Program to study and design a regional Low-Carbon Fuel Standard (LCFS) and identify the benefits and drawbacks of adopting a regional standard.

Other Involved Agencies: PennDOT, Pennsylvania Department of Agriculture (PDA).

Implementation Steps: This option quantifies the costs and GHG savings of expanded biofuel production and use. The biofuel pathway used in this quantification represents the amount of fuel that Pennsylvania would require in order to meet its share of the federal Renewable Fuels Standard (RFS). Pennsylvania accounted for 3.63 percent of national fuel consumption in 2007. The quantities of biofuel being considered in this analysis are shown in Table 2-2. The state biofuel mandate (Act 78) will be valuable to ensure that biofuel produced will be blended and sold in the state, thus ensuring a market for biofuel producers. However, because Act 78 does not specifically outline years in which certain levels of biofuel production must occur, the federal RFS was used as a stand-in.

The GHG impact of Act 78 was modeled separately and in combination with the national RFS. It was determined that the national RFS would result in the blending of 10 percent ethanol into all PA gasoline sooner and regardless of implementation of Act 78. The national RFS has minimum GHG life-cycle assessment standards for all biofuels. These standards were incorporated into the modeling. Because of the national RFS life-cycle standards for ethanol, no additional GHG reductions are expected for PA as a result of the cellulosic ethanol requirement in Act 78. However, there are additional reductions in GHG emissions beyond what is provided in the national RFS, because Act 78 ensures a greater volume usage of biodiesel, provided that in-state production and infrastructure requirements of Act 78 are met. The details of Act 78 that specify minimum production levels that will trigger the required blending of biofuels are as follows:

- E-10 required one year after in-state production of cellulosic ethanol reaches 350,000,000 gallons
- B2 required one year after in-state production of biodiesel reaches 40,000,000 gallons
- B5 required one year after in-state production of biodiesel reaches 100,000,000 gallons
- B10 required one year after in-state production of biodiesel reaches 200,000,000 gallons
- B20 required one year after in-state production of biodiesel reaches 350,000,000 gallons

In-state production must continue to increase, and the required infrastructure (blending, transportation, and storage) must continue to be installed and maintained.

Additional Potential Measures: In addition to Act 78 and the federal RFS, several other measures could be implemented to help advance biofuels production and use in Pennsylvania. These measures include:

Establish a Next-Generation Renewable Fuels Feedstock Program: This would encourage the sustainable production of next-generation bioenergy and biomass materials while reducing risk to landowners. For more information on the production of biofuels, see AG-2 - Leading a Transition to Next Generation Biofuels.

Create a Green Retailers Program (Tax Incentives for E85 and Biodiesel Sales): The state should establish a Green Retailers Program that rewards retail and wholesale outlets that attain benchmarks in the sale of biofuels. This would provide state recognition for achievement and important cost savings to both the seller and the consumer of biofuels. (To provide alternative fuel choice to consumers, promote state energy security needs and reduce GHG emissions.) Access to alternative fuels should address both gasoline and diesel fuels. A Green Retailer designation would be provided by the state to any retail outlet that sells a minimum level of gasoline biofuel (E85).[4]

A Green Retailer will receive incentives to support the infrastructure development needed for E85 and to help ensure that the retailer is able to provide value-based pricing for sustainable consumer use (ethanol's lower energy content requires a lower price per gallon to offset the fuel economy reduction). The applicable incentive will be a reduction in the payment of motor fuel tax on all gasoline sold at the facility. These incentives are needed in the early stages of E85 growth to accelerate the development of new production, distribution, and retail channels.

The same incentives should apply to diesel transportation fuels. A Green Retailer designation would apply for similar minimum levels of B20 biofuel sales.

As an alternative to the application of incentives to the Green Retailer described above, a feebate approach could also be considered, where increases in the motor fuel tax (fee) could be used to create a fund that would provide Green Retailers with an incentive (rebate) amount for each gallon of E85 or B20 sold. Such a public–private partnership is critically needed to accelerate consumer access to alternative fuels and to support consumer value, setting the stage for increased use of renewable fuels in the transportation sector beyond low-level blends.

Background on Low-Carbon Fuel Standards and the Northeast and Mid-Atlantic States Low-Carbon Fuel Standard Program: To make an increase in biofuel production and consumption more effective, it is likely that a regional push toward biofuel use will be required. The Northeast and Mid-Atlantic states are working on a Low-Carbon Fuel Standard Program, which aims to study and design a regional LCFS and identify the benefits and drawbacks of adopting the standard.

[4] The notations E85 and E100 are used to show the percentage of ethanol in a gallon of fuel. E85 contains 85% ethanol and 15% gasoline, while E100 contains 100% ethanol. B20 contains 20% biodiesel and 80% conventional diesel fuel.

The participating states (CT, DE, ME, MD, MA, NY, NH, NJ, PA, RI, and VT) will work toward drafting a Memorandum of Understanding concerning the development of a regional LCFS by December 31, 2009, or soon thereafter. The LCFS could require fuel providers in the Northeast and Mid-Atlantic states to ensure that the mix of fuel they sell into the consumer market meets, on average, a declining standard for GHG emissions measured in CO_2-equivalent grams per unit of fuel energy sold. The standard will be measured on a life-cycle basis in order to include all emissions from fuel consumption and production, including the "upstream" emissions that are major contributors to the global warming impact of transportation fuels.[1]

An LCFS is envisioned to be a market-based, technologically neutral policy to address the carbon content of fuels by requiring reductions in the average life-cycle GHG emissions per unit of useful energy. Such a standard is potentially applicable not only in transportation, but also for fuel used for heating buildings, for industrial processes, and for electricity generation. An LCFS has the potential to ease the transition to a low-carbon economy if implemented in the context of a broader strategy to reduce GHG emissions. Unlike an RFS, it allows other fuels (besides ethanol) to be used for compliance, rewards fuels with the lowest life-cycle GHG emissions, and discourages the development of high-carbon fuels, such as liquid coal. Fuels that may have the potential to reduce the carbon intensity of transportation include electricity and advanced bio-fuels that have lower life-cycle carbon emissions and are less likely to cause indirect effects from crop diversion and land-use changes than those on the market today.[2]

Reducing GHG emissions from transportation sources will involve controls on vehicles and fuels. Vehicle-borne technology is available to control GHG emissions from the petroleum-powered vehicle, but these controls will not reduce emissions sufficiently to meet projected LCFS reduction goals. Of all GHGs, controlling CO_2 emissions is the primary concern, because it is the most difficult GHG to control.

Just as emissions of criteria pollutants from transportation sources, such as PM, VOCs and NO_x, have been addressed by regulating vehicles and fuels, the same approach to curb GHG emissions should also be pursued. Vehicle-borne technology aimed at specifically controlling criteria pollutants (carbon monoxide, VOCs etc.,) comes in primarily two forms: after-treatment devices placed on the exhaust stream, and adjustments made to the engine operating parameters. These controls reduced criteria pollutant emissions from the tailpipe by up to 97 percent, and did not appreciably affect fuel economy In fact; vehicle-borne controls that regulate criteria pollutants are allowing greater engine efficiency improvements today. Installing after-treatment devices on the exhaust system of a vehicle is an impractical option when trying to control CO_2 emissions. Practically speaking, enhancing engine efficiency and operating characteristics are the best ways to control CO_2 emissions. Nevertheless, even with these improvements, the theoretical limit of efficiency for the internal combustion engine will soon be reached, and no more CO_2 reductions will be available. In all likelihood, this theoretical limit will be reached before the needed CO_2 reductions from the transportation sector occur. The need to control emissions from fuels will be even more necessary in the case of controlling CO_2 than criteria pollutants for the reasons outlined above.

Although the transition to an LCFS may prove difficult, the end result will derive many benefits. An LCFS can be developed to be market-oriented and consumer-friendly. Development of an

LCFS, if structured properly, will serve to diversify the fuel supply by encouraging transportation fueled by electricity, biofuels, and technologies and infrastructure that will be developed in the future. An LCFS will reduce our dependence on foreign sources of energy and address some of the security concerns that this country faces over that dependence.

As stated, eleven Northeast states and Pennsylvania have signed a letter of intent to study the LCFS issue in depth, in order to develop a Memorandum of Understanding. The final LCFS, if adopted, will rely on many technologies and fuels to reach the intended reduction targets.

Potential GHG Reductions and Economic Costs:

Table 2-1. Estimated GHG Reductions and Cost-effectiveness

GHG emission savings (2020)	3.47	$MMtCO_2e$
Net present value (2009–2020)	-$203	$million
Cumulative emissions reductions (2009–2020)	14.8	$MMtCO_2e$
Cost-effectiveness (2009–2020)	-$14	$/$tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate costs savings.

This analysis looks specifically at how biofuels could reduce the carbon content of fuel and, therefore, reduce overall transportation emissions. Electric propulsion was not considered in this analysis, although it could reduce the carbon content associated with fuels.

The gallons of diesel fuel and gasoline forecast to be used in Pennsylvania vehicles come from communication with PennDOT and Michael Baker, Inc., who provides technical assistance in this area to PennDOT. The goal is to reduce the life-cycle emissions from biofuels based on the quantities needed to fulfill Pennsylvania's portion of the federal RFS. Pennsylvania accounts for 3.63 percent of total U.S. fuel consumption. Using this breakdown, the amount of each biofuel required is shown in Table 2-2. Cellulosic ethanol is specifically required in the RFS, whereas other advanced biofuels were assumed to come from biodiesel, and later from algae biodiesel. Biodiesel is currently the most significant source of renewable fuel in Pennsylvania, and this is why advanced biofuels are assumed to come as biodiesel (personal communication, Mike Rader, PDA). No production of corn ethanol existed in Pennsylvania as of 2008, and since the GHG reductions associated with starch-based ethanol are not significant, it was not included in this analysis.

Table 2-2. Quantities of Biofuels Required in PA based on RFS, and Produced in the Agriculture, Forestry, and Waste Management Analysis

Year	Cellulosic Ethanol (Million Gals)	Gen-1 Biodiesel (Million Gals)	Algae Biodiesel (Million Gals)
2010	4	31	0
2011	9	40	0
2012	18	54	0
2013	36	64	0
2014	64	64	9
2015	109	64	27
2016	154	64	45
2017	200	64	64
2018	254	64	82
2019	309	64	100
2020	381	64	100

However, there are other demands on biodiesel resources from home heating oil. The Climate Change Advisory Committee's Residential/Commercial subcommittee is considering a policy that would require all home heating oil to contain 5 percent biodiesel. To avoid double counting biodiesel availability, it is assumed that all biodiesel will be going toward home heating oil, and then remaining quantities will be used in this analysis. It is possible that biodiesel would be imported from other states in this case, but such imported biodiesel will not be considered for GHG benefits in this analysis. The amount of biodiesel demand and remaining biodiesel supplies are shown in Table 2-3.

Table 2-3. Biodiesel Required for Home Heating and Remaining Quantities for Transportation

Year	Biodiesel Required for Home Heating (Million Gals)	Gen-1 Biodiesel Available (Million Gals)	Algae Biodiesel Available (Million Gals)
2010	44	0	0
2011	43	0	0
2012	42	13	0
2013	41	23	0
2014	40	29	4
2015	39	36	15
2016	38	41	29
2017	38	45	45
2018	37	48	61
2019	36	50	78
2020	35	50	78

The life-cycle emission factors used for gasoline (11.26 kilograms of carbon dioxide equivalent per gallon [kg CO_2e/gal]) and for diesel (11.25 kg CO_2e/gal) are from the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model (Argonne National

Laboratory [ANL], 2008). The figure for gasoline/diesel gallons replaced is determined based on the different heat contents of the biofuels (e.g., the heat content for gasoline is higher than that of ethanol but lower than that of diesel fuel) (Energy Information Administration [EIA], 2007). This means that in order to replace 1 gallon of gasoline, significantly more than 1 gallon of ethanol is needed to provide the same energy. The life-cycle emissions per British thermal unit (Btu) are shown in Table 2-4.

Table 2-4. Life Cycle CO_2e Emissions per Million Btu

Type of Fuel	Btu/Gal	kg CO_2e/Million Btu	kg CO_2e/Gal
Gasoline	125,100	90.01	11.26
Diesel	138,700	81.11	11.25
Cellulosic Ethanol (E100)	84,300	12.07	1.51
Soy/Grease Biodiesel (B100)	128,500	38.61	5.36
Algae Biodiesel	128,500	19.06	2.64

kg CO_2e = kilograms of carbon dioxide equivalent; Btu = British thermal unit; E100 = 100 percent ethanol; B100 = 100 percent biodiesel; gal = gallon.

The three biofuels being considered in this analysis are biodiesel from soy/waste grease, algae biodiesel, and cellulosic ethanol. The GHG savings of each individual fuel compared with conventional fossil fuels are shown in Table 2-5. Soy/waste grease biodiesel is considered Generation-1 (Gen-1) biodiesel and is currently being produced in Pennsylvania. This is assumed to increase until 2014, and then remain at that constant level for the rest of the period. Algae biodiesel production does not begin until 2014, and increases steadily from then on.

The amount of each biofuel required in the policy is shown in Table 2-5. The emission reductions of these biofuels are calculated by multiplying the gallons of fuel being replaced by the difference in GHG emission factors between the conventional fuel and the biofuel.

Table 2-5. Biofuel Quantities and the Associated Emission Reductions from the Implementation Path

Year	Life-Cycle Emissions Savings, Gen-1 Biodiesel ($MMtCO_2e$)	Life-Cycle Emissions Savings, Cellulosic Ethanol ($MMtCO_2e$)	Life-Cycle Emissions Savings, Algae Biodiesel ($MMtCO_2e$)	Total Life-Cycle Emissions Savings ($MMtCO_2e$)
2010	0.00	0.02		0.02
2011	0.00	0.06		0.06
2012	0.07	0.12		0.19
2013	0.12	0.24		0.36
2014	0.12	0.42	0.08	0.62
2015	0.12	0.72	0.23	1.07
2016	0.12	1.01	0.38	1.52
2017	0.12	1.31	0.53	1.97
2018	0.12	1.67	0.69	2.48
2019	0.12	2.03	0.84	2.99
2020	0.12	2.51	0.84	3.47
Total	**1.06**	**10.11**	**3.59**	**14.76**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

The costs of this option are calculated on the basis of the difference in cost between conventional fuels and biofuels. The cost estimates for gasoline and diesel come from the EIA *Annual Energy Outlook 2009* (AEO 2008). The cost estimates for cellulosic ethanol come from the analysis of the cost of producing cellulosic ethanol done for AG-2. This break-even cost for cellulosic producers ranges from $1.51 to $1.70 per gallon. Added to this cost is the profit margin for the producers and distributors, which also comes from AEO 2008. The difference in cost between the wholesale and retail price of corn ethanol found in the AEO was applied to cellulosic ethanol for each year. This resulted in a cost for cellulosic ethanol ranging between $1.93 and $2.26 per gallon. The cost for algae biodiesel was calculated based on the most conservative cost estimates from a study on algae biodiesel (Campbell et al., 2008). The costs of waste grease and soy biodiesel are projected into the future based on an EIA biodiesel report (Radich, 2004). For more information on how the biodiesel costs were calculated, see the discussion for AG-2. If biodiesel facilities can be located near a source of CO_2, then costs would be reduced. The total costs of each biofuel are shown in Table 2-6.

Table 2-6. Cost of Biofuels in T-2

Year	Additional Cost of Gen-1 Biodiesel (Million $)	Additional Cost of Algae Biodiesel (Million $)	Additional Cost of Cellulosic Ethanol (Million $)	Additional Cost of all Biofuels (Million $))
2010	0		0	0
2011	0		0	0
2012	7		-2	4
2013	11		-7	3
2014	28	-16	-22	-10
2015	48	-37	-63	-51
2016	76	-38	-53	-15
2017	93	-33	-57	3
2018	101	-30	-87	-16
2019	108	-24	-116	-33
2020	108	-27	-171	-90
Total				**-205**

Numbers may not sum due to rounding errors. Negative numbers indicate costs savings.

The prices of cellulosic ethanol are lower on a per-gallon basis than that of gasoline for the entire policy period. However, because more gallons of ethanol are needed to provide the same amount of energy as a gallon of gasoline, this price difference is significantly reduced. In years where the price of ethanol is predicted to be low (such as 2015), cellulosic ethanol is very cost-effective when compared to the predicted price of gasoline. On the other hand, in years (such as 2013) where the price of ethanol is quite comparable to that of gasoline (on a per-Btu basis), then the cost savings from using ethanol compared to using gasoline are relatively small. Gen-1 biodiesel has a lower energy content than traditional diesel fuel and is estimated to have relatively similar costs/gallon compared to traditional diesel fuel throughout the policy period. Algae biodiesel is more expensive than Gen-1 biodiesel, and has positive costs throughout the policy period. The costs of fuel in 2015 and 2020 are shown in Table 2-7.

Table 2-7. Fuel Costs in 2015 and 2020

Year	Gasoline ($/gal)	Diesel ($/gal)	Gen-1 Biodiesel Cost (B100) ($/gal)	BioDiesel From Algae ($/gal)	Cellulosic Ethanol (E100) ($/gal)
2015	3.72	3.74	$3.50	$4.12	$1.93
2020	3.85	3.79	$3.75	$4.38	$2.14

B100 = 100 percent biodiesel; E100 = 100 percent ethanol; $/gal = dollars per gallon.

If this policy were implemented as written, it would exceed the amount of ethanol that could be consumed through the use of E10 (10 percent ethanol blend) in gasoline. It would therefore require the introduction of additional flexible-fueled (flex-fuel) vehicles capable of running on E85. According to AEO 2008, the additional cost of a mid-sized vehicle that can run on flex fuel is $400. The number of vehicles that would be required to run on flex fuel is calculated by assessing the amount of ethanol produced beyond 10 percent (which can be burned in all gasoline engines as E10), and the number of new vehicles that would have to be sold to burn the additional quantities of ethanol. The number of new cars sold in PA comes from the estimate made in the feebates analysis (part of T-5). Table 2-8 shows the additional costs of vehicle modifications in T-2. The new cars sold in the state are based on the 537,000 figure for 2007 from Michael Baker, Inc. It is possible that the cost of these vehicles is being overestimated, because Pennsylvania already has a significant number of flex-fuel vehicles on the road. Biodiesel will not require additional vehicle modifications, because B20 can be used in vehicles without special modifications.

Table 2-8. Costs of Vehicle Modifications in T-2

Year	% Gasoline Replaced (volumetrically)	% of Cars Needed to be Flex-Fuel Vehicles	Number of Cars Needed to be Flex-Fuel Vehicles	Additional Cost of Flex-Fuel Vehicles (MM$)
2010	0.08%	0.00%	0	$0
2011	0.22%	0.00%	0	$0
2012	0.44%	0.00%	0	$0
2013	0.89%	0.00%	0	$0
2014	1.58%	0.00%	0	$0
2015	2.75%	0.00%	0	$0
2016	3.94%	0.00%	0	$0
2017	5.16%	0.00%	0	$0
2018	6.65%	0.00%	0	$0
2019	8.17%	0.00%	0	$0
2020	10.21%	0.21%	1,339	$1
Total				**$1**

MM$ = million dollars.

To sell these higher quantities of ethanol, more service stations must provide E85 pumps. E85 pumps are different from traditional gasoline pumps, because ethanol is more susceptible to contamination by mixing with water. Therefore, pumps must be modified to avoid any possible condensation/contamination. The cost of these pumps is estimated to be an additional $59,000 for each service station (NREL, 2008). Table 2-9 shows the costs of these modifications for the State of Pennsylvania.

Table 2-9. Costs of Service Station Equipment to Sell E85

Year	% of Service Stations That Need to Sell E85	Stations in Pennsylvania That Need to Sell E85	Cost of Service Station Upgrades (Million $)
2010	0.00%	0	$0
2011	0.00%	0	$0.0
2012	0.00%	0	$0.0
2013	0.00%	0	$0.0
2014	0.00%	0	$0.0
2015	0.00%	0	$0.0
2016	0.00%	0	$0.0
2017	0.00%	0	$0.0
2018	0.00%	0	$0.0
2019	0.00%	0	$0.0
2020	0.25%	11	$0.6
Total			**$0.6**

Table 2-10 shows the total costs of T-2, including the additional cost of using biofuels compared to using conventional gasoline/diesel fuel, as well as the additional costs of flex-fuel vehicles and service stations to enable them to sell biofuels.

Table 2-10. Total Costs of T-2

Year	Additional Cost of All Biofuels ($MM)	Additional Cost of Vehicles ($MM)	Additional Cost of Gas Stations ($MM)	Total Cost of T-2 ($MM)
2010	0	0	0	0
2011	0	0	0	0
2012	4	0	0	4
2013	3	0	0	3
2014	-10	0	0	-10
2015	-51	0	0	-51
2016	-15	0	0	-15
2017	3	0	0	3
2018	-16	0	0	-16
2019	-33	0	0	-33
2020	-90	1	1	-89
Total				**-$203**

Numbers may not sum due to rounding. Negative numbers indicate costs savings.
MM$ = million dollars.

<u>Key Assumptions</u>: The costs to produce each of the biofuels in this option come from the production costs in AG-2. The difference between wholesale and retail costs is estimated based on the difference seen between wholesale and retail corn ethanol costs.

This analysis does not include the potential infrastructure costs of transporting and blending ethanol into gasoline at terminals in rural areas of Pennsylvania. While historically, ethanol has been splash blended with conventional gasoline, it is expected to be match-blended by 2020. This same assumption was made by EPA in its RFS2 Regulatory Impact Analysis.

Key Uncertainties: Fuel price estimates come from AEO 2008, which is the best and most widely available estimate of fuel price forecasts. There are significant uncertainties in predicting the cost of fuel over a long period of time. Depending on the cost difference between conventional gasoline/diesel fuel and biofuels, the cost figures for this option could change significantly. The prices of cellulosic ethanol and algae biodiesel are particularly difficult to estimate and are largely speculative, because they are not currently available on a commercial scale. Many factors—such as economic growth, political stability in oil-producing regions, efficiency improvements, oil production, and fuel switching—influence fuel price forecasts. If fuel price estimates change dramatically in the next few years, then the cost-effectiveness of this option may be inaccurate. It is important to note that these costs are the best estimate that can be made for 2009, but as more data come out on fuel prices and production costs, better estimates can be made in the future.

Implementation of T-2 relies heavily upon cellulosic ethanol and biodiesel from algae. Uncertainties exist for these technologies concerning feedstock availability, logistics, and conversion technology. According to the *National Biofuels Action Plan* (October 2008):

> "Although R&D [research and development] on cellulosic ethanol has made progress in reducing estimated conversion costs, production costs remain too high for biomass-based fuels to compete in the marketplace. Transformational breakthroughs in basic and applied science will be necessary to make plant fiber-based biofuels economically viable."

Cellulosic ethanol and biodiesel-from-algae technology and production capacity have not yet been proven on a commercial scale. This raises concerns about the viability for volumes of cellulosic and biodiesel fuel.

Emission factors for these fuels come from national estimates. Depending on the blending, components, and production practices, emission factors can be significantly affected.

Some service stations have had difficulties installing E85 pumps. Issues such as the potential for leakage, fire safety concerns, and uncertain fuel quality make some station operators uneasy with installing the new technology. Improved standardization and certification of E85 pumps might help reduce these concerns.

There is considerable uncertainty in modeling the indirect effects (land-use changes) of biofuel production.

Additional Benefits and Costs: Other benefits or costs of increased biofuel use that are not quantified here include:

- The impact (positive or negative) on other air pollutants of concern.
- The sustainability of production.

- Flexibility to adjust based on the emergence of other technologies that might result in greater or more cost-effective GHG reductions.
- The impact on food prices.
- The impact on fuel tax revenue.
- The impact on the cost of goods delivery (i.e., fuel prices).
- Other environmental impacts, such as water quality and quantity, and conservation of land.
- Secondary land-use impacts.
- Security benefits from domestic fuel production.

Potential Overlap:

- PA Clean Vehicles
- Low-Rolling-Resistance Tires
- Diesel Anti-Idle
- Eco-Driving
- Public Transit

Subcommittee Recommendations

Broadly, the committee felt that within the transportation sector, we not only need to be finding ways to decrease vehicle trips and increase the efficiency of those trips, but also decrease GHG emissions from the fuel itself. That's what this work plan encompasses. With regard to costs and benefits, this work plan was projected to accomplish some of the most significant GHG reductions of any of our subcommittee's work plans (14.8MMtCO2E for 2009-2020), while saving money overall.

One member noted that the way in which crops for cellulosic ethanol are grown and harvested can impact the GHG and environmental impacts of the fuel.

References:

[1] The Role of a Low Carbon Fuel Standard in Reducing Greenhouse Gas Emissions and Protecting Our Economy. P.1. January 7, 2007; available at: http://gov.ca.gov/index.php?/fact-sheet/5155/ .

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Transportation 3. Low-Rolling-Resistance Tires

Summary: Require low-rolling-resistance (LRR) tires to be sold as replacement tires on vehicles that are normally equipped with them off the assembly line.

Other Involved Agencies: None. Automobile manufacturers already install low-rolling-resistance tires on all new automobiles in order to comply with CAFE standards. This situation is unlikely to change. Therefore, it is unnecessary for PennDOT to examine new vehicles as they are titled, as in the PCV Program.

Possible New Measure(s): LRR tires can improve vehicles' fuel efficiency from 1.5 percent to 4.5 percent when used in place of non-LRR tires. All automobile manufacturers install LRR tires on most new vehicles in order to meet federal CAFE standards. Some vehicles with certain high-performance characteristics are not equipped off the assembly line with LRR tires. The PennDOT would require LRR tires to be sold as replacement tires on vehicles that are normally equipped with them off the assembly line. This action could increase the use of LRR tires by 25 percent–35 percent on a VMT basis for light-duty vehicles, depending on the specific light-duty fleet mix in Pennsylvania.

Every state examining LRR tires claims that 3 percent better fuel efficiency is achievable using these tires. New vehicles, high-performance vehicles, certain vehicles that travel off-road, consumers who buy tires out of state, and consumers who already purchase LRR tires will be unaffected by this initiative. Therefore, a 35 percent rule penetration is estimated.

Potential GHG Reduction and Economic Costs:

Table 3-1. Estimated GHG Reductions and Cost-effectiveness of T-3

GHG emission savings (2020)	0.68	$MMtCO_2e$
Net present value (2009–2020)	-$1,244	$million
Cumulative emissions reductions (2009–2020)	4.15	$MMtCO_2e$
Cost-effectiveness (2009–2020)	-$353	$\$/tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate costs savings.

Rolling resistance reduces the amount of engine power that can be transferred to moving a vehicle along the road. This policy is intended to encourage the use of LRR tires as replacement tires, because new vehicles typically already use LRR tires to achieve their CAFE requirements. The fuel efficiency savings possible from installing LRR tires was estimated at 3 percent according to the California Energy Commission (CEC, 2003). The fuel efficiency savings from trucks is even more significant, with an average savings of 3.9 percent (Ang-Olson and Schroeer, 2001).[5] Life-cycle gasoline emissions for passenger cars were estimated to be 11.26 kg CO_2e/gal, while life-cycle diesel fuel emissions for freight trucks were estimated to be 11.25 kg CO_2e/gal

[5] The 3.9% figure is an average of the Bridgestone and Michelin Study on LRR tires.

(ANL, 2008). Both of these emission factors come from the GREET model. The implementation path represents the percentage of vehicles that will have LRR tires that otherwise would not have them. This policy assumes that this number increases to 35 percent of Pennsylvania vehicles by 2020. The implementation path used and the GHG savings from LRR tires are shown in Table 3-2.

Table 3-2. Implementation Path and Greenhouse Gas Savings of Low-rolling-resistance Tires

Year	Implementation Path	Reduction in Fuel Use, Passenger Cars	Reduction in Fuel Use, Freight Trucks	Gas Gallons Saved (Million Gallons)	Diesel Gallons Saved (Million Gallons)	Lifecycle Emissions Savings ($MMtCO_2e$)
2009	0.0%	0.00%	0.00%	0.0	0.0	0.00
2010	3.2%	0.10%	0.12%	4.1	1.7	0.06
2011	6.4%	0.19%	0.25%	8.0	3.4	0.13
2012	9.5%	0.29%	0.37%	11.9	5.2	0.19
2013	12.7%	0.38%	0.50%	15.6	7.0	0.25
2014	15.9%	0.48%	0.62%	19.2	8.9	0.32
2015	19.1%	0.57%	0.74%	22.7	10.9	0.38
2016	22.3%	0.67%	0.87%	26.1	12.9	0.44
2017	25.5%	0.76%	0.99%	29.5	15.0	0.50
2018	28.6%	0.86%	1.12%	32.8	17.2	0.56
2019	31.8%	0.95%	1.24%	36.0	19.4	0.62
2020	35.0%	1.05%	1.37%	39.1	21.7	0.68
Total						**4.15**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Estimates of the number of vehicles in the program were made by multiplying the passenger vehicles or commercial trucks registered in Pennsylvania by the implementation path (Wards, 2008). The costs of this policy were based on the additional cost of LRR tires, estimated to be $5 for a new set of tires for light-duty vehicles and $12 for four new tires for a freight truck (CEC, 2003). These costs were in 2001 dollars, so they need to be discounted forward to 2007. Other sources were considered for the cost differential, but these typically did not have such an exact figure or estimate for the difference in costs that comes with LRR tires. A 2006 Transportation Research Board (TRB) report found that LRR tires were not consistently more expensive than standard tires, so it is possible the costs of this program are overestimated (TRB, 2006). These costs were then applied to all vehicles in the program every 2.5 years, to represent tires being replaced. For trucks, the same cost factor was used, but was applied to 18 wheels rather than 4; thus, the additional cost of 18 new freight truck tires is $72 (2007 dollars). The costs of this policy are shown in Table 3-3. Taking into account the fuel savings over the course of the policy period, the use of LRR tires is a net cost savings.

Table 3-3. Costs and Cost Savings from Low-rolling-resistance Tires

Year	Cost LRR Tires, Passenger Cars ($ Million)	Cost, LRR Tires, Freight Trucks ($ Million)	Cost Savings, Passenger Cars (Million $)	Cost Savings, Diesel (Million $)	Net Cost, Low Rolling Resistant Tires (Million $)
2009	$0	$0	$0	$0	$0
2010	$1	$1	$12	$5	-$15
2011	$2	$2	$26	$11	-$33
2012	$3	$3	$40	$18	-$52
2013	$3	$4	$55	$25	-$72
2014	$4	$5	$70	$33	-$93
2015	$5	$6	$84	$41	-$114
2016	$6	$7	$98	$49	-$134
2017	$7	$8	$112	$56	-$153
2018	$8	$9	$125	$65	-$173
2019	$8	$10	$138	$73	-$193
2020	$9	$11	$151	$82	-$212
Total					**-$1,244**

LRR = low-rolling-resistance [tires]. Negative numbers indicate costs savings.

Key Assumptions: The analysis assumes that the GHG savings found in LRR tires can be applied to all vehicles. Different vehicle types and driving behavior can impact the fuel savings from LRR tires.

Key Uncertainties:

- A mandate on LRR tires could cause some customers to purchase less expensive (non-LRR) tires out of state.
- This analysis is based on fuel savings and costs, which are average values. It is possible that individual costs/fuel savings could be different.

Additional Benefits and Costs: LRR tires can require additional stopping distance at highway speeds, thus creating safety concerns.

Implementation Steps: A regulation specifying what types of tires are available for purchase in the commonwealth could be developed as a consumer product regulation where DEP is the only agency involved.

This would be a regulation that would go through DEP's rulemaking process, which would take 18–24 months. DEP would examine other state programs to form a basis for its own regulation. It would meet with tire industry and automobile industry representatives during the rulemaking process. DEP would provide ample opportunity for public comment.

Right now, not all car types have LRR tires as a purchase option. DEP could expand its requirements as tires for heavy trucks and other vehicles become available. DEP could also require tires that have even lower rolling resistance, as the technology develops.

An alternative approach would be to develop a public information program that would allow consumers to compare costs and performance of LRR tires, so that they could make a more informed decision when purchasing tires. The market penetration of LRR tires would be much less in a voluntary program and less GHG reductions would occur.

Potential Overlap:

- PCV Program
- Biofuels Incentive and In-State Production Act
- Eco-Driving

Subcommittee Comments

This is a fairly simple policy to implement, calling for the same tires found on most new cars to be used as replacement tires as well. It is projected to achieve 4.1MMtCO2E for 2009-2020, with a sizeable financial savings (-$300/tCO2E) from fuel savings.

References:

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Transportation 4. Diesel Anti-Idling Program

Summary: Implementation of Act 124 of 2008, the Diesel-Powered Motor Vehicle Idling Act, and DEP's related regulation.

Other Involved Agencies: The Pennsylvania State Police and local law enforcement agencies could be involved in enforcement action.

Possible New Measure(s): DEP developed a rulemaking that would restrict idling from diesel vehicles with a gross weight of 10,001 pounds or more throughout the commonwealth. The final-form rulemaking was approved by the Environmental Quality Board (EQB) in September 2008. The Pennsylvania House of Representatives, based on many of the provisions in DEP's rulemaking, amended Senate Bill 295, which was legislation that also restricted diesel idling in the commonwealth.

On October 8, 2008, the General Assembly enacted the Diesel-Powered Motor Vehicle Idling Act, Act 124. Governor Rendell signed Act 124 into law on October 9, 2008, and it went into effect on February 6, 2009. Act 124 restricts diesel idling to 5 minutes in any continuous 60-minute time period for diesel-powered vehicles with a gross weight of 10,001 pounds or more engaged in commerce. It offers exemptions for safety and practical concerns, as well as for the efficient movement of traffic.

Idling restrictions would also derive a co-benefit by reducing the amount of fuel that diesel-powered commercial motor vehicles consume. Not only would vehicle owners and operators realize cost savings by complying with Act 124, they would also be contributing to the commonwealth's energy independence.

Act 124 is primarily an air pollution control measure, and reductions in fuel use and CO_2 emissions are incidental. The Act does not specify how the trucking industry should comply. DEP believes that most trucking companies will choose options that will reduce idling and save fuel at the same time, while meeting the requirements of this air quality control measure. Technology options may exist in the near future, where acceptable idling practices outlined in the Act may be met, but no reduction in fuel consumption would be realized. For instance, the Act would allow for main engine idling in a diesel-powered commercial motor vehicle, if the engine met an alternative "clean idling" air emission standard. In this particular case, no fuel savings would result.

Potential GHG Reductions and Economic Costs:

Table 4-1. Estimated GHG Reductions from and Cost-effectiveness of T-4

GHG emission savings (2020)	0.07	$MMtCO_2e$
Net present value (2009–2020)	-$177	$million
Cumulative emissions reductions (2009–2020)	0.74	$MMtCO_2e$
Cost-effectiveness (2009–2020)	-$238	$/t CO_2e

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/t CO_2e = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate costs savings.

The total annual heavy-duty vehicle idling emissions (0.125 $MMtCO_2e$) are based on the report prepared for the EQB, *Quantification of Pennsylvania Heavy-Duty Diesel Vehicle Idling and Emissions—Final Report*, Michael Baker Jr., Inc, (March 2007). To reduce these idling emissions by 50 percent, anti-idling technologies will need to be installed in Pennsylvania. It is assumed that idling cannot be reduced without providing the services that previously were met with idling, typically either heating or cooling. The two technologies considered in this analysis are truck stop electrification (TSE) and auxiliary engine installation. The analysis divides the use of these technologies evenly (50 percent for each). The number of hours spent idling in Pennsylvania was estimated based on total idling emissions. Because a heavy-duty truck burns about 1 gallon of diesel fuel per hour of idling, the number of idling hours in PA was estimated to be 3.58 million hours (Stodolsky et al., 2000). The average vehicle idles 6.05 hours per day. Therefore, the number of vehicles idling in the state is estimated to be 5,073 (Baker, 2007).

Both TSE and auxiliary engines result in GHG emissions of their own (electricity emissions from TSE and diesel combustion from auxiliary engines). However, in both cases, these emissions are lower than traditional engine idling. TSE represents an 83 percent reduction in overall CO_2 emissions to provide the same services, whereas auxiliary engines provide a 73 percent emission reduction (Stodolsky et al., 2000). To achieve a 50 percent reduction in emissions, more than 50 percent of all vehicles require modifications that reduce idling. Table 4-2 shows the business-as-usual idling rate and the emission reductions estimated in the policy.

Table 4-2. GHG Savings from Truck Idling Reduction

Year	CO_2 Metric Tons per Year From Idling	Gallons Spent, Auxiliary Engines	Million Gallons Saved, Auxiliary Engines	MWh Spent, TSE	Million Gallons Saved, TSE	GHG Emissions, Anti-Idling Technologies	Net GHG Savings, Anti-Diesel Idling ($MMtCO_2e$)
2009	126,032	0.00	0.0	0	0.0	0.000	0.000
2010	125,953	0.96	3.6	13,443	3.6	0.017	0.063
2011	125,873	0.96	3.6	13,443	3.6	0.017	0.063
2012	125,794	0.96	3.6	13,443	3.6	0.017	0.063
2013	125,715	0.95	3.6	13,443	3.6	0.017	0.063
2014	125,636	0.95	3.6	13,443	3.6	0.017	0.063
2015	125,556	0.95	3.6	13,443	3.6	0.017	0.063
2016	125,477	0.95	3.6	13,443	3.6	0.017	0.063
2017	125,398	0.95	3.6	13,443	3.6	0.017	0.063
2018	125,239	0.95	3.6	13,443	3.6	0.017	0.063
2019	125,239	0.95	3.6	13,443	3.6	0.017	0.063
2020	125,239	0.95	3.6	13,443	3.6	0.017	0.063
Total							0.69

CO_2 = carbon dioxide; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; TSE = truck stop electrification.

The costs of TSE are estimated based on the costs of electricity, of vehicle modifications, and of truck stop modifications. Electricity costs were estimated to be 2,670 kilowatt-hours per year (kWh/yr) per space (TRB, 2004). The number of spaces was estimated to be 5,037, based on the hours of idling the policy is seeking to reduce (estimated from fuel consumption) divided by

710 hours, the average amount of use an electrified space receives in a year (TRB, 2004). These spaces cost an average of $3,517 (2007$) (Stodolsky et al., 2000). Modifications to individual trucks cost $2,393 (2007$), multiplied by the number of trucks using TSE technology, estimated to be 1,620 (Stodolsky et al., 2000). This estimate came from the number of long-haul trucks idling in the state (5,073 in 2009), multiplied by the percentage of trucks in the program (32 percent), in order to achieve the 50 percent idling reduction goal. The modifications for trucks and spaces occur only for the initial purchase in the first year of the program, as can be seen in Table 4-3.

The costs of auxiliary power units (APUs) are estimated based on the costs of APUs from the American Transportation Research Institute (ATRI) report ($8,085 in 2007$), annualized over 5 years (ATRI, 2006). These costs are annualized because it is assumed that these auxiliary engines only last 5 years, after which they will need to be replaced. Using a capital recovery factor (CRF) and a discount rate of 5 percent, the annualized cost is therefore $1,867. This figure is then multiplied every year by the number of trucks requiring this modification. This is calculated based on the number of trucks idling in the state (5,073 in 2009) multiplied by the percentage of trucks in the program to achieve the reduction goal (32 percent). Added to these costs are the costs of fuel for the APUs. The combined costs for the APUs are shown in Table 4-3. The cost savings from anti-idling measures are realized in the fuel savings from reduced engine idling, also shown in Table 4-3.

Table 4-3. Costs of and Cost Savings from Truck Idling Reduction

Year	Total Cost of TSE ($MM)	Total Cost of Auxiliary Engines ($MM)	Net Diesel Gallons Saved (Millions)	Fuel Savings from Idling Reduction ($MM)	Net Cost of Truck Anti-Idling ($MM)
2009	$0.0	$0.0	0.0	$0.0	$0.0
2010	$22.7	$5.8	6.2	$20.9	$7.6
2011	$1.2	$6.0	6.2	$22.4	-$15.2
2012	$1.3	$6.3	6.2	$24.2	-$16.7
2013	$1.2	$6.4	6.2	$25.0	-$17.4
2014	$1.2	$6.5	6.2	$26.1	-$18.3
2015	$1.3	$6.6	6.2	$26.7	-$18.8
2016	$1.3	$6.6	6.2	$26.7	-$18.8
2017	$1.3	$6.6	6.2	$26.7	-$18.8
2018	$1.4	$6.6	6.2	$26.8	-$18.8
2019	$1.4	$6.6	6.2	$26.9	-$18.9
2020	$1.4	$6.6	6.2	$26.9	-$18.9
Total					-$173

$MM = million dollars; TSE = truck stop electrification.

Reduced School Bus Idling

There are approximately 31,000 school buses in Pennsylvania based on estimates provided by the Pennsylvania Department of Motor Vehicles (DMV) (PA DMV, 2009). The number of school buses was increased based on the growth in school buses between 1999 and 2008 (2.2 percent annual growth). EPA's National Idle-Reduction Campaign calculator was used to estimate the potential fuel savings and fuel costs for a school bus idle reduction campaign. An idling reduction of 30 minutes per day would result in 45 gallons per year in saved diesel fuel. The GHG savings of applying these savings to all school buses are shown in Table 4-4. The buses were assumed to install engine block preheaters to be used in cold weather. These preheaters cost approximately $1,500; fuel costs are one-sixteenth those of traditional engine idling (EPA, 2009). Engine costs are considered as an annualized cost over 20 years, with a 5 percent discount rate. Because reduced engine idling also reduces engine wear, there would likely be savings in the cost of maintenance. These savings are not considered in this analysis. The costs and cost savings of reduced school bus idling are shown in Table 4-5.

Table 4-4. Greenhouse Gas Benefits from Reduced School Bus Idling

Year	Implementation Path	PA School Buses	School Buses in Program	Bus Savings (thousand diesel gals)	Emission Reduction ($MMtCO_2e$)
2009	0.0%	31,491	0	0	0.000
2010	4.5%	32,180	1,463	62	0.001
2011	9.1%	32,883	2,989	126	0.001
2012	13.6%	33,602	4,582	193	0.002
2013	18.2%	34,336	6,243	263	0.003
2014	22.7%	35,086	7,974	336	0.004
2015	27.3%	35,853	9,778	413	0.005
2016	31.8%	36,636	11,657	492	0.006
2017	36.4%	37,437	13,614	574	0.006
2018	40.9%	38,255	15,650	660	0.007
2019	45.5%	39,091	17,769	750	0.008
2020	50.0%	39,946	19,973	843	0.009
Total					**0.053**

Gals = gallons; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table 4-5. Costs of School Bus Idling Program

Year	Fuel Cost Savings (Million $)	Installation Costs (Million $)	Net Costs
2009	0.0	$0.0	$0.0
2010	0.2	$0.2	$0.0
2011	0.4	$0.4	$0.0
2012	0.7	$0.6	-$0.1
2013	0.9	$0.8	-$0.2
2014	1.2	$1.0	-$0.3
2015	1.5	$1.2	-$0.4
2016	1.8	$1.4	-$0.4
2017	2.2	$1.6	-$0.5
2018	2.5	$1.9	-$0.6
2019	2.8	$2.1	-$0.7
2020	3.2	$2.4	-$0.8
Total			**-$4.0**

Negative numbers indicate cost savings.

Implementation Steps: The Diesel Vehicle Idling regulation has been in effect since February 2009. DEP air inspectors, Pennsylvania State Police, and local police can all enforce this regulation. DEP will work with trucking companies and truck plaza owners and managers to develop the needed level of compliance and corresponding amount of GHG reductions.

Key Assumptions: The analysis assumes that a 50 percent idling reduction can be achieved through the use of TSE and auxiliary engines. Other technologies exist to provide the same services, but these two are used to demonstrate the overall cost-effectiveness of anti-idling programs.

It was assumed that school bus figures will increase at the rate seen in 1999–2008. If effective land-use policies are put into place in the next decade, fewer school buses will be required; thus, this may be an overestimate.

Key Uncertainties: It is also assumed that the average number of trucks idling can be determined based on the average idling taking place every day in Pennsylvania. However, this is likely an underestimate, because trucks leave the state in through traffic (travel which neither begins nor reaches its destination in Pennsylvania). If some estimate of the total number of different trucks idling in Pennsylvania could be found, that would improve the analysis (and would likely also make the option less cost-effective).

It is possible that an idle reduction program will be less successful if trucking companies cannot get carbon offsets by installing APUs and electrification equipment.

Much of the cost-effectiveness of this option has to do with the CRF chosen. If a 5-year payback is used, then capital costs are significant, and cost-effectiveness goes down. If a longer payback period is used, then a significant portion of the costs is occurring outside of the time period of the analysis, which makes the option seem more cost-effective.

Additional Benefits and Costs: Reductions in idling will also reduce emissions of toxics, NO_x, and particulate matter (PM). The primary co-benefits for Pennsylvania of this policy will be in reducing PM-2.5 (particulate matter 2.5 micrometers in diameter and smaller) precursor emissions, such as PM-2.5 and NO_x emissions in the state's PM-2.5 NAAQS nonattainment areas. Pennsylvania currently has two designated PM-2.5 nonattainment areas around Pittsburgh and Philadelphia. Initial implementation of this policy option should be in those areas.

Reducing fine-particle pollution, according to EPA studies, will mean improved health due to fewer cases of asthma, lost workdays, hospital visits, and premature deaths. Idle emission reductions will reduce wear from engine operation, thus leading to a cost savings from reduced maintenance costs.

Potential Overlap: Biofuel Development and In-state Production Incentive Act.

Subcommittee Comments

The subcommittee recommended consideration by the full CCAC. The subcommittee noted that in addition to GHG reductions, this will achieve significant local environmental and public health benefits, due to decreased overnight idling at truck stops leading to significant reductions in air pollution. It will also achieve substantial savings ($-238/tCO2E 2009-2020).

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Transportation 5. Eco-Driving

<u>Summary:</u> Implement a number of policies to encourage more efficient driving in Pennsylvania. This does not include public transportation, telecommuting, or carpooling, but rather finding ways to decrease the GHG emissions emitted by a car or truck traveling from point A to point B.

<u>Other Involved Agencies:</u> Department of Revenue (DOR), PennDOT, Pennsylvania Insurance Department, Pennsylvania State Police.

<u>Possible New Measure(s):</u>
Note: Not all of these measures have enough of a track record to warrant an extensive discussion here of implementation steps, and not all of them are quantifiable. Some elements of such measures will be considered for potential GHG benefits, but the scope of GHG savings and overall costs of such a program may not be considered.

<u>5A—Pay-As-You-Drive Insurance:</u> PAYD insurance provides financial incentives to motorists for driving less. PAYD links auto insurance policies to mileage by converting a portion of the insured driver's annual premium into a per-mile fee. The per-mile fee incorporates all existing rate factors.

<u>5B—Feebates:</u> This policy option aims to reduce GHG and other emissions by improving vehicle efficiency through feebates. Feebates usually comprise surcharges on the less publicly desirable personal vehicle, which in a revenue-neutral program, are used to fund rebates on the more publicly desirable personal vehicle. In this case, the 'pivot point' miles-per-gallon mark, that divides the more-efficient cars from the less-efficient vehicles, is set at a point which will ensure that rebates for the more efficient cars can be paid for by the fees on the less efficient vehicles. In the past, consumers tended not to take fuel costs (including higher taxes) over the lifetime of the vehicle into account when purchasing vehicles. Feebates/rebates could be implemented through sales tax, titling fees, or registration fees.

<u>5C—Education Regarding Efficient Driving Habits</u>: Regardless of what vehicle is being driven, there are ways to drive more efficiently, using less gas and thus emitting fewer GHG emissions. Information should be dispersed far and wide outlining efficient driving habits (not using cruise control going up hills, avoiding stop-and-go braking when possible, etc.). Dispersion points could include motor vehicle registration locations, new and used car lots, and auto body shops.

<u>5D—Require "Global Warming Index" Stickers for New Cars:</u> Such stickers would detail the GHG emissions of a new passenger vehicle, allowing consumers to more easily choose a more efficient new vehicle.

<u>5E—Enforce or Lower Speed Limits:</u> Going from point A to point B at a higher speed uses more fuel, creating more GHG emissions. By lowering the speed limit or more actively enforcing existing speed limits, some of these emissions could be avoided.

5F—Improve Truck Directional Assistance: Preventing drivers from getting lost prevents unnecessary VMT, and thus cuts emissions. Federal highway funds became available in 2005 to provide signage to truck stops, rest areas, industrial areas, warehouses, etc.; to date, color-coded detour routes and statewide Truckers' Guide/Map are available.

5G—Improved Tire Inflation: Keeping tires properly inflated increases the mpg achieved by vehicles and thus reduces emissions.

Implementation Steps - PAYD: Existing law needs to be reviewed to determine if additional legislation or regulation is required in the commonwealth to allow for a PAYD insurance program. PAYD insurance could be developed first as a pilot project to allow time to solve startup problems and to show the program's effectiveness. The pilot program would use electronic mileage monitoring only. Federal money was provided for a pilot program to purchase electronic mileage monitoring equipment in the Puget Sound Area through a Congestion Management Air Quality grant. The program would be expanded when problems are solved and if there is high demand for it.

High demand for a full PAYD insurance program could be determined by a survey or customer satisfaction reports from those enrolled in the pilot program. The commonwealth would need to create a network of certified auditors for a full program, which could be part of the state inspection program. Reasonable audit fees will need to be set. Any costs to the commonwealth to administer the program would need to be incorporated into either the audit fee or mileage premium. To achieve maximum reductions in CO_2 emissions, all motorists would be required to have PAYD insurance for the full program.

PAYD insurance would charge an extra cost for each mile traveled by a motorist, allowing motorists to pay for car insurance based on the distance that they travel. Most states that have initiated these programs believe that a 10 percent–15 percent reduction in VMT is possible while maintaining an overall neutral price impact on all insured motorists. The cost could be set so that any level of vehicle mile reductions could occur. The extra cost would send a signal to motorists to reduce the amount of miles that they drive. The actual distance the motorist drives is verified either through an electronic device installed in the vehicle or through an auditing program. In Pennsylvania, inspection centers in PennDOT's vehicle safety inspection program could serve as official auditors for PAYD insurance. This program could be initiated as a pilot project in order to measure performance and solve unforeseen problems, and could be ramped up to a full-scale program if deemed effective.

Full participation by all motorists in the commonwealth is essential to reducing GHG emissions. If motorists are allowed to choose between programs, they will cherry pick the type of insurance that gives them the greatest financial benefit. In other words, the drivers who travel the least amount of miles each year would pick PAYD, and little opportunity would be created for lowering VMT.

PAYD insurance bases a vehicle's insurance premiums directly on the number of miles a vehicle is driven during the policy term. The insurance is not based solely on miles. A motorist's risk factor also enters into the equation, so that a high-risk motorist pays a higher per-mile premium than a lower-risk motorist. Mileage is either audited for the project term by a certified auditor or recorded electronically and sent directly by a wireless connection to the insurance company.

It remains to be worked out how insurance companies would determine when a vehicle's policy had expired.

The commonwealth would need to create a network of certified auditors for a full program, which could be part of the state inspection program. Reasonable audit fees would need to be set. Any costs to the commonwealth to administer the program would need to be incorporated into either the audit fee or the mileage premium.

A mandatory program could be fashioned in such a way that it is neutral in cost or even has a modest savings for motorists. If insurance rates behaved unexpectedly, rates could be adjusted after the first year, so that the program becomes cost neutral. It is believed that more than half of all insured motorists, who drive less than the average number of VMT per motorist, would receive lower rates under PAYD automobile insurance. The rest of the drivers, who drive more than the average number of miles traveled per motorist, would need to pay more to make the program cost neutral. A modest savings for insurance premiums may result for policyholders, if decreases in VMT cause a decrease in traffic accidents.

Implementation Steps - Feebates: This policy is assumed to go into effect in 2010 and remain in place for the entire period (2010–2025). Much of the literature available discussing feebate designs agrees that the policy enacted should not interfere with consumer freedom of choice. This analysis considers a feebate program with two pivot points—one for passenger cars and the other for light trucks. Other feebate programs have only one pivot point, to discourage consumers from switching between large cars (which have a fee) and small trucks (which would get a rebate). Still other programs consider all eleven vehicle classes, with a pivot point for each. This would likely have the smallest impact on the domestic auto industry, which typically has larger vehicles than many import brands. Each class of vehicle would then have a designated gallon-per-mile pivot point and a surcharge/rebate designated for values above and below.

It is recommended that if more than two pivot points are being used, vehicle size by footprint/shadow should be considered. This is because measurements based on vehicle weight could have efficiency concerns (because of the incentive to increase weight to be in a higher feebate class, reducing overall efficiency decline). Measurements based on vehicle height could have balance/tipping concerns (because of the incentive to increase vehicle volume by increasing height). Pivot points based on vehicle footprint (width times height) would have an incentive to produce lighter and larger vehicles, which could have safety benefits (Mims and Hauenstein, 2008).

Take, for example, a pivot point of 24 mpg. A vehicle that gets more than 24 mpg will be eligible for a rebate, while a vehicle falling below that level will be assessed a fee. How will this work in reality? This analysis proposes a feebate of $500 per 0.01 gallons per mile (gpm, the inverse measurement of mpg) above or below the pivot. Using a pivot point of 24 mpg, or 0.0417 gpm:

* A 6-cylinder Toyota Camry getting 23 mpg, which equals 0.0435 gpm, would be 0.0018 gpm above the pivot, meaning that the Camry would be assessed a fee of $90.
* A Toyota Prius getting 55 mpg, or 0.0182 gpm, would be 0.0235 gpm below the pivot, meaning that the buyer would receive a rebate of $1,175.

How will this affect the final sticker prices of the two cars? A standard 6-cylinder Toyota Camry has a retail price of $22,530. Adding $90, the final price of the Camry would be $22,620. The Prius has a retail price of $20,975, meaning that after the $1,175 rebate, its final cost would fall to $19,800, costing $2,820 less than the Camry.

The pivot point needs to be reviewed regularly and carefully to maintain an incentive for consumers to purchase the publicly desired vehicle, to avoid potential legal obstacles (see possible legal obstacles under Possible New Measure(s) section), and to maintain the cost-neutrality of the program. A pivot point would be established by using factors such as the known fuel economy and sales volume of the fleet of vehicles for which the pivot point is being set, cost of fuel, and the program's desired effect on fuel economy. The pivot point should be set as accurately as possible in the first year of the program in order to send the correct signal to consumers and vehicle manufacturers for them to base their decisions. The pivot point could be adjusted annually based on updated information to establish revenue neutrality. Although the pivot point can be adjusted annually, sudden, large annual changes should be avoided because this could be confusing to manufacturers. Manufacturers would be uncertain on whether their vehicles in the design phase would be receiving a rebate or not.

The most accepted feebate programs are revenue neutral. Fees and rebates must, however, be large enough to influence behavior; by their nature, they will benefit some consumers and be costly to others. Changes in vehicle purchasing behavior would also provide an advantage to some automobile companies and have a negative effect on others. For instance, companies that produce the least fuel-efficient vehicles would be at a disadvantage.

Feebate programs are usually applicable to passenger cars and light-duty trucks. The feebate program should be designed by first deciding what the desired outcome is:

- To alter public choice of vehicles from one class to another.
- To alter public choice of vehicle in the same class.

The impact on the funding of transportation agencies should be studied, as these agencies depend on revenue from gas taxes for funding, and more fuel-efficient cars will likely mean less gas being purchased and thus less revenue from gas taxes. Also, legislation would be needed, as this would be a change to the taxing structure of new vehicle purchases, implemented by DOR at Pa. Code Title 61, Chapter 31, §31-41-31.50. Registration fees are established by Title 75, Part II, Chapter 19.

Sales tax is due and payable at the time of application for certificate of title or registration upon the sale or use of a motor vehicle. Titling fees are due at the time of application of title, and registration fees are due annually. A mechanism would have to be found to ensure the proper amount of tax is being paid for the type of vehicle; currently, tax rates and fee amounts are uniform within a vehicle class.

Examples of Feebate Programs and Proposals:

- Maryland**:** In 1992, Maryland enacted a feebate program that would add a motor vehicle titling surcharge to vehicles with low fuel economy and a motor vehicle titling credit to vehicles with high fuel economy. The program has not been implemented due to a preemption ruling by the National Highway Transportation Safety Administration (NHTSA). The challenge and subsequent ruling came from Maryland's requirement that auto dealers label each car with a notice of the fuel efficiency surcharge or tax credit. NHTSA ruled that the 1975 Federal Energy and Conservation Act preempted the Maryland law, based on the argument that states cannot enact laws that conflict with the federal regulations on fuel economy disclosures or tax vehicles based on fuel economy.[2] Maryland's Attorney General reviewed the law and concluded that the federal law does not preempt the state from using the federal fuel mileage ratings to compute taxes owed in Maryland. The Attorney General suggested that the state could implement the feebate program by amending the sticker requirement to not conflict with federal disclosure requirements.
- District of Columbia**:** In 2004, the District of Columbia approved the Motor Vehicle Reform Act. The law essentially raised the excise tax for "luxury" SUVs from 7 percent to 8 percent and increased registration fees by $40, while eliminating the excise tax on clean fuel and electric vehicle purchase and reduced registration fees by a comparable amount. A luxury SUV is defined as being greater than 5,000 lbs. This measure is considered to be significant because it is an example of a measure similar to a feebate without federal preemption. Unfortunately, there has been no study of the effects of the program.
- California: AB 493 was introduced in early 2007 and failed to pass on a close vote in the California House. The bill would have required CARB to create and implement a feebate program. California has been considering a feebate program for some time, although typically as something to pursue if its EPA waiver request is denied (to enforce the CA Clean Cars program, similar to what is being considered in T-1).
- Connecticut: The legislature passed Special Act No. 05-6 in 2005 to study the effects of a graduated sales tax for vehicles based on GHG emissions. No study results have been published.
- Maine: LD 305, proposed in 2005, would exempt 100 percent of the sales tax on the sale or lease of a new gasoline-electric hybrid. Additionally, a 5 percent surcharge would be placed on the sale or lease of a vehicle that does not attain at least 27.5 mpg. The measure did not pass.
- North Carolina: Bill 1038, introduced in 2005, would address emissions as a registration fee based upon miles traveled, emissions of pollutants, and fuel consumption. The bill was not acted upon**.**
- Vermont: Vermont's State Action Plan of 2005 suggests a sliding scale based on sales tax. The most efficient vehicles would be charged no sales tax, whereas the most inefficient vehicles would be charged up to a 10 percent sales tax. An average vehicle would be charged the existing state sales tax of 5 percent.

State vs. National Program: Manufacturers will not be as responsive to a localized program as they would be to a national program. This policy would have significantly greater fuel savings and GHG benefits if it were part of a larger (regional or national) policy.

Possible "Legal" Obstacles to Traditional Feebate Programs: To date, only Maryland and the District of Columbia have enacted feebate laws. (The Maryland program was enacted but not implemented [see Maryland above]). Legislation has been proposed in other states. Many programs and/or proposals languish due the legalities of tailoring a program that does not appear to conflict with the 1975 Federal Energy and Conservation Act as incorporated into the United States Code (U.S.C.), which direct the NHTSA to establish the CAFE standards (49 U.S.C., Subtitle VI, Part C, Chapter 329, § 32919). The argument is that language in the aforementioned citation forbids states to adopt regulatory controls on GHG emissions from automobiles, reasoning that these standards could be met only by improvements in fuel economy (CAFE standards). Thus, it makes any state or local "laws or regulations relating to fuel economy" illegal. This obstacle could be avoided if the feebate program were tailored around the federal fuel mileage, so as not to create competing measurement and labeling regulations for manufacturers. The only purpose of the feebate is to create incentives for the production and purchase of more fuel-efficient vehicles.

Another objection that has been raised is the language of the Clean Air Act (CAA), as incorporated into U.S.C. In general, the language prohibits states from adopting or enforcing any standard related to the control of emissions from new motor vehicles or new motor vehicle engines (42 U.S.C. Chapter 85, Subchapter II, Part A, §7543(a)), with special provisions for California and the ability of states to adopt California standards. The relevance of this statement stems from the regulation of air pollutants. EPA held that GHGs did not fit the definition of air pollutant. The U.S. Supreme Court found in April 2007 (*Massachusetts* v. *EPA*) that the GHGs were "air pollutants" by definition in the CAA and could be regulated. In July 2008, EPA issued an Advanced Notice of Proposed Ruling stating why, even though GHGs have been deemed "air pollutants" by the Supreme Court, EPA and other agencies have concerns as to the ability to adequately regulate these emissions—a job the EPA indicates is a task for Congress. However, a feebate program is an incentive mechanism, not an emission standard, so the preemption in the Clean Air Act may have little relevance.

Potential GHG Reductions and Economic Costs:

Table 5-1. Estimated Combined GHG Reductions and Cost-effectiveness for all T-5 Programs

Quantification Factor	**5A**	**5B**	**5C**	**5E**	**5H**	Unit
GHG emission savings (2020)	0.43	0.41	0.62	0.09	1.96	$MMtCO_2e$
Net present value (2009–2020)	-1,065	-810	-605	-137	4,153	$million
Cumulative emissions reductions (2009–2020)	1.76	2.74	4.53	0.58	23.0	$MMtCO_2e$
Cost-effectiveness (2020)	-$605	-$296	-$134	-$238	$181	$/tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate costs savings.

5A – Pay As You Drive Insurance: A according to a study by the Arizona Public Interest Research Group, a PAYD program can reduce VMT by 8 percent (Ridlington and Brown, 2006). While the correlation between VMT and vehicle emissions is not perfect, this analysis makes the assumption that an 8 percent reduction in VMT will have a corresponding 8 percent reduction in emissions. If the VMT reduction is occurring when the vehicle is typically at lower efficiency (in traffic for instance), then the emissions savings would likely be higher. Conversely, if the VMT reduction is primarily occurring when the vehicle is operating very efficiently (steady highway driving), then the emission savings are likely to be overestimated. The implementation of the PAYD program and the emission savings that come from it are shown in Table 5-2.

Table 5-2. Emissions Savings from a PAYD Program

Year	Percentage of People With PAYD Insurance	VMT Reductio n Overall	On-Road Gasoline Emissions ($MMtCO_2e$)	On-Road Diesel Emissions ($MMtCO_2e$)	Gasoline Emissions Reduction ($MMtCO_2e$)	Diesel Emissions Reduction ($MMtCO_2e$)	Total Emissions Reduction ($MMtCO_2e$)
2009	0%	0.0%	4.20	1.33	0.00	0.00	0.00
2010	3.33%	0.3%	4.28	1.35	0.01	0.00	0.02
2011	6.66%	0.5%	4.21	1.38	0.02	0.01	0.03
2012	9.99%	0.8%	4.15	1.40	0.03	0.01	0.04
2013	13.32%	1.1%	4.09	1.42	0.04	0.02	0.06
2014	16.65%	1.3%	4.02	1.44	0.05	0.02	0.07
2015	20%	1.6%	3.96	1.46	0.06	0.02	0.09
2016	36.0%	2.9%	3.91	1.49	0.11	0.04	0.16
2017	52.0%	4.2%	3.87	1.51	0.16	0.06	0.22
2018	68.0%	5.4%	3.82	1.54	0.21	0.08	0.29
2019	84.0%	6.7%	3.77	1.56	0.25	0.11	0.36
2020	100%	8.0%	3.73	1.59	0.30	0.13	0.43
Total							**1.8**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; PAYD = Pay-As-You-Drive; VMT = vehicle miles traveled.

To determine the cost-effectiveness of a PAYD insurance program, the full fuel savings need to be calculated. The fuel saved is calculating by dividing the emission savings by the direct emissions rate for gasoline (10.46 tCO_2e/1,000 gals) and diesel (9.12 tCO_2e/1,000 gals) (CCAR, 2008). In addition to fuel savings, there are savings from reduced congestion. Because VMT is being reduced statewide, there will be fewer cars on the road, and the costs of delay from traffic congestion are reduced. The Brookings Institution found congestion costs to average 5 cents per mile, although this number can be higher or lower in more or less densely populated areas (Brookings, 2008). The same study found that the implementation costs of a PAYD insurance program (for enforcing the new standards, etc.) would be an average of $40 per vehicle per year. The costs and cost savings of a PAYD insurance program are shown in Table 5-3.

Table 5-3. Costs and Cost Savings of PAYD Insurance

Year	Million Gallons Gasoline Saved	Million Gallons Diesel Saved	Fuel Savings ($MM)	Administrative Costs ($MM)	Congestion Savings ($MM)	Total Net Cost
2009	0	0	$0	$0	$0	$0
2010	1	0	$4	$13	$14	-$5
2011	2	1	$9	$27	$30	-$12
2012	3	1	$15	$41	$46	-$20
2013	4	2	$20	$55	$63	-$29
2014	5	2	$26	$69	$81	-$39
2015	6	3	$32	$83	$100	-$49
2016	11	5	$58	$150	$183	-$91
2017	15	7	$84	$218	$268	-$135
2018	20	9	$110	$286	$356	-$180
2019	24	12	$136	$355	$446	-$228
2020	29	14	$162	$425	$539	-$277
Total						**-$1,065**

Negative numbers indicate cost savings.

5B—Feebates

This policy will determine the GHG benefits and costs of a $500/.01 gallon-per-mile feebate in the state. Table 5-4 provides an example of a feebate program and the impact on cars with different efficiencies. In this scenario, assume a pivot point of 24 mpg, and a fee of 500$/0.01 gallon per mile.

Table 5-4. Feebate Impacts at Various Vehicle Efficiencies

mpg	Fee Assessed
20	$417
24	$0
25	-$80
30	-$418

Negative numbers indicate cost savings.

mpg = miles per gallon.

To quantify the GHG emissions of this feebate policy, first the number of new vehicles sold in Pennsylvania was estimated. To do this, the percentage of U.S. vehicles in Pennsylvania (4.09 percent) was multiplied by the number of passenger cars and light trucks sold in the country. This provided the estimate of passenger cars (314,000) and light-duty trucks (400,000) sold in Pennsylvania in a given year (Wards, 2008). The average vehicle efficiency for passenger cars and light-duty trucks was used to estimate the mpg of vehicles after the new CAFE standards go into effect (EIA, 2008). This baseline efficiency was then compared to the efficiency predicted after the feebate program went into effect.

The efficiency improvement predicted in this analysis comes primarily from the modeling done by Oak Ridge National Laboratory (ORNL) and published in the journal *Energy Policy* (Greene et al., 2005). This found that a $500 feebate for every .01 gallon per mile could expect to see a 12.7 percent improvement in passenger car efficiency and a 25.6 percent improvement in light truck efficiency. However, the vast majority (96 percent) of this improvement would come from manufacturers producing more efficient vehicles (to benefit from the feebate), and only 4 percent would come from people choosing more efficient vehicles from the existing vehicle choices (Greene et al., 2005). It is possible that such a dramatic efficiency improvement is no longer possible, because with the new CAFE standards passed in 2007, manufacturers are already taking significant steps to improve fuel economy. It is still very likely that addition efforts could be made, although the overall impact of feebates on manufacturer behavior may have been reduced.

Because Pennsylvania only makes up a little over 4 percent of the U.S. car market, the ability to singlehandedly influence the automakers would be limited. The consumer-side benefit for passenger cars equals 12.7 percent (estimated improvement from feebates) * 4 percent (improvement on the consumer side). The manufacturer-side efficiency benefit equals 12.7 percent (estimated improvement from feebates) * 96 percent (improvement on the manufacturer side) * 4.09 percent (percentage of U.S. auto market in Pennsylvania). Using this approach (adding manufacturer and consumer-side efficiency estimates together) for both passenger cars and light-duty trucks gives an estimated improvement of 1.01 percent in the fuel efficiency of passenger cars and 2.03 percent for light-duty trucks. Table 5-3 shows vehicle efficiency before and after the feebate policy is implemented. In all cases, the recent changes to CAFE have been accounted for.

The estimate for average VMT of passenger cars (12,375) and light-duty trucks (11,114) in Pennsylvania came from Wards (2008). This was used to estimate the fuel savings that come from the mpg improvements shown in Table 5-5. It was assumed that all new vehicles sold under the feebate program will operate for an average of 10 years. This VMT estimate was then used to estimate the GHG savings, based on the emission factors for both gasoline (11.26 kg CO_2e/gal) and diesel (11.25 kg CO_2e/gal) (ANL, 2008). These savings are shown in Table 5-6.

Table 5-5. Estimated Efficiency Improvements from Feebates

Year	On-Road Passenger Car (mpg)	On-Road Light Truck (mpg)	Feebate Passenger Cars (mpg)	Feebate Light Truck (mpg)
2010	25.7	19.2	26.0	19.6
2011	26.3	19.8	26.5	20.2
2012	26.5	20.5	26.7	20.9
2013	26.6	21.1	26.9	21.6
2014	27.7	21.7	28.0	22.1
2015	28.7	22.5	29.0	23.0
2016	30.1	23.0	30.4	23.4
2017	31.2	23.6	31.5	24.1
2018	32.6	24.3	32.9	24.8
2019	33.6	24.8	34.0	25.3
2020	34.7	25.7	35.1	26.2

mpg = miles per gallon.

Table 5-6. Estimated GHG Benefits from Feebates

Year	Million Gallons Saved, Passenger Cars	Million Gallons Saved, Light-Duty Trucks	$MMtCO_2e$ Emission Savings, Gasoline	$MMtCO_2e$ Emission Savings, Diesel	Total GHG Savings ($MMtCO_2e$)
2010	2.8	1.5	0.03	0.02	0.05
2011	5.6	2.9	0.06	0.03	0.09
2012	8.3	4.2	0.09	0.05	0.14
2013	11.1	5.4	0.13	0.06	0.19
2014	13.4	6.6	0.15	0.07	0.23
2015	15.6	7.7	0.18	0.09	0.26
2016	17.4	8.8	0.20	0.10	0.30
2017	19.3	9.8	0.22	0.11	0.33
2018	20.9	10.8	0.24	0.12	0.36
2019	22.6	11.8	0.25	0.13	0.39
2020	24.2	12.6	0.27	0.14	0.41
Total					**2.7**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

A feebate program is typically aimed at being revenue neutral. The amount of money being collected below the efficiency pivot point is equal to the amount of money being given out for vehicles above the pivot point. The pivot is changed regularly to ensure this is the case. It is possible to have the program run a slight profit, so as to deal with administrative costs, etc. One estimate of administrative costs for a national feebate program was $200 million annually (Greene et al., 2005). Scaling this down to Pennsylvania, using the same percentage of U.S. vehicle sales in the state (4.09 percent), results in annual administrative costs of $8.2 million.

However, there are also significant fuel savings as a result of this program. Fuel costs come from the AEO 2008, which are then adjusted to 2007 dollars (EIA, 2009). The fuel savings more than cover the costs of the feebate program. The overall costs are shown in Table 5-7.

Table 5-7. Estimated Costs and Cost Savings from Feebates

Year	Motor Gasoline Cost (2005 $/gal)	Diesel Cost (2005 $/gal)	Administrative Costs ($MM)	Fuel Savings ($MM)	Net Costs ($MM)
2010	$3.01	$2.93	$8.2	$13	-$5
2011	$3.24	$3.14	$8.2	$27	-$19
2012	$3.40	$3.38	$8.2	$42	-$34
2013	$3.50	$3.51	$8.2	$58	-$50
2014	$3.62	$3.65	$8.2	$73	-$65
2015	$3.72	$3.74	$8.2	$87	-$78
2016	$3.75	$3.75	$8.2	$99	-$90
2017	$3.78	$3.75	$8.2	$110	-$102
2018	$3.81	$3.77	$8.2	$120	-$112
2019	$3.83	$3.78	$8.2	$131	-$123
2020	$3.85	$3.79	$8.2	$141	-$133
Total					**-$810**

Negative numbers indicate costs savings.

$MM = million dollars; gal = gallon.

5C—Education Regarding Efficient Driving Habits

Direct eco-driver training encourages driving habits that reduce fuel consumption. These habits include shifting to a higher gear earlier, using cruise control, coasting to stoplights, and accelerating more gradually. Habits such as these have both environmental and economic benefits to the driver. An eco-driving course in Europe found that reductions in fuel consumption of 15 percent–25 percent were quite possible for drivers in the first year (Ecodrive, 2007). This improvement typically decreases as old driving habits return, so subsequent years had an average of 6.3 percent reduction in fuel consumption (Ecodrive, 2007). This policy was applied only to drivers of passenger vehicles, because it is assumed that while eco-driving techniques could save fuel in freight trucks, they are likely to have costs and benefits different from a program aimed at cars. The reduction in fuel consumption and GHG benefits are shown in Table 5-8.

Table 5-8. Implementation Path and GHG Savings of Direct Eco-driver Training

Year	Implementation Path (Driver Training)	Percentage Fuel Reduction From Driver Training	GHG Reduction, Direct Driver Education ($MMtCO_2e$)
2009	0.0%	0.00%	0.00
2010	1.8%	0.36%	0.18
2011	3.6%	0.47%	0.23
2012	5.5%	0.58%	0.28
2013	7.3%	0.68%	0.33
2014	9.1%	0.79%	0.37
2015	10.9%	0.89%	0.42
2016	12.7%	1.00%	0.46
2017	14.5%	1.11%	0.50
2018	16.4%	1.21%	0.54
2019	18.2%	1.32%	0.58
2020	20.0%	1.43%	0.62
Total			4.53

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

The costs for direct eco-driver training for Pennsylvania were estimated based on a cost of 2 million Euros to train 6,500 driving instructors in a similar program in the Netherlands (Wilbers et al., 2006). Ninety-two percent of these driving instructors said that they would take into account the methods taught in the course; therefore, it is assumed that 92 percent of driving instructors will begin teaching eco-driving methods (Wilbers et al., 2006). These training costs were multiplied by the number of drivers assumed to be taking an eco-driving course, as shown in the implementation path, reaching 20 percent of the population by 2020. The costs of direct eco-driver training are shown in Table 5-9.

Table 5-9. Costs of Direct Eco-driver Training

Year	Cost of Driver Training (passenger cars) (Million $)	Cost Savings, Driver Training (passenger cars) (Million $)	Net Costs, Driver Training (Million $)
2009	$0	$0	$0
2010	$72	$47	$25
2011	$72	$64	$8
2012	$73	$81	-$9
2013	$73	$98	-$25
2014	$73	$115	-$42
2015	$74	$132	-$58
2016	$74	$147	-$73
2017	$74	$162	-$87
2018	$75	$177	-$102
2019	$75	$191	-$115
2020	$76	$204	-$129
Total			-$605

Negative numbers indicate costs savings.

5D—Require "Global Warming Index" Stickers for New Cars

This option has not been quantified.

5E—Speed Limit Reduction

This option seeks to quantify the GHG savings and costs of reducing vehicle speeds on highways from 65 mph to 55 mph. This analysis begins with the total VMT on Pennsylvania roads where the speed limit is 65 mph (15.8 billion miles in 2008) (personal communication, Dan Szekeres, 2009). It was assumed that this speed limit change would go into effect in 2010. It was further assumed that this change in speed limits will actually impact vehicle speeds accordingly. It is possible that reducing highway speed limits by 10 mph will not result in a similar reduction in overall highway speeds. However, this is assumed to be a problem of enforcement, rather than with the policy; therefore, the analysis works on the assumption that an actual reduction in overall highway speed is taking place.

To estimate the fuel savings that come with reduced vehicle speeds, a survey of vehicle efficiency at different speeds was used. This ORNL study found an average efficiency improvement of 7.8 percent when a vehicle slowed from 65 mph to 60 mph, and an 11.3 percent improvement when the vehicle slowed from 65 mph to 55 mph. This improvement is applied equally across all light-duty vehicles. For commercial trucks, each 1-mph reduction of speed from 70 mph to 55 mph yields a fuel economy increase of 0.1 miles per gallon for heavy-duty diesel trucks (EPA, 2004). This efficiency improvement is then multiplied by the overall vehicle efficiency for each category (from AEO 2008), to get the fuel savings if the vehicles were travelling at a lower speed (EIA, 2009). The estimated fuel and GHG savings of reducing the speed limit from 65 mph to 60 mph are shown in Table 5-10. The additional savings that would come from reducing the speed limit from 60 mph to 55 mph is shown in Table 5-11, along with the GHG savings compared to a 65-mph speed limit or a 60-mph speed limit.

Table 5-10. Fuel Savings with a 60-mph Speed Limit

Year	Cars Millions Gallons Spent at 65 mph	Light-Duty Truck Gallons Spent at 65 mph	Heavy-Duty Trucks Gallons Spent at 65 mph	Car Fuel Savings at 60 mph (million gals)	Light-Duty Trucks Savings at 60 mph (million gals)	Heavy-Duty Trucks Savings at 60 mph (million gals)	GHG Savings 65–60 mph ($MMtCO_2e$)
2010	252	336	733	20	26	72	1.33
2011	246	330	738	19	26	72	1.32
2012	238	322	741	19	25	72	1.30
2013	232	315	741	18	25	71	1.28
2014	226	309	738	18	24	70	1.26
2015	220	308	734	17	24	69	1.24
2016	216	307	730	17	24	68	1.22
2017	213	306	726	17	24	66	1.20
2018	212	305	722	17	24	65	1.19
2019	212	305	720	17	24	64	1.18
2020	213	304	719	17	24	63	1.17
Total							**13.7**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; mph = miles per hour.

Table 5-11. Additional Fuel Savings with 55-mph Speed Limit

Year	Additional Car Fuel Savings at 55 mph (million gals)	Additional Light-Duty Truck Savings at 55 mph (million gals)	Additional Heavy-Duty Truck Savings at 55 mph (million gals)	GHG Savings 60–55 mph ($MMtCO_2e$)	GHG Savings 65–55 mph ($MMtCO_2e$)
2010	9	11	59	0.89	2.22
2011	8	11	59	0.89	2.21
2012	8	11	59	0.88	2.19
2013	8	11	59	0.87	2.16
2014	8	11	58	0.86	2.12
2015	7	11	57	0.85	2.08
2016	7	10	56	0.83	2.05
2017	7	10	55	0.82	2.02
2018	7	10	54	0.81	2.00
2019	7	10	54	0.80	1.98
2020	7	10	53	0.80	1.96
Total				**9.3**	**23.0**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; mph = miles per hour.

It is important to carefully consider the costs that come with reduced highway speed. Travel time will be increased for all Pennsylvania highway traffic, and this time is valuable. The hours lost were estimated based on the amount of time required to travel the highway VMT estimate (15.8 billion miles) while going 65 mph, compared to 60 mph or 55 mph. These hours are shown in Table 5-12.

Table 5-12. Travel Time Increases at Different Speed Limits

Year	VMT at 65 mph (million miles)	Travel Time at 65 mph	Travel Time at 60 mph	Time Loss to Travel at 60 mph (million hours)	Travel Time at 55 mph	Time Loss to Travel at 55 mph (million hours)
2010	16,117	248	269	21	293	45
2011	16,279	250	271	21	296	46
2012	16,441	253	274	21	299	46
2013	16,606	255	277	21	302	46
2014	16,772	258	280	22	305	47
2015	16,940	261	282	22	308	47
2016	17,109	263	285	22	311	48
2017	17,280	266	288	22	314	48
2018	17,453	269	291	22	317	49
2019	17,627	271	294	23	320	49
2020	17,804	274	297	23	324	50

mph = miles per hour; VMT = vehicle miles traveled.

To estimate the value of highway travel time, the delay cost of $32.15 per hour was used. This comes from the Federal Highway Administration’s (FHWA's) Highway Economic Requirements System model’s conservative estimate for calculating national highway delay costs. The costs of changing the speed limit are shown in Table 5-13.

Table 5-13. Cost of Lost Time from Decreased Speed Limits

Year	Cost of Lost Time (60 mph) ($MM)	Cost of Lost Time (55 mph) ($MM)
2010	$664	$1,449
2011	$671	$1,464
2012	$678	$1,479
2013	$684	$1,493
2014	$691	$1,508
2015	$698	$1,523
2016	$705	$1,539
2017	$712	$1,554
2018	$719	$1,570
2019	$727	$1,585
2020	$734	$1,601

mph = miles per hour; $MM = million dollars.

In addition to these costs are the fuel savings that come from driving at lower speeds. Fuel costs for gasoline and diesel saved come from the AEO 2008 reference case forecast. The fuel savings, along with net costs of reduced vehicle speeds, are shown in Table 5-14.

Table 5-14. Net Costs of Reduced Speed Limits

Year	Motor Gasoline (2007$/gal)	Diesel Cost (2007$/gal)	Discounted Net Costs (65–60 mph) ($MM)	Discounted Net Costs (65–55 mph) ($MM)
2010	$3.01	$2.93	$225	$670
2011	$3.24	$3.14	$180	$582
2012	$3.40	$3.38	$138	$500
2013	$3.50	$3.51	$111	$443
2014	$3.62	$3.65	$83	$386
2015	$3.72	$3.74	$61	$339
2016	$3.75	$3.75	$48	$307
2017	$3.78	$3.75	$35	$278
2018	$3.81	$3.77	$22	$247
2019	$3.83	$3.78	$8	$216
2020	$3.85	$3.79	-$6	$185
Total			**$905**	**$4,153**

gal = gallon; mph = miles per hour; $MM = million dollars.

5F—Improved Truck Directional Assistance

This item has not been quantified.

5G—Improved Tire Inflation

The U.S. Government Accountability Office (GAO) estimated that 25 percent of vehicles have tires that are 8 pounds per square inch (psi) or more underinflated (GAO, 2008). In passenger cars, tires at 1 psi below optimal inflation reduce fuel efficiency by 0.4 percent (Carcare, 2008). Freight trucks with underinflated tires are estimated to have a reduced fuel efficiency of 0.6 percent (Ang-Olson and Schroeer, 2001). This policy involves modeling a tire inflation campaign for the State of Pennsylvania after a similar program adopted in Sarasota, Florida. The implementation path used for this policy approaches 20 percent; therefore, 20 percent of drivers who otherwise would have had underinflated tires are assumed to now be practicing proper tire maintenance. The implementation path of the policy can be seen in Table 5-15. The reduction in fuel consumption from the proper tire inflation campaign is determined by multiplying the percentage of fuel improvement possible for both passenger cars and trucks by the amount of fuel consumed in the state by the emissions factor for a gallon of each fuel. The total GHG reductions possible with this policy are shown in Table 5-15.

Table 5-15. Implementation Path and Greenhouse Gas Reduction from Proper Tire Inflation

Year	Implementation Path (tire inflation)	Fuel Improvement Possible, Tire Inflation, Passenger Cars	Fuel Improvement Possible, Tire Inflation, Commercial Trucks	GHG reduction, Tire Inflation ($MMtCO_2e$)
2009	0%	0.00%	0.00%	0.00
2010	1.8%	0.01%	0.01%	0.01
2011	3.6%	0.03%	0.02%	0.02
2012	5.5%	0.04%	0.03%	0.03
2013	7.3%	0.06%	0.04%	0.04
2014	9.1%	0.07%	0.05%	0.04
2015	10.9%	0.09%	0.07%	0.05
2016	12.7%	0.10%	0.08%	0.06
2017	14.5%	0.12%	0.09%	0.07
2018	16.4%	0.13%	0.10%	0.08
2019	18.2%	0.15%	0.11%	0.09
2020	20.0%	0.16%	0.12%	0.09
Total				**0.58**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

The costs of the tire inflation campaign were modeled after the Sarasota, Florida, tire information campaign (Florida, 2008).[6] This program sought to inform the public on tire issues, particularly tire inflation and proper disposal. The costs of this program were adjusted to Pennsylvania's population relative to that of Sarasota's, and scaled to an annual cost of $3.4 million in 2009. The cost savings come from reduced fuel use. The costs and cost savings are shown in Table 5-16.

[6] This program aims to reduce tire waste and promote better tire care and maintenance. It is possible that a campaign aimed only at improving tire maintenance and inflation could be run at a lower cost.

Table 5-16. Costs of and Cost Savings from Proper Tire Inflation Program

Year	Cost of Tire Inflation Campaign (Million $)	Cost Savings, Tire Inflation (Million $)	Net Costs, Tire Inflation (Million $)
2009	$3.4	$0.0	$3.4
2010	$3.4	$2.3	$1.1
2011	$3.4	$4.9	-$1.5
2012	$3.4	$7.7	-$4.3
2013	$3.5	$10.5	-$7.0
2014	$3.5	$13.5	-$10.0
2015	$3.5	$16.4	-$12.9
2016	$3.5	$19.2	-$15.7
2017	$3.5	$22.0	-$18.4
2018	$3.5	$24.7	-$21.2
2019	$3.6	$27.4	-$23.9
2020	$3.6	$30.2	-$26.6
Total			**-$137**

Negative numbers indicate cost savings.

Key Assumptions:

PAYD—The PAYD analysis assumes that there is a direct link between VMT and vehicle emissions. This is not always a perfect correlation, although decreasing VMT does invariably result in a decrease in emissions.

Feebates—This analysis assumes that new vehicle sales will remain constant at 2005 levels. Having more detailed trend data on changes in vehicle sales in Pennsylvania would be valuable.

When vehicle efficiency is improved, there is less incentive to reduce VMT (because fuel costs are less significant). Thus, improving vehicle efficiency through feebates could result in a "rebound effect" that will increase VMT and reduce the fuel savings predicted in this analysis. The full extent of the rebound effect is difficult to predict.

Lower Speed Limit—This analysis assumes that vehicles drive the speed limit. It is possible to create an analysis where all vehicles travel above the speed limit (5–10 mph) to more accurately reflect actual driving conditions. It is also possible that reduced speed limits, without a concurrent increase in speed enforcement, would result in minimal, if any, changes in driver behavior. It is difficult to model and predict driver behavior (with respect to vehicle speed) in the face of a speed limit change. This analysis instead focuses on the GHG benefits and economic costs of a speed limit change causing an actual change in vehicle speeds, without addressing concerns of enforcement and universality.

Key Uncertainties:

Feebates—The GHG benefits of this policy are based on modeling regarding customer behavior with respect to vehicle costs and fuel efficiency. The feebate policies in the District of Columbia and in Canada have not been in effect long enough to be studied. Therefore, there remains significant uncertainty regarding the true impact of a feebate policy.

As the quantification currently stands, 2005 sales estimates are used. Since the economic downturn, auto sales have declined dramatically. It is possible that, at least in the near term, the analysis overestimates new vehicle sales, and therefore also underestimates the number of vehicles affected by the program.

Note that the California feebate initiative is viewed as an alternative to achieving GHG reductions in the event that the California waiver is not granted by EPA. With the May 19, 2009, Notice of Intent by EPA and DOT to coordinate proposed fuel economy standards consistent with the California standards, a feebate program may be unnecessary, especially if the coordinated standards provide maximum feasible fuel economy benefits.

Tire Inflation—It is difficult to assess the overall effectiveness of a tire inflation program. This policy assumes that the public information campaign will increase the number of vehicles with proper tire inflation by 20 percent. It is difficult to estimate the accuracy of this assumption. As more vehicles are equipped with tire-pressure monitors, the fraction of vehicles with underinflated tires should decline.

Additional Benefits and Costs:

Pay-As-You-Drive—Because PAYD seeks to reduce overall VMT, there will likely be safety benefits associated with this policy as well. While it is difficult to assess a reduction in overall crashes and injuries as a result of a given policy, it is quite logical that reduced VMT means fewer vehicles on the road, and therefore fewer accidents and improved roadway safety.

Feebates—It is possible that this policy will have an adverse impact on the domestic auto industry. Because American vehicles are generally heavier and less fuel efficient than the most popular imported vehicles, a feebate policy might provide an incentive toward buying non-American vehicles produced in America and abroad.

The feebate program should result in reduced gasoline and diesel fuel consumption, which will reduce the amount of revenue in Pennsylvania from fuel taxes. It would be possible to counterbalance this revenue loss with increased fuel taxes, but then the policy would no longer be “revenue neutral” to the consumer.

Lower Speed Limit—Much of the argument in favor of lower speed limits concerns reducing highway fatalities. The potential safety benefits of this policy have not been quantified, although if vehicles do indeed drive slower (as is assumed in the analysis), then it is highly likely that the safety benefits could be significant.

Potential Overlap:

- Smart growth and other transportation-related initiatives.
- Public transit.
- Biofuels Incentive and In-State Production Act
- LRR tires.
- PCV Program.

Subcommittee Comments

With the exception of the lowered speed limit measure, these represented some of the most cost-effective measures considered by the subcommittee, saving between -$134 and -$605/tCO2E from 2009-2020. At the other end, while lowered speed limits carried a larger price tag, it also would achieve 23 MMtCO2E in 2009-2020 reductions, the largest reduction of any measure considered by the subcommittee.

One member commented that a more detailed explanation should be provided for the feebate component of this work plan, explaining how the pivot point for fuel efficiency will be selected to ensure the revenue neutrality of the feebate program (and periodically reviewed and adjusted to maintain this).

References:

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Transportation 6. Utilizing Existing Public Transportation Systems

Summary: This initiative presents a strategic approach to shift passenger transportation mode choice to increase ridership on public transit systems, without the implementation of any major new policies or regulations. It reduces GHG emissions by reducing personal VMT, which has been growing as fast as or faster than population in the commonwealth. In addition, it optimizes reduction of GHGs through efficient operation and maintenance practices of transit agencies. This initiative proposes that transportation is integrated with and appropriately serves land development and redevelopment plans. Transit services encompass all high-occupancy modes, including local, express, commuter, van/carpools, and intercity services. Reducing the growth of personal vehicle use is a key component of reducing GHG emissions in both the short and long terms.

Other Agencies Involved: PennDOT, PA DEP, local transit agencies, metropolitan and rural planning organizations (MPO/RPOs), local governments.

Possible New Measure:

This work plan has four key components:

1. Provide Stable and Adequate Funding for the Current System.
   a. Fund existing levels of transit service under Act 44 of 2007.[7]
   b. Fully fund existing capital needs, as recommended by the Pennsylvania Transportation Funding and Reform Commission.[8]
2. Invest in Growth.
   a. Expand the transit network:
      i. Incremental expansion of existing services, and
      ii. Implement new services.
3. Develop a Public Transportation Strategic Plan for Long-Term Ridership Growth.
4. Address Related Factors That Influence Personal Travel Behavior.

1. Fund the Current System

This component encompasses the provision of stable and sufficient funding to maintain existing services, including both annual operating funds and long-term capital funds to bring the systems to a state of good repair and provide for ongoing capital replacement. Sufficient funding will maintain existing transit ridership, but not necessarily mode share, in geographic areas now served by transit. This avoids increases in GHGs that would occur if transit users changed to personal vehicles, and maintains the foundation on which to significantly increase ridership.

[7] Final version available is at House Bill 1590 of 2007 at http://www.legis.state.pa.us/CFDOCS/Legis/ PN/ Public/btCheck.cfm?txtType=PDF&sessYr=2007&sessInd=0&billBody=H&billTyp=B&billNbr=1590&pn=2342

[8] Pennsylvania Transportation Funding and Reform Commission, "Investing in Our Future: Addressing Pennsylvania's Transportation Funding Crisis," Commission Final Report, November 2006. Available from PennDOT or at: http://www.dot.state.pa.us/Internet/pdCommissCommitt.nsf/

[9] This estimate is based on revenue generated for public transportation in Act 44 of $250 million annually after 2011, since the conversion of Interstate-80 (I-80) was not initially approved by the federal government.

This foundation simultaneously provides a basis for at least incremental transit ridership increases on existing services. However, large increases in transit ridership, either absolute or in proportion to the total number of personal vehicle trips or population, are likely not feasible absent implementation of the three other components of this work plan.

The Transportation Funding and Reform Commission's (TFRC's) findings and recommendations included the provision of adequate operating and capital assistance to maintain the current system. Act 44 of 2007 provided the basis to accomplish this (and included reforms and efficiency improvements that are in process), but did not achieve the TFRC's recommended funding amounts. Under present conditions, given the inability to enact key portions of Act 44, approximately 33 percent of the envisioned $760 million in transit annual funding will be realized in fiscal year (FY) 2011 and beyond, leaving an annual gap of $510 million.[9]

Funding the current system also recognizes that public transportation systems must take advantage of opportunities to improve their efficiency. The TFRC recommended a series of efficiency improvements and Act 44 mandated a series of performance measures that account for and base additional funding on improved efficiencies. In addition, there are other operational improvements transit agencies can make (route analysis and restructuring, technology investments, etc.) that can improve their service delivery.

2. Invest in Growth

Investing in growth recognizes that public transportation is first and foremost a public service, and that the sustainability of transit systems and services is dependent on demonstrating sound management practices and prudent use of public funding to attract and retain riders.

As the state's overall and special-needs populations increase, efficient and effective personal mobility are increasingly necessary in the present and emerging economies. High-occupancy modes, when provided efficiently and used effectively, decrease GHGs and other harmful emissions. Land development plans and implementations that provide sufficient density and connectivity for the institution of efficient and effective transit services are integral to system and ridership growth.

Local or intracity transit ridership growth potential is most likely in the larger urbanized areas with the highest population densities. These areas can provide the most efficient, cost-effective high-quality transit services that attract riders, including fixed-guideway modes, such as bus rapid transit (BRT), priority corridors, rail, etc. Transit services in the Philadelphia and Pittsburgh areas, for example, currently comprise over 90 percent of total Pennsylvania transit ridership.

Similarly, key intercity markets exist and may continue to emerge, as travelers continue to seek lower-cost, higher-quality, and more dependable travel modes. Examples are the Keystone Corridor (commuter rail between Harrisburg and Philadelphia), and may include other intercity pairs inadequately or not served by rail or air modes.

Investment is necessary to better serve the state's present citizens, and provide attractive service to populations in future residential areas, employment areas, and other activity centers. This investment, made wisely, will significantly increase transit ridership and the proportion of total trips served by transit, *at a minimum* reducing the projected growth of vehicle-related GHG emissions, reducing highway vehicle-related GHG emissions from current projections, and striving to reduce the vehicle-related carbon footprint of each Pennsylvanian.

Two forms of key investments in service expansions are possible: incremental and strategic.

- *Incremental service expansions* may be performed largely or completely within the context of existing capital assets. Capital expenditures to initialize such services would be relatively minor, such as several buses added to a fleet. Incremental improvements, such as relatively inexpensive steps that improve transit efficiency or effectiveness, are included in this category. Sample service expansions and improvements include: add buses to an existing route to alleviate crowding or improve headways (also improving service quality); expand the days and/or span of services (add weekend service, provide service earlier in the morning or later in the evening); install traffic-signal-priority technology to provide faster bus services and improve vehicle utilization; and add bus-only priority lanes in congested corridors to decrease passenger travel times and increase productivity.

- *Strategic service expansions* require significant additional capital investment to initialize the service and significant additional ongoing funding to operate the service. Examples include: new services requiring a significant number of new-revenue vehicles, equipment, or storage/maintenance facilities; new or expanded fixed-guideway (e.g., rail, busway, BRT) services; additional rail cars or power units for rail fleets; electrification of existing diesel rail service; and new networks of park-and-ride lots served by bus and/or rail transit.

  For the purposes of this GHG work plan, strategic service expansions are conservatively estimated to be $1–$3 billion for initial capitalization and $30–$60 million annually for operating funds.

All transportation investments must be appropriate to the existing and planned environment to ensure implementation of Smart Transportation approaches. Service improvements and expansions, and new services may include the following modes and services:

- Expand and improve existing services by providing more days/hours of service, modernizing equipment and facilities, expanding NextBus systems, implementing electronic fare systems, and improving modal connectivity (including park & ride).
- Upgrade traditional local motor bus and demand-response services.
- Expand BRT lines.
- Expand Light-rail lines.
- Expand Heavy- and commuter-rail lines.
- Develop employer and private-sector programs to boost transit use.
- Create and integrate high-occupancy-vehicle (HOV) lanes/systems into the transportation network.

- Engage in multistate collaboration to implement new and improve existing intercity high-speed rail links.
- Complete the streets program, including pedestrian, bicycle, and transit-friendly networks of lanes, sidewalks, etc.
- Implement commuter flexibilities to reduce travel demand and increase transit's viability. Strategies include flexible and compressed work weeks, flexible work hours, telecommuting programs, live-near-your-workplace, etc.
- Include transit and all non-SOV-mode information in educational efforts regarding energy efficiency, conservation, and the effects of GHG emissions on climate change.

3. Develop a Public Transportation Strategic Plan for Long-Term Ridership Growth

Pennsylvania needs to develop a strategic plan for its large number of diverse public transportation services and to guide future expansion of existing systems and institution of new major services and facilities.

There are two very large urban systems (Southeastern Pennsylvania Transportation Authority [SEPTA] and Port Authority of Allegheny County [PAAC]), 22 smaller urban systems, 15 rural systems, and 54 community transit systems (shared ride). SEPTA and PAAC account for approximately 75 percent and 17 percent, respectively, of all PA transit ridership.

Additionally, the commonwealth supports 16 intercity bus routes serving 39 counties and commuter rail services along the Keystone Corridor (Harrisburg to/from Philadelphia).[10] Amtrak services between Harrisburg and Pittsburgh are not subsidized by the state.

A transit strategic plan would be developed within the processes and guidelines established by the 2007 Pennsylvania Mobility Plan.[11] The strategic plan could recommend a statewide transit ridership goal (i.e., double 2007 transit ridership by 2020), establish parameters linked to goal achievement, identify key mobility needs that services could serve and substantially contribute to reducing GHG emissions.

In addition to this public transportation strategic plan, PennDOT should develop a technical intercity rail network plan. This plan will allow the commonwealth to understand realistic investment structures and service models that are needed to implement a 21st-century intercity rail network in Pennsylvania.

Inherent in the public transportation strategic plan will be adherence to the applicable Keystone Principles (see PA Mobility Plan) and recommendations of the TFRC as prerequisites for prudent investment of public funds, both initially and ongoing.

[10] Pennsylvania Public Transportation Annual Performance Report, Fiscal year 2006-7, PennDOT, April 2008.
[11] Plan and supporting documents at http://www.dot.state.pa.us/Internet/Bureaus/CPDM.nsf/CPMDHomepage?openframeset

4. Address Related Factors That Influence Personal Travel Behavior.

For transit to successfully compete with the private auto for a significantly larger share of personal trips, transit must be competitive in terms of cost and convenience, to make it the logical choice for many travelers. Part of this challenge is for the transit provider to meet the expectations of riders who *choose* to use transit by improving elements within their control, such as connectivity between travel origin and destination, on-time performance, safety, courtesy, ease of use, etc. The other portion of the challenge is to alter the balance of external factors—which transit alone cannot change—that influence an individual's choice of modes to meet a particular travel need.

External factors that influence travel demand and mode choice include, but are not limited to:

- Land use, including density and mixed land use.
- Context-sensitive design for transportation and other facilities.
- Smart growth communities and corridors.
- Efficiency of infrastructure and services.
- Convenience versus other modes.
- Cost versus other modes.
- Subsidies for auto use.
- Disincentives for auto use.

These external factors are well recognized in the research literature and are included in four Pennsylvania-specific reports:

- PA Mobility Plan and its "Keystone Principles"[12]
- Transportation Funding and Reform Commission report[13]
- *Back to Prosperity: A Competitive Agenda for Renewing Pennsylvania*[14]
- *Smart Transportation Guidebook: Planning and Designing Highways and Streets That Support Sustainable and Livable Communities*[15]

The Transit Strategic Plan would identify barriers and opportunities and propose approaches to minimize the former and maximize the latter consistent with the time frame and other constraints.

[12] See: http://www.pamobilityplan.com/.
[13] *Investing in Our Future: Addressing Pennsylvania's Transportation Funding Crisis.* Commission Final Report, Pennsylvania Transportation Funding and Reform Commission, November 2006. Available from PennDOT or at: http://www.dot.state.pa.us/Internet/pdCommissCommitt.nsf/HomePageTransFundReform_Comm?OpenForm
[14] *Back to Prosperity: A Competitive Agenda for Renewing Pennsylvania*, The Brookings Institution Center on Urban and Metropolitan Policy, 2003. http://www.brookings.edu/reports/2003/12metropolitanpolicy_pennsylvania.aspx
[15] *Smart Transportation Guidebook: Planning and Designing Highways and Streets That Support Sustainable and Livable Communities*. Pennsylvania and New Jersey Departments of Transportation, March 2008 http://www.smart-transportation.com/guidebook.html

Transit agencies, MPO/RPOs, and municipalities should use all existing tools, techniques, processes, and options at their disposal, specifically including those regarding land use, zoning, and site design, to create communities supportive of non-single-occupant-vehicle (SOV) travel in general and transit in particular. See the related work plans for transportation-related site development and general land-use planning improvements.

Potential GHG Reductions and Economic Costs:

Option 1: Funding of Current System

The analysis conducted for this option assumes investments to maintain the current transit system, while providing for strategies to improve transit efficiency and performance. This includes operational improvements, route restructuring, and technology improvements that may encourage lower headways, shorter wait times, and increased travel time reliability. Limited information is available on the specific benefits of such programs. Typical elasticities indicate that with each 1 percent increase in transit service levels (improved coverage, operating hours, etc.) average ridership increases by approximately 0.5 percent.[16] Based on this assumption, a statewide program to increase transit operations may benefit GHG emissions as illustrated in Table 6-1.

Table 6-1. Potential GHG Benefit of Transit Operational Improvements in Pennsylvania

Increase in Transit Service Level	Resulting Benefit in GHG (MMtCO$_2$e) By Analysis Year			
	2010	**2020**	**2025**	**2030**
5%	-0.03	-0.03	-0.02	-0.02
10%	-0.06	-0.05	-0.05	-0.04
20%	-0.12	-0.10	-0.09	-0.08

As such, a 20% increase in transit service is expected to yield a 10% increase in transit ridership. Actual results may be higher or lower, depending on the effectiveness of the transit service improvement and local conditions. The above results are impacted by the analysis year in which the strategies are applied due to projected improvements in vehicle fuel economy as a result of the CAFE standards.

[16] CCAP Transportation Emissions Guidebook2003. http://www.ccap.org/

Why fully fund public transportation?

The Commonwealth's public transportation systems provide both mobility and environmental benefits to the citizens of Pennsylvania. If Act 44 of 2007 is not fully funded, any mobility or environmental gains attributable to public transportation are at risk. Act 44 provides for both operating and capital assistance for the 38 public transportation systems that serve Pennsylvania. Operating assistance is key to maintaining affordable service and improving services. Capital assistance is vital to maintaining and replacing infrastructure and vehicles. Without capital renewal, existing systems will initially become more expensive to operate and will eventually cease operation for lack of vehicles, rails, and facilities.

- Existing transit services avoid approximately 2.65 $MMtCO_2e$ in GHG emissions annually.
- Public transportation provides a vital environmental benefit. If an individual switches a 20-mile round-trip commute to public transportation, his or her annual CO_2 emissions will fall by 4,800 pounds per year, equal to a 10 percent reduction in a two-car household's carbon footprint.
- The GHG reductions from growing transit services and ridership from its current, substantial base are estimated to be 0.55 $MMtCO_2e$ under current funding and other conditions (i.e., vehicle ownership and operating costs).

In 2007, Commonwealth transit systems estimated that if Act 44 was not fully funded, the following *immediate* impacts would have resulted:

- Service reductions of up to 20 percent on weekdays and 50 percent on weekends.
- Fare increases of up to 35 percent.
- Indefinite postponement of fleet replacements and rehabilitations, including more than 400 hybrid electric and CNG-powered buses. Indefinite postponement of station, transit center, and facility improvements and replacements.
- Cessation of plans for new fixed-guideway services and most bus service expansions.

These impacts will extend to roadways and their users, as more demand is placed on roadways when transit service no longer meets traveler needs. This will increase congestion, pollution, and roadway maintenance. Demand for additional roadway capacity likely cannot be met. Former transit users will be forced to spend more to meet their travel needs and will suffer reduced mobility—with commensurate loss of opportunities for employment, medical access, shopping, and other life activities. Transit is estimated to reduce Pennsylvania VMT by 3 billion annually, equaling a congestion savings to Pennsylvania of approximately $750 million.

Option 2: Investing in Growth

The analysis for this option provides estimates for the potential GHG impacts of key transit service expansion projects throughout the state. The investments have the potential to significantly increase transit ridership, especially in the larger urban areas with high population densities.

The determination of the potential ridership increases due to investment will ultimately be influenced by available transit funding and the types and locations of projects. A review was conducted of key transit projects for the Philadelphia region as prepared by Delaware Valley Regional Planning Commission (DVRPC) in its Long-Range Vision for Transit[17] and discussed for an FHWA/FTA(Federal Transit Administration) peer exchange roundtable meeting in 2004.[18] These resources provided ridership and cost estimates that were used to develop a ratio of increased ridership versus transit investment funding. Based on the data, nearly 21 million annual riders may result for each billion dollars spent on transit investments.

The state funding for capital enhancements will most likely be constrained to levels close to the $1–$3 billion dollar range. Federal matching funds may be estimated at the same level—i.e., a 1:1 matching ratio not atypical of the federal share for fixed-guideway projects. Table 6-2 summarizes the GHG benefit related to investments of $3 billion using the assumptions discussed above.

Table 6-2. Potential GHG Benefit of Transit Service Expansion in Pennsylvania

Level of Transit Investment	***Resulting Benefit in GHG (MMtCO2e) By Analysis Year***			
	2010	***2020***	***2025***	***2030***
$3 billion	-0.06	-0.05	-0.05	-0.04

The ridership and corresponding GHG benefits were calculating using resources and data based on 2007 or earlier conditions; therefore, additional strategy elements that improve transit access (e.g., higher-density and mixed land use, transit-oriented development [TOD]) may provide additional benefits in both ridership and GHG reductions beyond those prepared for this analysis.

Table 6.3 summarizes the total emission benefits assumed for transit funding. Funding is assumed to be evenly distributed among the 10 years of analysis.

Table 6-3. Estimated GHG Reductions and Cost-effectiveness

GHG emission savings (2020)	0.05	$MMtCO_2e$
Net present value (2009–2020)	3000	$million
Cumulative emissions reductions (2009–2020)	0.55	$MMtCO_2e$
Cost-effectiveness (2009–2020)	5,454	$\$/tCO_2e$

[17] DVRPC Long-Range Vision for Transit, 2008.
http://www.dvrpc.org/asp/pubs/publicationabstract.asp?pub_id=08068
[18] Transportation Planning Capacity Building Program Peer Exchange Report, June 2004.
http://www.planning.dot.gov/Peer/Philadelphia/Philadelphia.htm

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate costs savings.

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Transit Benefits and Costs

The over 427.5 million annual passenger trips taken on Pennsylvania transit systems in 2008 avoided personal VMT by approximately 3 billion, and approximately 2.65 $MMtCO_2e$, plus other air pollutants, such as ozone precursors. The GHG reductions from growing transit services and ridership from this base (0.55 $MMtCO_2e$) highlight the benefits of maintaining the current transit system at a minimum.

This analysis is expedited and accounts for the cost of transit investments but does not account for all of the additional environmental and economic benefits attributable to public transportation. Benefits additional to those resulting from GHG reductions include:

- Reduced congestion and lost time by 250–375 million PA vehicle trips ($18 billion nationally).
- Reduced demand for highway and roadway infrastructure and maintenance.
- Reduced gasoline consumption (4.2 billion gallons nationally).
- Increased mobility and access to opportunities for employment and access to vital goods and services.
- Improved air quality (reduction of other criteria pollutants, particularly VOCs, NOx and $PM_{2.5}$ from automobile use).
- Reduced living costs for transit users.
- Each $1 spent on transit investment generates $6 in economic activity.
- Creation of 15,000 direct and 50,000 indirect jobs.

A full analysis of costs and benefits for this and other work plans was not possible due to resource and schedule constraints in Act 70 of 2008.

Other Associated GHG Reduction Approaches:

- Improve operations to increase the speed of transit services.
- Continue and enhance multimodal connectivity, including for bicycles and pedestrians.
- Continue and enhance introduction into the transit fleets of new technology, low-energy-consumption vehicles.
- Include GHG/climate change analyses and measures in statewide and metropolitan transportation planning processes.
- Minimize GHG emissions from new and existing transportation facilities, services, operations, and maintenance activities.

Cost to Regulated Entities: If any, to be determined.

Cost to State:

Estimated Cost	*Borne by / Purpose*
$1–$3 billion total	State share of capital expansion
$30–$60 million	State operating assistance
To be determined	Local funds matching amount for capital expansion
To be determined	Local funds matching amount for annual operating funds

Existing and Potential Funding Sources: Transit needs stable, predictable, inflation-sensitive, and adequate funds to continue existing services, effect capital replacement, and plan and implement new and expanded services. Existing funding sources are highly constrained and limited to supporting existing operations and capital replacement. Pennsylvania is currently using all federal transit funds available. Funding under the Federal Transit Administration's (FTA's) “New Starts” and “Small Starts” programs is highly competitive nationally, and generally provides matching amounts of 50 percent (versus up to 80 percent for formula funding categories). Expanding these funding sources and locating new sources are integral to any substantial expansion of transit services.

As presented above, given the inability to enact key portions of Act 44, approximately 33 percent of the envisioned $760 million in transit funding will be realized in FY 2011 and beyond, leaving a state funding gap of $510 million.

Existing Funding Sources:

State/PennDOT:

- Public Transportation Trust Fund
  - PA Public Transportation Assistance Fund
  - PA General Fund (sales and use tax (4.4 percent)
  - Lottery Funds (support senior citizen fare discounts)
  - Capital Facilities Fund

Federal:

- FTA formula grants (Title 49 U.S.C.)
  - Multiple categories for urban and rural programs (Title 49 U.S.C.)
- FTA “New Starts” and “Small Starts” programs
- Flexible funds between Titles 23 and 49 U.S.C.
- Congestion Mitigation and Air Quality (CMAQ) program

Local:

- 15 percent minimum match for operating assistance*
- 3.33 percent minimum match for capital assistance
- Discretionary additional local funds

* Phase-in per Act 44 of 2007

Other:

- Private parties
- Nonprofit agencies
- Other state and local governmental agencies

Potential New Funding Sources: Public and elected official advocacy and support for new and expanded funding at federal, state, and local levels are necessary to maintain existing services and expand transit services and networks. See the TFRC report for detailed recommendations as to funding sources and amounts. New funding sources are possible, and may include the following:

State:

- Increased sales tax, personal income tax or realty transfer tax (2006 TFRC report)
- Oil Company Profits Tax (proposed in 2007 Governor's Budget Address)
- Securitize Turnpike (proposed in 2007 by Governor Rendell
- Energy efficiency and climate change legislation may contain funding mechanisms, of which a portion of receipts could be dedicated to transit.

Federal:

Support of federal, state and elected officials is critical to fulfilling transit's needs.

- The federal transportation funding bill—SAFETEA-LU (The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users)—expires in September 2009 and is to be replaced with another 6-year funding bill. Additional funding for existing funding accounts and categories could ensure adequate support of ongoing operations and new and expanded services.
- Energy efficiency and climate change legislation may contain funding mechanisms, of which a portion of receipts could be dedicated to transit.

Local:

- Discretionary additional local funds "overmatch."
- County funding sources recommended under Act 44.

Other:

- Private parties.
- Nonprofit agencies.
- Other state and local governmental agencies.
- Public-private partnerships.

Other Potential Benefits and Drawbacks:

Additional potential benefits of increasing public transit ridership include:

- Decreased emissions of ozone precursors (VOCs and NO_x), carbon monoxide (CO), and PM.
- Decreased motor fuel use.
- Enhanced mobility for citizens and visitors.
- Direct support of Smart Transportation initiatives, projects, and programs.
- Reduced congestion.
- Reduced sprawl.

Potential drawbacks of specific funding mechanisms for public transit could include:

- Unintended consequences of incentives that reduce business activity in certain locations.
- Funding mechanisms based on taxes or fees could have a disproportionate and adverse impact on those entities and/or sectors being taxed.

Ease of Implementation: Varies, based on individual transit projects. Incremental transit expansions likely have low barriers, other than funding availability at the state and local levels. Expansion of existing and implementation of new fixed-guideway projects may have significant financial, technical, and environmental challenges specific to each project. Federal funding availability is contingent upon a complex rating scale that compares projects nationally, resulting in only the best projects receiving federal assistance.

Implementation Steps: Implementation steps are described in the previous sections.

Key Assumptions: As noted in text.

Key Uncertainties: Funding availability—state, local, and federal—is anticipated to be the most significant uncertainty. Appropriate locally supported land-use policies are necessary for large-scale service expansions and new and extended fixed-guideway projects. See list of synergistic items, below.

Additional Benefits and Costs: Transit services provide increased mobility, encourage denser and mixed land uses, and reduce overall emissions of other criteria pollutants (ozone precursors NO_x and VOCs, CO, $PM_{2.5}$).

Potential Interrelationships With Other GHG Reduction Measures: This initiative recognizes that land use, including redevelopment and new development, is a key factor in influencing the selection of multi-occupancy vehicle, bicycle, and pedestrian access over personal vehicle use. Significant increases in transit use are also linked to appropriate incentives and disincentives that influence the selection of transit over other modes for commuting and other personal trips and personal choice that result from changing behaviors.

Synergistic:

- Measures that increase or monetize the true costs of driving, such as PAYD insurance and feebates).
- Smart Growth, for both localized (i.e., TOD) and broader applications.
- Measures that decrease the cost of transit to users, including travel demand management (TDM) measures, fare discount programs, and tax preferences for transit costs.

- Measures that increase the actual or perceived cost of SOV use.

Other:

- Creation and preservation of GHG sinks.
- Renewable fuels (Biofuels Incentive and In-State Production Act).
- Federal renewable fuels.
- PCV Program.
- LRR tires.
- Biofuels (light-duty vehicle portion).

There are no apparent disincentives of the proposed measure.

Subcommittee Comments

While the 2020 benefits are not as impressive as some of the other work plans, the benefits for improving and expanding public transportation systems (especially when combined with effective land use policies) can be substantial in the future. Initial capital investments (this is by far our most costly work plan at $5,454/tCO2E for 2009-2020) are high but necessary to provide more and improved transit services far into the future.

One member recommended that in addition to working within existing laws and regulations, the state, especially with the help of federal dollars, needs to consider pursuing more aggressive expansions of existing transit systems (new lines, high speed rail, etc). Simply making incremental improvements on existing transit systems will not be enough to realize the full potential benefits of public transit systems.

References:

See footnotes.

Transportation 7. Increasing Participation in Efficient Passenger Transit

Summary: This initiative presents an array of specific new measures that can be adopted to decrease GHG emissions from the state's passenger transportation sector by influencing the transportation choices of Pennsylvanians. Specifically, these measures aim to (1) increase public transit ridership, (2) decrease SOV trips, and (3) avoid motor vehicle trips altogether where possible. As compared to the T-6 Work Plan, many of these measures would require the passage of new policies or the implementation of new regulations.

This initiative does *not* outline implementation steps for—or the potential benefits of—large-scale expansions of existing public transportation systems, or the construction of new public transportation systems. Still, these are key steps that the state should consider implementing, especially with the help of federal dollars discussed in other work plans.

Other Agencies Involved: PennDOT, local transit agencies, MPO/RPOs, local governments.

Possible New Measures:

I. Increase Public Transportation Ridership

Workplace Incentives for Public Transit Use: To encourage public transit use by employees at workplaces with access to public transit systems, the state and local governments could work with businesses to provide incentives for their employees to use public transit for their work commute. Such programs should also include state workers, and incentives could include free/discounted bus or train tickets, or vouchers for discounts at businesses in the area.

II. Decrease Single-Occupant Vehicle Trips

Workplace Incentives for Carpooling: State and local governments could work with businesses to provide incentives for their employees to carpool for their work commute. Such incentives could include free/discounted parking, or vouchers for discounts at businesses in the area.

III. Decrease Vehicle Trips

Telecommuting in the Private Sector*:* By working from home, workers can avoid vehicle trips and their resulting GHG emissions. Actions to encourage more telecommuting in the private sector include business tax incentives for employers to provide telecommuting as an option to their employees (could include local wage tax adjustments), and funding for regional telecommuting centers (which provide an office-like environment for workers in a given area closer to home and away from their employer's office).

Telecommuting in Public Sector: To help set the example and establish some of the regional telecommuting centers, the state should offer telecommuting as an option for employees wherever appropriate, and set clear targets and timelines for the number of employees utilizing the telecommuting option.

Sales-Tax Exemption for e-Commerce: Encouraging online shopping will help to decrease shopping trips in cars (though it's important to factor in the potential increase in small-truck delivery traffic).

Urban and Intercity Tolls: By tolling trips into cities, those cities and the state could create a new pool of money for transportation improvements, while decreasing vehicle trips and congestion in the cities, and encouraging the use of public transportation.

Potential GHG Reductions and Economic Costs:

Table 7-1. Estimated GHG Reductions from and Cost-effectiveness of T-7

GHG emission savings (2020)	0.12	$MMtCO_2e$
Net present value (2009–2020)	< $0	$million
Cumulative emissions reductions (2009–2020)	2.02	$MMtCO_2e$
Cost-effectiveness (2009–2020)	< $0	$/tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent.

Cost-effectiveness was determined to be not quantifiable, pending the specifics of the measures to be implemented and their scale. The literature indicates that a mix of TDM incentives and disincentives can result in zero or negative (savings) to the commonwealth.

Key Assumptions

Key assumptions are outlined in the quantification section, below.

Quantification:

The impact of TDM programs was calculated starting with the existing mode shares as found in the Census Journey to Work datasets and applying recommended reduction factors reported in the Center for Clean Air Policy (CCAP) *Transportation Emissions Guidebook.*[19] The suggested reduction at the employer level was 5 percent to 25 percent. However not all employers are located where these programs can be implemented effectively. The EPA Commuter Model documentation reports employer participation rates in TDM programs ranging from 10 percent to 30 percent.[20] It was also recognized that the effectiveness of TDM programs would vary, depending on the nature of the community, with more urbanized areas having the greatest potential (primarily due to the presence of more robust transit services, a key factor in the success of TDM programs).

The Census Journey to Work data were used as the basis for the calculation of the TDM impacts. Using Census state place and urban definitions, each city/town/township in the commonwealth

[19] Dierkers, Greg; Silsbe, Erin; Stott, Shayna; Winkelman, Steve & Wubben, Mac. CCAP Transportation Emissions Guidebook - Part One: Land Use, Transit & Travel Demand Management. Center for Clean Air Policy, US Environmental Protection Agency & the Surdna Foundation. http://www.ccap.org/guidebook/downloads/CCAP%20Transportation%20Guidebook%20(1).pdf

[20] US Environmental Protection Agency. Procedures Manual for Estimating Emissions Reductions from Voluntary Measures and Commuter Choice Incentives Programs. October 2000.

was identified as having a high, medium, or low propensity for TDM, based on existing mode shares and local knowledge. The percentage of new workers participating in the programs was based on the high- and low-end estimates in the Commuter Programs section of the CCAP Guidebook (5 percent–25 percent). Eligibility for the programs was based on the employer participation rates in the Commuter Model documentation, with a 30 percent high-end value being used. Table 7-2 summarizes the reduction rates developed.

Table 7-2. TDM Reduction Rates

TDM Propensity	Estimated Reduction Due to TDM	Share of Area Workers Eligible	Estimated SOV Reduction Due to TDM
High	25.0%	30.0%	7.5%
Medium	12.5%	30.0%	3.8%
Low	5.0%	30.0%	1.5%

The reduction rates were applied to the total number of workers using SOVs. The affected trips were reassigned to the alternative modes based on current distributions. Total trips were based on average values of 1.8 vehicle trips/day/worker and 260 workdays/year. VMT reductions were estimated first by calculating the net reduction in vehicle trips (SOV trips reduced less the new carpool vehicle trips), and multiplying the remainder by the average commuter trip length in the commonwealth. The net VMT reduction calculated for 2000 (the year of the Census data) was factored to 2020 using growth rates found in the PA Greenhouse Gas On-Road inventory (Personal Communication with Bob Kaiser, 2009). Emission rates were also based on the values reported in the inventory, and reflect 2020 gasoline on-road values. The defaults, intermediate values, and final reductions are summarized in Tables 7-3 and 7-4.

Table 7-3. Default Values Used in the Calculation of TDM GHG Benefits

Car Pool Occupancy	2.14
Average Commuter Trip Length (Miles)	9.52
Average Trips/Work Day/Worker	1.8
Workdays/Year	260
% increase in VMT 2000–2020	33.0%

Table 7-4. VMT and Emission Reductions for TDM Measures

Total Auto Trips Reduced (SOV)	164,377
Additional Carpool Auto Trips	32,849
2000 Total Daily Vehicle Auto Trips Reduced	131,528
2000 Total Daily VMT Reduced	1,252,149
2000 Annual VMT Reduced	325,558,691
2020 Reduction in VMT	**432,993,060**
2020 Avg. Emission Rate (kg CO_2e/Mile)	0.258
2020 GHG Reductions (kg CO_2e Reduced/Year)	111,712,209
2020 GHG Reductions (MMtCO_2e/Year)	**0.12**
Cumulative Benefits 2009–2020 (MMtCO_2e/Year)	**2.02**

(see below for references)

<u>Cost to Regulated Entities</u>:

Most costs would fall to the state and the businesses that partner on the workplace initiatives. These costs would also have to be determined.

<u>Other Potential Benefits and Drawbacks:</u>

Additional potential benefits of changing behaviors to decrease greenhouse gas emissions from the transportation include:

- Decreased emissions of ozone precursors (VOCs and NO_x), CO, and PM.
- Decreased motor fuel use.
- Enhanced mobility for citizens and visitors.
- Direct support of Smart Transportation initiatives, projects, and programs.
- Reduced congestion.
- Reduced sprawl.

<u>Ease of Implementation</u>

Will vary depending on the specific measure.

<u>Implementation Steps</u>

Implementation steps will vary based on the specific measures, but could include a mix of market incentives and mandates.

<u>Key Uncertainties:</u> Not identified.

<u>Potential Interrelationships With Other GHG Reduction Measures:</u> These measures aimed at changing behavior need to be implemented in coordination with system changes within the transportation sector, and with transportation-focused land-use measures.

Subcommittee Comments

While the initial benefits of this work plan are smaller than others (2.02MMtCO2E reductions for 2009-2020), these policies will be critical to encouraging use of the transit systems that are set up and expanded, as well as other efficient transportation options. The analysis also suggests that most of these measures can be implemented at a net savings due mainly to decreased fuel use.

References:

Dierkers , Greg; Silsbe, Erin; Stott, Shayna; Winkelman, Steve & Wubben, Mac. CCAP Transportation Emissions Guidebook - Part One: Land Use, Transit & Travel Demand Management. Center for Clean Air Policy, US Environmental Protection Agency & the Surdna Foundation.
http://www.ccap.org/guidebook/downloads/CCAP%20Transportation%20Guidebook%20(1).pdf

US Environmental Protection Agency. Procedures Manual for Estimating Emissions Reductions from Voluntary Measures and Commuter Choice Incentives Programs. October 2000.

Personal Communication, Bob Kaiser at Michael Baker, Inc, email received by Jackson Schreiber on 6/12/09.

Transportation 8. Cutting Emissions From Freight Transportation

Summary: This initiative presents an array of specific measures that can be adopted to decrease GHG emissions from that state's freight transportation sector, which is forecast for continued growth, despite the economic downturn and decreased transportation funding. Primarily, these measures aim to (1) improve the efficiency of vehicle trips, (2) reduce large diesel engine idling and emissions, and (3) shift freight from trucks to other modes. With regard to this last point, draft U.S. Senate legislation has a goal of increasing the proportion of national freight provided by means other than trucks by 10 percent by 2020.

Other Agencies Involved: PennDOT, American Trucking Association (ATA)/PA Motor Truck Association (PMTA), Keystone State Railroad Association/members, PennPORTS (Department of Community and Economic Development [DCED]), MPO/RPOs, local governments.

Possible New Measures:

I. Improve Trucking Efficiency

a. Expand EPA SmartWay Truck Transport: This option entails development of a technology option package modeled after the EPA's SmartWay Transport Partnership (EPA, 2009a). This voluntary partnership is designed to encourage shippers and fleets to reduce air pollution and GHG emissions through lower fuel consumption. By identifying and promoting fuel-saving retrofit technologies, the partnership enables truck fleets to better understand how to reduce fuel consumption via the most economical means available. In many cases, fuel-saving retrofits can result in net cost savings over the long run. The two technology options analyzed are listed below:

- **Aluminum Wheels With Single-Wide Tires:** Replacing the typical configuration of two wheels and tires at the end of each axle on heavy-duty trucks and commercial trailers with an aluminum wheel and a single-wide tire improves fuel economy by 4 percent by decreasing rolling resistance and weight (EPA, 2009b).
- **Trailer Fairings:** Adding front and side fairings (e.g., skirts) to trailers reduces aerodynamic drag and improves fuel economy by 5 percent (EPA, 2009b).

While the combined costs associated with installing both technology options (<$10,000) is modest compared to the cost of a tractor-trailer, such up-front costs may be prohibitive for some truck owners. While grants may help, a revolving loan program is a better financial assistance option (Bynum, 2009). With a payback of roughly 3 years, the money loaned from the initial fund is quickly returned and used for new loans. The SmartWay Transport Partnership is currently working with iBank, a company that provides businesses with access to its network of loan lenders (Bynum, 2009; iBank, 2009). The advantage is that these lenders will bid on the loan request, lowering the interest rate and simplifying the process of acquiring a loan. The process is similar to what LendingTree is doing for consumer loans (Bynum, 2009).

The following ATA recommendations target reduced fuel consumption by 86 billion gallons and the carbon footprint of commercial vehicles by nearly 1 billion tons over the next 10 years nationwide:

- **Increase Fuel Efficiency**: Under SmartWay, CO_2 reductions of 119 million tons expected nationwide by 2018 (19.4 and 22.2 lbs/gal gasoline and diesel, respectively).
- **Install Heavy Truck On-Board Emission Sensors*:*** Devices alert a driver when the emissions system is malfunctioning. An EPA rule phases in beginning in 2010, with a universal engine mandate by 2013. The rule is modeled after passenger vehicle systems and CARB. Emissions are reduced by up to 90 percent. However, current costs are high.
- **Lower State Speed Limits*:*** See Work Plan T-5.
- **Outfit Trucks With Speed Governors:** Use the EPA calculator to estimate fuel savings. Obtain cost information on and set a goal for what percentage of PA trucks might have this technology installed within 10, 15, and 20 years, and the type of state policy/program needed to achieve these goals.
- **Install Idling Reduction Technologies:** See Work Plan T-4.

Approximately 30 (2 percent) of more than 1,600 PMTA members are enrolled in SmartWay. EPA and ATA could work more closely with state trucking associations (including possible customization and state-run SmartWay plans) to facilitate greater participation.

b. More Productive Truck Combinations: Advocated by the ATA, this option expands (geographic) operation of higher-productivity vehicles, including single tractor trailer maximum gross vehicle weight of 97,000 lbs, heavier double 33-foot trailers, and triples. Determine the relationships between truck weight, fuel consumption, and increased ability to move freight. Establish goals for how this initiative would lead to changes and improvements in PA at the same 10-, 15-, and 20-year intervals listed previously.

c. Future Federal Requirements*:* Current federal/EPA requirements mandate reductions in NO_x and PM, but not CO_2. Regulations are under congressional consideration and development, and the plan will be updated should legislation including significant emission reductions be passed.

II. <u>Expand Rail Freight and Improve Efficiency</u>

A. Switchyard Initiatives

Low-Emission Locomotive: This is Norfolk Southern's (NS's) preferred/approved terminology to allow flexibility regarding current and future technologies. The current focus on the new General Electric (GE) engine is due to a favorable cost-benefit ratio and a long history with GE; PA DEP/ NS/GE federal stimulus grant application pending.

"GenSet Switcher" Locomotive: GenSets use two small diesel engines instead of one large one, with one switched off during idle (see Section B) or when not hauling a heavy load or climbing grade. This is a good option for smaller class II/III railroads operating locomotives individually or not transporting a lot of freight cars at once; Class I (e.g., NS) can't cover costs with fuel savings to date. Over 60 PA railroads use hundreds of locomotives that would be candidates for

GenSet conversion. This reduces emissions by 80 percent–90 percent, and uses up to 37 percent less fuel versus older models.

Electric Wide-Span Cranes: Operating from electric power, these cranes produce zero emissions on site. The wide-stance design eliminates up to six diesel trucks (hostlers) for shuttling containers. A hybrid model is also under development.

Battery Powered Locomotives: NS has received grants from the Federal Railroad Association and the U.S. Department of Energy to support research of electric locomotives powered by lead acid batteries. Successful project completion will enable diesel locomotive regenerative braking and reduce fuel consumption.

Mother/Slug Engine Re-Powers: Switcher/yard locomotives often operate in pairs to move large numbers of cars to other locations after long-haul delivery. A mother/slug is a locomotive pair configuration that consists of one four-axle locomotive (mother) powered by an engine approaching current EPA standards for controlling emissions of criteria pollutants, and one four-axle platform of four traction motors without an engine (slug). Typically, switchers are powered by pre-1973 engines not mandated to be rebuilt by existing federal law/regulations. A mother/slug realizes fuel benefits over existing pairs due to one engine instead of two, and the new replacement engine is more fuel efficient. Fuel savings for converting a switcher pair from traditional configuration to mother/slug are estimated at 25 percent–38 percent, with corresponding GHG emission reduction.

Because these projects reduce criteria pollutants in many cases, re-powering the mother/slug could be partly funded by CMAQ funding, with a match provided by the railroad. This yard locomotive configuration can be built at NS's Juniata Locomotive Shop, and the new engine can be built at the GE plants in Erie and Grove City. Currently, NS operates about 27 pair (54) of switcher locomotives in PA, and each locomotive uses approximately 82,000 gallons of fuel per year.[21] CSX also operates about 38 yard locomotives statewide.

B. Reduce Locomotive Engine Idling (not included in PA Act 124)

Auxiliary Power Units: Railroads use APUs to warm engines, allowing them to shut down in cold weather. CSX pioneered APUs, and hundreds are currently in use in PA. NS plans to ultimately phase out APUs, which still produce emissions, and future engine requirements will result in much greater idling reductions.
Automatic Engine Stop-Start Idling Reduction: This technology allows the main engines to shut down when ambient conditions are favorable. It is currently built and installed in Altoona (e.g., NS). Railroads are establishing and reinforcing shutdown requirements, including driver training/rewards.

"GenSet Switcher" Locomotives (see also Section A): Their smaller engines are the only ones that use antifreeze, allowing them to shut down in cold weather.

[21] Procedures for Emission Inventory Preparation Volume IV: Mobile Sources, Chapter 6, United States Environmental Protection Agency, 1992.

C. Long-Haul Initiatives

Expand/Upgrade Existing Rail: Each ton-mile of freight moved by rail versus road reduces GHG emissions by two-thirds or more. If 10 percent of nationwide long-haul truck freight converted to rail, annual GHG emissions would fall by more than 12 million tons (equivalent to taking 2 million cars off the road), and cumulative reductions through 2020 could be 200 million tons. Upgrading existing rail capacity to facilitate double-stacked trailers significantly enhances freight delivery, reduces fuel use, and minimizes freight reconfiguration during delivery. NS's impending Crescent Corridor expansion consists primarily of upgrading track to accommodate double-stacked containers the 6-state length of I-81 (Tennessee to upstate New York), as well as upgrading/installing some double track. (The Heartland Corridor will reduce 200 route miles from each shipment and transit time by one day.) However, the large majority of rail expansion is intermodal, which still involves truck transport to/from the facility. Finally, significant improvement in the NS-Amtrak relationship could expand rail capacity.

Expand EPA SmartWay Rail Transport*:* SmartWay members agree to improve their fuel efficiency, reduce their environmental footprint, reduce their energy consumption, and engage in corporate citizenship. Freight trains are three or more times more fuel-efficient than trucks. (See I, Trucking, for additional guidance).

Policy Issues: Class I rail expansion is contingent on significant public-sector cost sharing at the federal and state levels. PA's draft budget includes $45 million for NS expansion and $25 million for CSX expansion. Current state and federal regulatory roadblocks to public-private partnerships (P3s) must be eliminated, while at the same time ensuring the "public interest" (including economic benefit) is being served.

III. Expand Marine Freight and Improve Efficiency

There are two recommended PA initiatives for the commercial marine sector. One is to make the infrastructure improvements needed to allow the amount of freight shipped by vessel in PA to increase in situations where marine vessel transport is more energy efficient than truck or rail transport. Growth possibilities and issues differ for each of the three major PA port areas: the Philadelphia area, the Pittsburgh area, and the Erie area. The second initiative is to provide the financing and incentives (and regulations) needed to improve the energy efficiency and associated GHG emissions of the vessels and cargo handling equipment in use at the major PA port facilities. This second initiative is designed to make the PA port operations as GHG efficient as possible.

Superior Efficiency: Water transport is generally 40 percent more efficient than rail; rail is already three times more fuel efficient than trucks. For example, in the Port of Pittsburgh, one 15-barge tow replaces 1,000 trucks.

Philadelphia/South Jersey/Delaware River Ports: These ports have signed a Memorandum of Understanding (MOU, 2008) to reduce or neutralize the impacts of operations and expansion by reducing energy consumption, employing cleaner energy sources, and replacing and modernizing vehicles and equipment.

Marine Diesel Engine Retrofits: The Port of Pittsburgh's "gap financing" plan contains $20 million (including CMAQ funds) to repair and upgrade engines per EPA **r**equirements.

Diesel Engine Containerized Cranes: The Port of Philadelphia has developed a plan to electrify all (20+) current cranes by the fall of 2009.

Intermodal Port/Rail*:* PennDOT Rail Freight Assistance Program has awarded $1million to the Port of Erie/Industrial Development Corporation to restore rail service to industrial parks, replace 12,000 trucks, and serve biodiesel manufacturers. GE Locomotive is seeking to partner on hybrid locomotive and tugboat prototypes.

America's Marine Corridor/Ben Franklin Corridor*:* The Port of Philadelphia is applying for federal funds to glean business from Panama Canal widening (2014), which is expected to reroute significant volumes from the West Coast. The conversion of cross-country truck/rail freight to ships/barges will reduce regional emissions.

Policy Issues: Federal regulations (e.g., Jones Act) present roadblocks to short sea shipping and other marine conversion opportunities. Environmental concerns regarding waterway dredging (water quality, wildlife, etc.) must also be resolved/balanced.

Potential GHG Reductions and Economic Costs:

Table 8-1 summarizes the emission benefits and costs of the measures applied to truck freight and locomotives. Marine freight measures are not yet included in this table.

Table 8-1. Estimated GHG Emissions Reductions and Cost-Effectiveness

GHG emission savings (2020)	0.99	$MMtCO_2e$
Net Present Value (2009-2020)	-1,495	$million
Cumulative Emissions Reductions (2009-2020)	6.67	$MMtCO_2e$
Cost-effectiveness (2009-2020)	-224	$\$/tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate cost savings.

Heavy-Duty Trucks

The two technology options considered in the heavy-duty truck analysis are based on EPA's SmartWay Transport Partnership (EPA, 2009b). The first option is the installation of aluminum wheels for single-wide tires to reduce vehicle weight and rolling resistance. The second option is the installation of fairings (e.g., front and side skirts) to improve vehicle aerodynamics. The improved fuel economy and associated GHG emission reductions for each option are additive (Bynum, 2009).

GHG Reduction from Installing Aluminum Wheels

Replacing the typical heavy-duty truck configuration of two wheels and tires at the end of each axle with an aluminum wheel and a single-wide tire decreases rolling resistance and weight. This technology can be applied to all tractor and trailer tire positions, except for the steer tires. When applied to these tire positions, it can reduce fuel consumption by 4 percent (EPA, 2009b). Since half of the tires suitable for retrofitting are located on the tractor, and half are located on the trailer, the fuel savings is allocated equally between the tractor and the trailer (i.e., the fuel savings from retrofitting a tractor-truck is assumed to be 2 percent, and the fuel savings from retrofitting a trailer is assumed to be 2 percent). DOT reports the number of tractor-trucks registered in Pennsylvania in 2007 as 74,404 (DOT, 2008b) and the number of commercial trailers as 152,489 (DOT, 2008c). Table 8-2 shows the assigned penetration rate for retrofits and the total tractor-trucks and trailers retrofitted through 2020 under this policy option.

Table 8-2. Total Tractor-Trucks and Trailers Retrofitted With Aluminum Wheels

Year	Heavy-Duty Trucks Registered in PA	Penetration Rate for Tractor-Trucks	Trucks Retrofitted	Commercial Trailers Registered in PA	Penetration Rate for Trailers	Trailers Retrofitted
2009	74,404	0	0	152,489	0	0
2010	74,404	10	7,440	152,489	5	7,624
2011	74,404	20	14,881	152,489	10	15,249
2012	74,404	30	22,321	152,489	15	22,873
2013	74,404	40	29,762	152,489	20	30,498
2014	74,404	50	37,202	152,489	25	38,122
2015	74,404	60	44,642	152,489	30	45,747
2016	74,404	70	52,083	152,489	35	53,371
2017	74,404	80	59,523	152,489	40	60,996
2018	74,404	90	66,964	152,489	45	68,620
2019	74,404	100	74,404	152,489	50	76,245
2020	74,404	100	74,404	152,489	55	83,869

The estimated GHG emission reductions from replacing existing two-wheel, two-tire configurations with a single aluminum wheel are based on diesel fuel savings. To calculate these emissions, the total VMT in the state (108,699 million miles; DOT, 2008a) are multiplied by the fraction of miles traveled by heavy-duty trucks (0.07; PA DEP, 2007) to obtain total annual VMT by heavy-duty trucks in Pennsylvania in 2007. Total annual VMT is then divided by the average fuel economy of heavy-duty trucks (6.0 mpg; Bynum, 2009) to obtain total diesel fuel consumed (1,268 million gallons). Fuel savings are based on the total diesel fuel consumed, the percentage of fuel savings associated with the retrofits, and the penetration rate for tractor-trucks and trailers:

Total fuel savings = (1,268 million gallons)*(0.02)*((penetration rate for tractor trucks+penetration rate for trailers)/100)

Total fuel savings is multiplied by GHG emissions per million gallons of diesel fuel consumed (0.01125 MMt; DOE, 2008) to obtain the total annual GHG emission reduction.

Table 8-3. GHG Emission Reduction From Installing Aluminum Wheels

Year	Vehicle Miles Traveled by Heavy Trucks in PA (million miles)	Average Fuel Economy of Long-Haul Heavy Trucks (miles per gallon)	Diesel Fuel Savings (million gallons)	GHG Emission Reduction ($MMtCO_2e$)
2009	7,609	6.00	0.00	0.00
2010	7,609	6.00	3.80	0.04
2011	7,609	6.00	7.61	0.09
2012	7,609	6.00	11.41	0.13
2013	7,609	6.00	15.22	0.17
2014	7,609	6.00	19.02	0.21
2015	7,609	6.00	22.83	0.26
2016	7,609	6.00	26.63	0.30
2017	7,609	6.00	30.44	0.34
2018	7,609	6.00	34.24	0.39
2019	7,609	6.00	38.04	0.43
2020	7,609	6.00	39.31	0.44
Total				**2.80**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Heavy-Duty Trucks: Costs Associated With Installing Aluminum Wheels

The cost of retrofitting a tractor-truck and trailer with aluminum wheels is approximately $5,600 (2007$; EPA, 2009b). Since half of the wheels suitable for retrofit are located on the tractor-truck and half are located on the trailer, the cost is assumed to be $2,800 for each. The total cost of retrofitting is calculated by multiplying the number of trucks and trailers being retrofitted in a given year by $2,800. The cost savings, shown in Table 8-4, are realized in the fuel savings from reduced vehicle weight and lower rolling resistance. Fuel cost savings are simply the diesel fuel saved multiplied by the price per gallon of diesel fuel. Net costs are the installation costs minus the fuel cost savings. Since two standard tires cost roughly the same as one single-wide tire and wear at a comparable rate, there is no additional tire cost imposed by retrofitting (EPA, 2004a). Trucks retrofitted with aluminum wheels and new-generation wide tires cause no more damage to roads than trucks with conventional tire configurations (EPA, 2004a).

Table 8-4. Costs of and Cost Savings From Installing Aluminum Wheels for Single-Wide Tires

Year	Installation Costs ($MM)	Diesel Fuel Saved (million gallons)	Fuel Cost Savings ($MM)	Net Costs ($MM)
2009	0.00	0.00	0.00	0.00
2010	42.70	3.80	11.14	31.56
2011	42.70	7.61	23.91	18.79
2012	42.70	11.41	38.62	4.07
2013	42.70	15.22	53.38	-10.68
2014	42.70	19.02	69.50	-26.80
2015	42.70	22.83	85.45	-42.75
2016	42.70	26.63	99.92	-57.22
2017	42.70	30.44	114.26	-71.56
2018	42.70	34.24	129.02	-86.33
2019	42.70	38.04	143.75	-101.05
2020	21.35	39.31	148.95	-127.60
Total				**-469.56**

$MM = million dollars. Negative net costs indicate costs savings.

Heavy-Duty Trucks: GHG Reduction From Installing Fairings

At highway speeds, aerodynamic drag accounts for the majority of truck energy losses (EPA, 2004b). Reducing drag improves fuel efficiency. Since the majority of long-haul tractor trucks on the road in 2009 (>75 percent) already contain aerodynamic features, such as air deflectors mounted on the top of the cab, drag-reduction options should focus on trailer aerodynamics (Bynum, 2009). The addition of front and side fairings (e.g., skirts) to a trailer can reduce fuel consumption by 5 percent (EPA, 2009b). These panels are attached to the side or bottom of the trailer and hang down to enclose the open space between the rear wheels of the tractor and the rear wheels of the trailer. Such enclosure reduces wind resistance.

The estimated GHG emissions reductions from installing front and side fairings on trailers are based on diesel fuel savings. To calculate these emissions, the total VMT in the state (108,699 million miles; DOT, 2008a) are multiplied by the fraction of miles traveled by heavy-duty trucks (0.07; PA DEP, 2007) to obtain total annual VMT by heavy-duty trucks in Pennsylvania in 2007. Total annual VMT is then divided by the average fuel economy of heavy-duty trucks (6.0 miles per gallon; Bynum, 2009) to obtain total diesel fuel consumed (1,268 million gallons). Fuel savings are based on the total diesel fuel consumed, the percent fuel savings associated with the retrofits, and the penetration rate for trailers. DOT reports the number of commercial trailers registered in Pennsylvania in 2007 as 152,489 (DOT, 2008c). Since there are more trailers than tractor-trucks, the probability of realizing the fuel savings associated with a trailer retrofit is the ratio of tractor-trucks to trailers.

Total fuel savings = (1,268 million gallons)*(0.05)*(penetration rate for trailers/100)*(# of heavy-duty trucks/# of commercial trailers)

Total fuel savings is multiplied by GHG emissions per million gallons of diesel fuel consumed (0.01125 MMt; DOE, 2008) to obtain the total annual GHG emissions reduction.

Table 8-5. GHG Emission Reductions From Installing Fairings

Year	Commercial Trailers Registered in PA	Penetration Rate	Trailers Retrofitted	Diesel Fuel Savings (million gallons)	GHG Emissions Reduction ($MMtCO_2e$)
2009	152,489	0	0	0.00	0.00
2010	152,489	5	7,624	1.55	0.02
2011	152,489	10	15,249	3.09	0.03
2012	152,489	15	22,873	4.64	0.05
2013	152,489	20	30,498	6.19	0.07
2014	152,489	25	38,122	7.73	0.09
2015	152,489	30	45,747	9.28	0.10
2016	152,489	35	53,371	10.83	0.12
2017	152,489	40	60,996	12.38	0.14
2018	152,489	45	68,620	13.92	0.16
2019	152,489	50	76,245	15.47	0.17
2020	152,489	55	83,869	17.02	0.19
Total					**1.15**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Heavy-Duty Trucks: Costs Associated with Installing Fairings

The cost of retrofitting a trailer with front and side fairings is approximately $2,400 (2007$; EPA, 2009b). The total cost of retrofitting is calculated by multiplying the number of trailers being retrofitted in a given year by $2,400. The cost savings, shown in Table 8-6, are realized in the fuel savings from reduced vehicle drag. Fuel cost savings are simply the diesel fuel saved multiplied by the price per gallon of diesel fuel. Net costs are the installation costs minus the fuel cost savings.

Table 8-6. Costs of and Cost Savings From Installing Fairings

Year	Installation Costs ($MM)	Diesel Fuel Saved (million gallons)	Fuel Cost Savings ($MM)	Net Costs ($MM)
2009	0.00	0.00	0.00	0.00
2010	18.30	1.55	4.53	13.77
2011	18.30	3.09	9.72	8.58
2012	18.30	4.64	15.70	2.59
2013	18.30	6.19	21.70	-3.40
2014	18.30	7.73	28.26	-9.96
2015	18.30	9.28	34.75	-16.45
2016	18.30	10.83	40.63	-22.33
2017	18.30	12.38	46.46	-28.16
2018	18.30	13.92	52.46	-34.16
2019	18.30	15.47	58.45	-40.15
2020	18.30	17.02	64.47	-46.17
Total				**-175.84**

$MM = million dollars. Negative net costs indicate cost savings.

Locomotives

The two technology options considered in the locomotive analysis are based on EPA's SmartWay Transport Partnership (EPA, 2009c). The first option is the retrofitting of switchers and line-haul locomotives with APUs to reduce idling. The second option is the installation of a wheel flange lubrication system on line-haul locomotives to reduce friction. The improved fuel economy and associated GHG emissions reduction for each option are additive.

Locomotives: GHG Reduction from Anti-Idling Technologies

There are two types of locomotives commonly used by railroad companies—switcher and line-haul. Switcher locomotives are used to move materials within a rail yard, while line-haul locomotives are used to move freight across long distances (EPA, 2005). Switchers idle approximately 12 hours a day to avoid difficult startups and possible freezing inside the engine in cold weather (locomotive engines do not use antifreeze). Installing auxiliary engines in these locomotives can decrease fuel consumption, which helps reduce GHG emissions as well as local air pollutants and noise. This reduction is achieved by reducing fuel consumption while idling. Installing an APU is highly cost-effective, with a payback period of 2–2.5 years without taking any environmental benefits into account (EPA, 2005).

Approximately 27 percent of a switcher's annual fuel consumption is attributed to idling (DOE, 2002). While idling, the locomotive's main engine burns about 3 gallons of diesel fuel per hour in warm weather and 11 gallons per hour in cold weather (a higher idle setting is required to keep the engine from freezing). Assuming 4 months of cold weather a year, the average switcher would consume over 24,000 gallons of diesel fuel annually just idling. An APU can reduce fuel consumption to 0.8 gallons per hour, saving 20,500 gallons of fuel (EPA, 2005).

The number of switchers operating in Pennsylvania was estimated using the total fuel consumed for rail transport in Pennsylvania (provided by Michael Baker Consulting, 2009). Since switchers account for roughly 7.5 percent of the total diesel fuel burned by locomotives and an average switcher consumes 89,000 gallons of fuel per year, the number of switchers is calculated by dividing the total fuel consumed by switchers by 89,000 gallons (EPA, 1998). The number of line-haul locomotives operating in Pennsylvania was estimated by multiplying the total number of Class I locomotives operating in the United States (24,143; AAR, 2009a) by the fraction of U.S. rail tons carried in Pennsylvania (0.0237; AAR, 2009b). The number of locomotives in 2009 is grown through 2020 using the annual growth rate of fuel consumption.

The estimated GHG emission reductions from retrofitting locomotives with auxiliary power units are based on the total diesel fuel consumed, the percentage of fuel savings associated with the retrofits, and the penetration rate:

Total fuel savings = (total fuel consumed by switchers)*(0.23)*(penetration rate for switchers)/100) + (total fuel consumed by line-haul)*(0.10)*(penetration rate for line-haul/100)

Table 8-7. Estimated Number of Switchers and Line-Haul Locomotives in Pennsylvania

Year	Total Fuel Consumed by All Locomotives in PA in 2007 (thousand gallons)	Total Fuel Consumed by Switchers in PA (thousand gallons)	Total Fuel Consumed by Line-Haul Locomotives in PA (thousand gallons)	Estimated Number of Switchers in PA	Estimated Number of Line-Haul Locomotives in PA
2009	113,128	8,485	104,643	95	571
2010	117,119	8,784	108,335	99	591
2011	121,110	9,083	112,027	102	611
2012	125,101	9,383	115,719	106	632
2013	129,093	9,682	119,411	109	652
2014	133,084	9,981	123,103	112	672
2015	137,075	10,281	126,795	116	692
2016	141,066	10,580	130,486	119	712
2017	145,058	10,879	134,178	122	732
2018	149,049	11,179	137,870	126	752
2019	153,040	11,478	141,562	129	773
2020	157,032	11,777	145,254	132	793

Total fuel savings is multiplied by GHG emissions per thousand gallons of diesel fuel consumed (0.00001125 MMt; DOE, 2008) to obtain the total annual GHG emissions reduction. This calculation likely overestimates the incremental benefit of the policy option, since some locomotives are already equipped with APUs.

Table 8-8. GHG Emissions Reduction From Retrofitting Locomotives With APUs

Year	Penetration Rate of Switcher Retrofits (percent)	Number of Switchers Retrofitted	Penetration Rate of Line-Haul Locomotive Retrofits (percent)	Number of Line-Haul Locomotives Retrofitted	Diesel Fuel Savings (thousand gallons)	GHG Emissions Reduction ($MMtCO_2e$)
2009	0	0	0	0	0	0.00
2010	20	20	10	59	1,487	0.02
2011	40	41	20	122	3,074	0.03
2012	60	63	30	189	4,764	0.05
2013	80	87	40	261	6,554	0.07
2014	100	112	50	336	8,446	0.10
2015	100	116	60	415	9,967	0.11
2016	100	119	70	499	11,562	0.13
2017	100	122	80	586	13,231	0.15
2018	100	126	90	677	14,974	0.17
2019	100	129	100	773	16,790	0.19
2020	100	132	100	793	17,228	0.19
Total						**1.22**

APUs = auxiliary power units; GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Locomotives: Costs Associated With Anti-Idling Technologies

The cost of retrofitting a locomotive with an APU is approximately $27,250 (2007$; EPA, 2009c). The total cost of retrofitting is calculated by multiplying the number of locomotives being retrofitted in a given year by $27,250. The cost savings, shown in Table 8-9, are realized in the fuel savings from reduced idling. Fuel cost savings are simply the diesel fuel saved multiplied by the price per gallon of diesel fuel (DOE, 2009). Net costs are the installation costs minus the fuel cost savings.

Table 8-9. Costs of and Cost Savings From Retrofitting Locomotives With APUs

Year	Installation Costs ($MM)	Diesel Fuel Saved (thousand gallons)	Fuel Cost Savings ($MM)	Net Costs ($MM)
2009	0.00	0	0.00	0.00
2010	2.15	1,487	4.35	-2.20
2011	2.30	3,074	9.66	-7.36
2012	2.44	4,764	16.12	-13.68
2013	2.59	6,554	22.99	-20.40
2014	2.74	8,446	30.86	-28.12
2015	2.25	9,967	37.31	-35.06
2016	2.36	11,562	43.38	-41.02
2017	2.47	13,231	49.67	-47.20
2018	2.58	14,974	56.42	-53.84
2019	2.69	16,790	63.44	-60.75
2020	0.64	17,228	65.27	-64.63
Total				**-374.26**

$MM = million dollars; APUs = auxiliary power units. Negative net costs indicate cost savings.

Locomotives: GHG Reduction From Wheel Flange Lubrication System

Ineffective lubrication at the wheel/rail interface of trains results in wear and friction that costs the country's railroads more than $2 billion each year (DOE, 2006). Installing a wheel flange lubrication system significantly reduces track degradation and noise, and decreases line-haul locomotive fuel consumption by 5 percent (Mitrovitch, 2009).

The estimated GHG emission reductions from retrofitting locomotives with wheel flange lubrication systems are based on the total diesel fuel consumed, the percentage of fuel savings associated with the retrofits, and the penetration rate:

Total fuel savings = (total fuel consumed by line-haul)*(0.05)*(penetration rate for line-haul)/100)

Total fuel savings is multiplied by GHG emissions per thousand gallons of diesel fuel consumed (0.00001125 MMt; DOE, 2008) to obtain the total annual GHG emissions reduction. Note that a limited number of PA locomotives may already be equipped with lubrication systems.

Locomotives: Costs Associated With Wheel Flange Lubrication System

The cost of retrofitting a locomotive with an auxiliary power unit is approximately $650 (2007$; Mitrovitch, 2009). The operation and maintenance (O&M) cost of replacing springs and lubrication sticks is approximately $1,110 per year (Mitrovitch, 2009). The total cost of retrofitting is calculated by multiplying the number of locomotives being retrofitted in a given year by $650 and adding the O&M costs for all locomotives with wheel flange retrofits. The cost savings, shown in Table 8-11, are realized in the fuel savings from reduced friction. Fuel cost savings are simply the diesel fuel saved multiplied by the price per gallon of diesel fuel (DOE, 2009). Net costs are the installation costs minus the fuel cost savings.

Table 8-10. GHG Emissions Reduction From Retrofitting Line-Haul Locomotives with Wheel Flange Lubrication Systems

Year	Penetration Rate of Line-Haul Locomotive Retrofits (percent)	Number of Line-Haul Locomotives Retrofitted	Diesel Fuel Savings (thousand gallons)	GHG Emissions Reduction ($MMtCO_2e$)
2009	0	0	0	0.00
2010	50	296	5,417	0.06
2011	100	611	11,203	0.13
2012	100	632	11,572	0.13
2013	100	652	11,941	0.13
2014	100	672	12,310	0.14
2015	100	692	12,679	0.14
2016	100	712	13,049	0.15
2017	100	732	13,418	0.15
2018	100	752	13,787	0.16
2019	100	773	14,156	0.16
2020	100	793	14,525	0.16
Total				**1.51**

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table 8-11. Costs of and Cost Savings From Retrofitting Line Haul Locomotives With Wheel Flange Lubrication Systems

Year	Installation Costs ($MM)	Diesel Fuel Saved (thousand gallons)	Fuel Cost Savings ($MM)	Net Costs ($MM)
2009	0.00	0	0.00	0.00
2010	0.52	5,417	15.85	-15.33
2011	0.88	11,203	35.20	-34.31
2012	0.71	11,572	39.16	-38.44
2013	0.74	11,941	41.88	-41.15
2014	0.76	12,310	44.98	-44.22
2015	0.78	12,679	47.47	-46.68
2016	0.80	13,049	48.96	-48.15
2017	0.83	13,418	50.37	-49.55
2018	0.85	13,787	51.95	-51.10
2019	0.87	14,156	53.49	-52.62
2020	0.89	14,525	55.03	-54.14
Total				**-475.70**

$MM = million dollars. Negative net costs indicate cost savings.

Marine Vessels and Port Machinery

One of the possibilities for evaluating potential GHG emission reductions from marine vessels and port machinery is to examine information available from other states. For example, through the Global Warming Solutions Act of 2006 (AB 32), California has committed to reducing GHG emissions to 1990 levels by 2020. Measure T-6 in the AB32 scoping plan—freight transport efficiency measures—is a broad initiative designed to achieve at least a 3.5-$MMtCO_2e$ reduction in GHG emissions from the freight transport sector by 2020 (CARB, 2008). This represents about a 20 percent reduction in the projected 2020 GHG emissions from this sector. Due to the complexity of this sector and the need for a thorough investigation of a variety of approaches to determine how best to improve freight transport efficiency, an overall emission reduction goal was established for California measure T-6, rather than assigning emission reduction targets to individual measures.

The current components of California's freight efficiency measure are:

1. Port Drayage Trucks (replacement/retirement)
2. Transport Refrigeration Units Cold Storage Prohibition and Energy Efficiency
3. Cargo-Handling Equipment—Anti-Idling, Hybrid, Electrification
4. Goods Movement System-Wide Efficiency Improvements
5. Commercial Harbor Craft—Maintenance and Design Efficiency
6. Clean Ships
7. Vessel Speed Reduction
8. Long-Haul Trucks
9. Locomotives

Since GHG reduction options for trucks and locomotives in Pennsylvania have already been discussed, only items 2 through 7 are considered for the marine emissions reduction strategy. Similar to California, individual reduction targets are not assigned due to the complexity of the sector. Instead, an overall emission reduction goal of 18 percent is evaluated. The reduction target is lower than California's, since some options are simply moving the emissions from ports to power plants. With the electricity generation mix in PA (ReliabilityFirst Corporation [RFC] East subregion), GHG reductions are currently about 50 percent less than in California by switching from diesel fuel to shore power.

The overall GHG savings is calculated by multiplying the projected 2020 GHG emissions from ships (2.71 $MMtCO_2e$; Baker, 2009) and port machinery (0.29 $MMtCO_2e$; assumed to be 10 percent of "other" non-highway emissions; Baker, 2009) in PA by 0.18. Some strategies, such as vessel design improvements, will also achieve GHG emission reductions beyond PA. The costs and costs savings associated with marine reduction strategies are difficult to estimate due to the variety of control options and limited data availability. Thus, GHG reductions and costs associated with the marine sector are not included in Table 8-12.

Table 8-12. Potential GHG Emission Reductions for Marine Transport

Reduction Measures and Targeted Vehicles	Potential 2020 GHG Reduction ($MMtCO_2e$)	Net Costs ($MM)
All Measures Combined	0.54	Not Quantified
Ocean-Going Vessels		
Commercial Harbor Craft		
Cargo Handling Equipment		
Transportation Refrigeration Units		
Goods Movement System-Wide Efficiency Improvements		

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Marine: Ocean-Going Vessels

Options to improve the fuel efficiency of ocean-going vessels (OGVs) include advanced hull and propeller coatings, advanced engine design, heat recovery, wind power assistive devices, shore power, and vessel speed reduction. The last two options are discussed below.

Providing shore power at port facilities typically requires an up-front capital investment to purchase a more efficient engine, and the cost savings result from reduced fuel usage compared to the original equipment. The length of the payback period for this capital investment is often the most important question when considering the feasibility of an option such as this. While CARB anticipates that the overall savings due to reduced fuel consumption will offset the costs associated with retooling ships and ports in California, the costs may be substantially higher for Pennsylvania, with only modest GHG emissions reduction (CARB, 2008).

Shore power is becoming a major part of the green port strategies being implemented at ports on the U.S. West Coast. For example, the Port of Long Beach has adopted a green port policy that is intended to guide the port's operations in a green manner (CARB, 2006). The port has committed to providing shore power to all new and reconstructed container terminal berths and other berths, as appropriate. Through lease language, the port will require selected vessels to use shore power and all other vessels to use low-sulfur diesel in their auxiliary generators. The primary method for providing shore power at California ports is cold ironing, a strategy whereby ships shut down onboard auxiliary engines while in port and connect to electrical power supplied at the dock. Without cold ironing, auxiliary engines run continuously while a ship is docked, or "hotelled" at a berth, to power lighting, ventilation, pumps, communication, and other onboard equipment. Ships can hotel for several hours or several days.

In an example of cold ironing, an analysis was done on the cost-effectiveness of three ships that each visited the port 17 times during the year. On every trip, the ships were electrified for 60 hours in port, saving a total of 1,478 metric tons of fuel and reducing GHG emissions by 4,741 tCO_2e annually. Given the estimated annual cost of $1,583,000, this means that $334/$tCO_2e$ can be avoided through fuel consumption. However, the production of electricity for use in the ship will reduce the GHG savings with this approach. Using Pennsylvania emission factors, the annual GHG benefits of this program would be reduced to only 1,297 tCO_2e. This would mean a cost of $1,221/$tCO_2e$ reduction from the cold ironing method.

There are several other important factors to consider on the issue of cold ironing. This process has significant up-front costs. While the analysis above considers the annual costs of the program over a 10-year period, the initial costs are considerable. In this example, the port requires an initial investment of $4.5 million to provide electrification, and each of the three ships must undergo a $1.5 million modification to accept electricity from the ports. If very few ships make this modification, then the costs per tCO_2e would increase dramatically. Labor and electricity are also part of the cost estimate, though these are less of a problem in terms of up-front capital. Finally, the example is of ships that use the port 17 times a year. If a ship does not frequent a particular port more than a few times a year, it is unlikely that the owner would want to undertake the modification. And even if the ship were equipped to engage in cold ironing, the benefits of such a case would be far reduced.

Establishing vehicle speed reduction (VSR) zones around ports can reduce GHG emissions by reducing fuel consumption. A California study indicates that reducing the speed of a cargo ship from 22 knots to 12 knots from 6 to 24 miles offshore (outside the 6-mile precautionary zone) saves 1,249 gallons of fuel (CARB, 2008b). This translates into fuel cost savings of approximately $3,600. However, the costs associated with increased transit time must be considered. In the California study, the inbound time spent in the VSR zone was 1 hour longer for a trip traveling at 12 knots. Terminals may incur costs of $10,000–$20,000/hour for vessel delays. Ships may incur costs of up to $5,000/hour for delays if the vessel does not make up time during other segments of the voyage. If ships increase speed outside the VSR zone to make up time, total GHG emissions may increase.

Marine: Commercial Harbor Craft

Reducing GHG emissions from harbor crafts depends upon maintenance and operational improvements. Recommended options to evaluate are optimization of scheduling and vessel speed, improved hull surface finish and reduced hull fouling to reduce friction, and improved propeller design and maintenance.

Marine: Cargo-Handling Equipment

Cargo-handling equipment includes diesel-powered vehicles and cranes operating at ports. Recommended options to evaluate are reduced idling, hybrid propulsion technologies, and electrification of cranes (IAPH, 2009).

Marine: Transport Refrigeration Units

To transport temperature-sensitive products, shipping containers employ refrigeration systems powered by internal combustion engines. To reduce GHG emissions from these transportation refrigeration units, energy efficiency guidelines should be implemented and a best practices guidance document should be prepared to help educate the industry about potential costs and GHG savings.

Marine: Goods Movement System-Wide Efficiency Improvements

Intermodal transport in PA should be evaluated, with emphasis on improving marine, truck, and rail freight movement. All stakeholders, such as railroad operators, shipping companies, terminal operators, trucking companies, government agencies, and the public, should contribute to developing a program to achieve system-wide GHG emission reductions beyond existing individual measures. Such collaboration is likely to present opportunities to reduce GHG emissions from the overall freight movement supply chain.

Table 8-13 provides CO_2 emission factors from the recent Winebrake et al. *Journal of the Air and Waste Management Association* paper for the three primary freight transport modes. These factors can be used to estimate how shifting 100,000 20-foot equivalent units (TEUs) from rail and truck to ships in Pennsylvania might affect GHG emissions.

Table 8-13. Data for Transport Modes for Case Studies

Mode of Transport	Cost ($/TEU-mile)	Energy (Btu/TEU-mile)	CO_2 (g/TEU-mile)	PM-10 (g/TEU-mile)	SO_X (g/TEU-mile)
Truck	0.87	10,704	1,001	0.12	0.22
Rail	0.55	2,590	201	0.09	0.04
Ship	0.50	13,040	1,094	0.98	3.33

$/TEU-mile = dollars per 20-ft equivalent units-mile; Btu = British thermal unit; CO_2 = carbon dioxide; g/TEU-mile = grams per 20-ft equivalent units-mile; PM10 = particulate matter 10 microns in diameter or smaller; SOx = sulfur oxides.

Ships vary significantly in their sizes, speeds, and installed power, which means that their energy and emission characteristics vary. The information in Table 8-13 is based on ship characteristics that have been highlighted favorably in recent short sea shipping reports, because this policy option was intended to represent a short movement of freight. The ship used in this analysis is a roll-on/roll-off vessel capable of speeds of up to about 25 knots with about 11,000 kilowatts (kW) of power, which carries about 200 TEUs. Using the characteristics of other vessel groups would produce different results than the comparison shown in Table 8-13.

Trucking, Rail, and Marine Freight Transport: The GHG reduction analysis still needs to account for the different commodities, infrastructures, and expected near-term changes occurring in each of the major port areas in PA. This information is briefly summarized below:

- *Port of Philadelphia*—The expectation is that trade will pick up after the recession. A major port expansion is occurring as this port expands south into the Navy yard. This may bring as much as 1 million additional TEUs of freight into this port. The current freight volume via the Port of Philadelphia is 250,000 TEUs. Part of this expansion involves a deepening of the Delaware River channel from 40 to 45 feet. This will allow larger vessels (carrying 1,000 TEUs per vessel) to access this port. With this port expansion comes the need to make infrastructure improvements—mainly to nearby highways. Local truck and rail traffic is expected to increase. Pennsylvania's "America's First Marine Highway Enterprise" would extend the Ben Franklin Corridor (a surface transportation corridor linking the Columbus Regional Airport Authority intermodal terminal in Columbus, Ohio, as well as military depots and commercial distribution hubs in New York, New Jersey, Ohio, and Pennsylvania) to a new marine highway corridor connecting the Port of Philadelphia to other U.S seaports. The project includes highway, rail seaport, and intelligent transportation system solutions consistent with federal policy, as well as a proposed shipbuilding strategy for the U.S. domestic trade. Furthermore, the project supports and leverages considerable investments that the commonwealth of Pennsylvania has already made in upgrading and expanding Philadelphia marine terminals.

- *Port of Pittsburgh*—This is really 200 miles of a series of privately owned ports along the three rivers. It is expected that the freight volumes will increase with trade. Note that 75 percent of the current freight volume in southwestern Pennsylvania ports is coal transport. Impending EPA and federal legislative requirements for GHG reductions in the energy supply sector would be expected to change historical coal production, transport, and use patterns in this corridor.

- *Port of Erie*—This is a Great Lakes port with the possibility of rapid growth in the 2009-2020 time horizon. Expected growth is a doubling or tripling in cargo handled. Erie is within the bi-national Great Lakes St. Lawrence Seaway system. Therefore, new policies that affect the Port of Erie need to consider their compatibility with the established policies affecting ports within this system.

A December 2007 study by the Texas Transportation Institute found that efficient short sea shipping is more fuel efficient per ton-mile than goods movement by trucks and even railroads. For example, an inland barge enjoys 576 ton miles to the gallon, compared to 155 on a truck and 413 on a train. From a GHG emissions perspective, short sea shipping can offer substantial reductions.

Numerous industry stakeholders agree that the Harbor Maintenance Tax is an onerous roadblock to the energy bill’s short sea transportation provisions. This imposes an additional tax on trucking companies that move their cargo from roads and rails to water vessels. Efforts are underway to urge Congress to waive the Harbor Maintenance Tax for short sea transponders. The legislation would not impose the tax to cargo in intermodal cargo containers and loaded by crane on a vessel, or cargo loaded on a vessel by means of wheeled technology. If this is passed by Congress, it would remove a large barrier to implementing the short sea shipping program.

Cost to Regulated Entities: The options that have been evaluated and included in the summary quantification table for trucking and railroads involve some upfront cost to the regulated entities (and in one case some operating and maintenance expenses); however, the fuel savings will be expected to offset the investment costs in a relatively short period of time (one to three years) such that the entities that install these controls will save money.

Ease of Implementation:

Will vary depending on the specific measure.

Implementation Steps:

To be determined. EPA staff have indicated that implementation of SmartWay truck transport initiatives has been more successful via loan programs than by grants.

Key Assumptions:

The trucking analysis assumes that the penetration rates for the aluminum wheel and fairing retrofits are feasible by 2020. The ability to meet these penetration rates depends on the availability of vehicle body shops that can perform the retrofitting.

Since the technology options analyzed for trucks are retrofit options, new trucks entering the fleet are not considered. Under business as usual, the fuel economy of the existing truck fleet is assumed to remain constant through 2020.
Truck and trailer registrations are assumed to be accurate surrogates for the number of trucks operating in Pennsylvania. In reality, interstate transport may add significantly to the number of trucks and trailers operating in Pennsylvania.

The locomotive analysis assumes that no locomotives are currently retrofitted with the technologies evaluated. Since some locomotives are likely to already be retrofitted, the analysis likely overestimates the incremental GHG benefits.

The cold-ironing project estimate makes assumptions regarding the level of use of cold-ironing facilities, and the amount of emissions from OGVs while at sea and in the harbor. These estimates were based on previous analyses of emission reduction projects in New York and Long Beach. If the factors involved in Pennsylvania harbors are significantly different, then the costs and emissions savings would likely change.

Key Uncertainties:

The fuel efficiency gains for truck and trailer retrofits are based on test track conditions. The actual on-road fuel efficiency improvement may be less.

The diesel fuel consumed by heavy-duty trucks in Pennsylvania is approximated based on an estimate of heavy-duty truck VMT in the state. The actual diesel fuel consumed may be different.

Establishing VSR zones may increase overall emissions (outside VSR zones) if ships speed up during other segments of voyage.

Other Potential Benefits and Drawbacks:

Additional potential benefits of changing behaviors to decrease GHG emissions from freight transportation include:

- Decreased emissions of ozone precursors (VOC and NO_x), CO, and PM.
- Decreased motor fuel use.
- Direct support of Smart Transportation initiatives, projects, and programs.
- Reduced congestion.

Potential Interrelationships With Other GHG Reduction Measures:

These measures aimed at changing behavior need to be implemented in coordination with system changes within the transportation sector, and with transportation-focused land-use measures.

Subcommittee Comments

While freight transport is often overlooked when investigating GHG reductions, the analysis of this work plan showed significant potential GHG reductions (6.67MMtCO2E 2009-2020) at a substantial net financial savings (-$224/$/tCO2E).

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Transportation 9. Increasing Federal Support for Efficient Transit and Freight Transport in PA

Summary: Many of the advancements needed in Pennsylvania's transit systems will not come without a significant increase in federal support, especially through federal funding. This initiative outlines several measures aimed at increasing federal support for efficient transit projects and freight transport in Pennsylvania, including public transit, car- and vanpooling, telecommuting, and other advancements that will help cut GHG emissions from the transportation sector. Efficient transportation and freight transport systems also reap many other benefits as well, including cleaner air, increased mobility, revitalized communities, decreased oil use, and less incentive for overdevelopment.

Other Agencies/Officials Involved: PennDOT, local transit agencies, regional planning organizations, metropolitan planning organizations, rural planning organizations.

Possible New Measures:

Three specific pieces/types of federal legislation could be vehicles for increased support for efficient transit and freight transport in Pennsylvania:

I. Federal Transportation Bill—This legislation provides the guidelines for how federal transportation dollars are doled out to the states. It is up for reauthorization this year, and there is a push both to use this bill to map out a comprehensive strategy for the growth of the country's transportation systems (versus the scattershot policy implemented in the past), and to make this bill more supportive of efficient transit and efficient, multimodal freight transportation—both efforts that Pennsylvania should be a part of.

II. Federal Stimulus Bills—In addition to the recently passed stimulus package, which included funds for public transit and freight mobility projects, there could very well be additional stimulus bills in the near future. Pennsylvania officials should be pushing the federal government to carve out significant sums of money from such stimulus packages for efficient transit and freight options.

III. Federal Climate Legislation—Congress is expected to try to pass a comprehensive global warming bill in 2009. Pennsylvania officials should be working to ensure that efficient transit and freight options receive significant support from such a bill, given their critical role in cutting GHG emissions. Most notably, funds for efficient transit should be secured from the sale of pollution credits within a cap-and-trade system, and funds for efficient freight transportation should center on engine fuel economy and idling reduction technology, as well as rail infrastructure investment.

With the help of a national transportation strategy, and with additional federal funds, the state could more realistically consider major new projects, such as high-speed rail systems, expansions of existing light rail systems, connecting all of the state's major cities via rail, and more aggressive shifting of freight transport to rail.

To help secure a national transportation strategy and additional funds for efficient transit and freight transport, several steps should be taken:

- Direct contact between state legislators and Pennsylvania's federal delegation, stressing the importance of their active involvement in this debate in Congress.
- Direct contact between local elected officials and Pennsylvania's federal delegation, stressing the importance of their active involvement in this debate in Congress.
- Citizen education about the need for federal support, to help mobilize Pennsylvania's federal delegation.
- Outreach by transit groups, transit agencies, freight shippers, logistics professionals, and other interested parties to the federal delegation, to provide local information and to encourage active involvement in these federal debates.

Potential GHG Reductions and Economic Costs:

Table 9-1. Estimated GHG Reductions and Cost-effectiveness

GHG emission savings (2020)	1.17	$MMtCO_2e$
Net present value (2009–2020)	$1,004*	$million
Cumulative emissions reductions (2009–2020)	12.9	$MMtCO_2e$
Cost-effectiveness (2009–2020)	$78	$\$/tCO_2e$

*Because T-9 uses federal dollars exclusively, it should be noted that the cost figures for T-9 are calculations of how many federal dollars—not state dollars—would be required to implement the work plan.

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate costs savings.

The emission benefits of increasing federal support for efficient transit and freight transport were evaluated by examining the criteria pollutant emission benefit estimates for the CMAQ projects funded in the commonwealth of Pennsylvania during FY 2008. This evaluation used the relationship between highway vehicle GHG emissions and criteria pollutant emissions to estimate the GHG benefit of these CMAQ project investments. The *CMAQ Detailed Project Listing Report* (FY 2008) was used to identify the project amounts (dollars) and criteria air pollutant emission benefits (kg/day). CMAQ-funded project types in this report include traffic flow improvements, demand management, pedestrian/bicycle, shared ride, transit, and Surface Transportation Program/CMAQ.

Table 9-2 summarizes the spending amounts and the criteria air pollutant emission benefits for the *CMAQ Detailed Project Listing Report* (FY 2008).

**Table 9-2. Commonwealth of Pennsylvania CMAQ Projects—
Amounts and Criteria Pollutant Benefit Estimates**

Project Amount ($)	$91.6 Million
VOCs Reduced	18,352 kg/day
CO Reduced	151,402 kg/day
NO_x Reduced	8,541 kg/day

National estimates of GHG emissions from the EPA *Inventory of Greenhouse Gas Emissions and Sinks: 1990–2006* for 2006 were used to estimate the current year relationship between CO_2 equivalent and CO emissions. CO emissions were selected as the appropriate criteria pollutant indicator because CO is a product of combustion, and the controls installed on vehicles to reduce criteria pollutant tailpipe emissions also reduce CH_4 and N_2O emissions. The 2006 CO_2 emission estimates were taken from Table 3-7 of the EPA Inventory for onroad gasoline and diesel, while CH_4 and N_2O emission estimates are from Tables 3-21 and 3-23, respectively.

Table 9-3. EPA GHG Inventory—U.S. National Emission Estimates 2006

Source Type	CO_2 (Tg CO_2e)	CH_4 (Tg CO_2e)	N_2O (Tg CO_2e)	Totals (Tg CO_2e)
Gasoline-Onroad	970.7	1.7	29.0	1,001.4
Diesel-Onroad	215.3	+	0.3	215.6
Totals	1,186.0	1.7	29.3	1,217.0

EPA's *National Emission Trends* report indicates that the 2006 CO emissions from highway vehicles were 44,726 thousand short tons, or 40.56 MMt. Therefore, the ratio of CO_2e to CO emissions for highway vehicles in 2006 was 30:1.

The 151,402 kg/day CO emission benefit of the PA CMAQ projects, if observed on work weekdays (260 days/year), is equal to an annual benefit of 39 million kg or 39 gigagrams (Ggs). If the benefits occur 365 days/year, then the annual benefit is 55 Ggs. The estimated CO_2e benefit, applying the 30:1 emission ratio yields an emission reduction of 1.17–1.65 MMtCO_2e.

Costs:

Minimal. These measures revolve around influencing federal policy, and requesting and securing funds from the federal government. As noted in Table 9-2, the CMAQ federal spending in Pennsylvania for FY 2008 was $91.6 million, or $55–$78/t of GHGs reduced.

Other Potential Benefits and Disbenefits:

Additional potential benefits of expanding efficient transportation systems include:

- Decreased emissions of ozone precursors (VOC and NO_x), CO, and PM.
- Decreased motor fuel use.
- Enhanced mobility for citizens and visitors, as well as for multimodal freight transport.
- Direct support of Smart Transportation initiatives, projects, and programs.
- Reduced congestion.
- Reduced sprawl.

Ease of Implementation

As suggested above, this work plan shall be fairly easy to implement, as it does not require any new state regulation or legislation. It simply involves a more concerted effort by state leaders to influence federal decision-making so that Pennsylvania receives more federal dollars.

Implementation Steps

Specific actors and federal decision-making opportunities are outlined above.

Key Assumptions

These are explained within the quantification section.

Key Uncertainties

Any uncertainties around cost and benefits estimates were noted within the quantification section. There are no other uncertainties of note.

Additional Benefits and Costs

These are described above within the benefits and disbenefits section.

Potential Interrelationships with Other GHG Reduction Measures:

Most notably, many of the system improvement projects called for in the transportation sector will be greatly aided by an increase in federal funding support.

Subcommittee Comments

Transit projects and freight transport projects within Pennsylvania will forever be limited to a certain degree if the state does not seek greater financial support from the federal government for such projects. The GHG reductions for this work plan were found to be substantial (12.87MMtCO2E for 2009-2020), reflecting the potential gains to be made.

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Transportation 10. Enhanced Support for Existing Smart Growth/Transportation & Land-Use Policies

Summary: This initiative recommends the continued adoption and acceleration of existing and future statewide land-use and transportation policies that follow more sustainable "smart growth" principles. Smart growth seeks to create more compact communities throughout the state featuring increased density and a mixture of land uses that generate less vehicle traffic while being more supportive of auto trip-reduction measures, such as transit, non-motorized modes and TDM programs, such as car sharing, carpooling, etc. Smart growth also sites commercial and industrial facilities and growth with ready access to an efficient, multimodal freight transportation system.

Smart growth land-use approaches and incentives need to be initiated as soon as possible and as aggressively as possible to secure early GHG reductions, which are then cumulative through the 2020 analysis year. Early, successful implementations also encourage other parties to implement similar approaches, and yield earlier state and local infrastructure investments that are more efficient and cost-effective.

This effort seeks to expand the collaborative process between state and local agencies to promote smart growth as a viable and preferable alternative to the current sprawled development pattern. In addition, the statewide land-use policies and programs promoted will continue to seek to limit the encroachment of development onto farmland and natural spaces, in particular wooded areas, which act as carbon sinks. Trip reduction, transit enhancements, and other measures cannot reach their full potential without the adoption of supportive land-use measures. As such, the adoption of smart growth principles helps to ensure the success of the proposed transportation measures. In addition, these policies should foster more compact development, which in turn reduces transportation and other infrastructure costs.

Quantification of work plans T-10 and T-11 was combined and is presented in work plan T-10.

Other Agencies Involved: DEP, PennDOT, DCED, local transit agencies, MPO/RPOs, county and local governments.

Possible New Measures:

The Keystone Principles & Criteria for Growth, Investment & Resource Conservation adopted by the Economic Development Cabinet May 31, 2005, provides a policy framework for greater support for smart growth measures. These 10 principles and related criteria can be more actively pursued and expanded upon to encourage more development and redevelopment using smart growth concepts. The principles include:

- **Redevelop first**
- **Provide efficient infrastructure**
- **Concentrate development**
- Increase job opportunities
- **Foster sustainable business**
- **Restore and enhance the environment**
- **Enhance recreational and heritage resources**
- Expand housing opportunities
- **Plan regionally; implement locally**
- Be fair

While all of these principles have value, seven of them (highlighted in bold) are noted as having direct impacts on GHG emissions and should therefore be key pieces of any climate action plan.

Additionally, the 2006 report by the Pennsylvania Transportation Funding and Reform Commission, *Investing in Our Future: Addressing Pennsylvania's Transportation Funding Crisis,*[22] provides clear goals that address transportation funding and demand issues, which in turn intrinsically address GHG emissions:

- Link land use and transportation through the implementation of "Smart Transportation" design practices and preconditioning major capacity improvements on a community land use/transportation vision that provides for sustainable investments.

- Develop an incentive-based funding program to link land- use and multimodal community investments through collaboration with partners, including municipalities, Metropolitan Planning Organizations, Rural Planning organizations, and other interested parties.

The sub committee supports the full promulgation of these core policies, including accelerated and enhanced actions as appropriate:

1. Link land use and transportation through the implementation of "Smart Transportation" design practices and preconditioning major capacity improvements on a community land use/transportation vision that provides for sustainable investments.

The report *Back to Prosperity: A Competitive Agenda for Renewing Pennsylvania*[23] noted that the current development patterns within the commonwealth are both spreading out the population and industry and "hollowing out" the urban fabric, with city neighborhoods and services in decline, while unsustainable suburban and exurban development continues unabated. The result of this development pattern is an increased need for auto travel, communities where transit is not viable, households that generate an excessive number of auto trips per capita, and sparse, outlying development of commercial and industrial facilities, and retail and employment centers, all of which result in increased GHG emissions. Additionally, there is a backlog of both state and local transportation maintenance needs that are not being met, while at the same time a public demand for additional capacity. In response, the commonwealth and PennDOT have instituted the concept of "Smart Transportation" with regard to the planning process.

Smart Transportation is defined as partnering to build great communities for future generations by linking transportation investments and land-use planning to decision making. Smart Transportation aims to accommodate growth without taxing the transportation infrastructure, and

[22] *Investing in Our Future: Addressing Pennsylvania's Transportation Funding Crisis*, Commission Final Report, Pennsylvania Transportation Funding and Reform Commission, November 2006. Available from PennDOT or at: http://www.dot.state.pa.us/Internet/pdCommissCommitt.nsf/HomePageTransFundReform Comm?OpenForm

[23] *Back to Prosperity: A Competitive Agenda for Renewing Pennsylvania*, The Brookings Institution Center on Urban and Metropolitan Policy, 2003. http://www.brookings.edu/reports/2003/12metropolitanpolicy_pennsylvania.aspx

in doing so reducing vehicle travel and associated GHG emissions. By linking transportation and land-use decisions, growth can occur in more sustainable ways that do not require the infrastructure or land area that current development patterns would demand. Smart Transportation fully supports both the guiding principles from the Transportation Funding and Reform Commission and the Keystone Principles.

The intent is that this GHG reduction work plan will build on and fully implement the various Smart Transportation concepts and Keystone Principles already advocated by the state, promoting these concepts such that they become intrinsic to the decision process at PennDOT, other state agencies, MPO/RPOs, and local governments. The goal is to align the project planning and approval process throughout the commonwealth to recognize smart growth and smart planning concepts as core values for all projects and related activities. While existing work has identified and begun implementing these principles, the Land Use-Transportation Subcommittee recommends that an increased effort to adopt these as standard practice statewide would result in the benefits being realized sooner and the final impact being greater. The subcommittee therefore recognizes the established framework as the path forward, and feels that a greater emphasis on these concepts will further the commonwealth goal toward meeting its GHG reduction needs.

Smart Transportation Principles

PennDOT's 2008 *Sound Land Use Implementation Plan, Building a Strategic Agenda for Smart Transportation* identified 10 principles that define the core concepts in this approach to land use and transportation planning:

1. Money counts
2. Choose projects with high value to price ratio
3. Enhance the local network
4. Look beyond level-of-service
5. Safety first, and maybe safety only
6. Accommodate all modes
7. Leverage and preserve existing investments
8. Build towns and not sprawl
9. Understand the context; plan and design within the context
10. Develop local governments as strong land use partners

While all of these concepts are necessary for Smart Transportation to succeed as a guiding principle, three of the concepts (**bold** highlight) are noted as having direct impacts on greenhouse gas emissions. The Subcommittee endorses all these core concepts. We highlight the following as principles of particular interest in regards to reducing greenhouse gases:

Enhance the Local Multimodal Transportation Network

One of the basic tenets of smart growth is the need to focus on local communities and develop a transportation network that connects local residents, employment and services rather than supporting segregated land uses. Enhancing the local network of both local and state facilities provides this continuity and in doing so encourages trips to remain local and supports the use of modes other than private auto and truck. At the same time an enhanced and connected local network minimizes the need to travel between more distant centers for services and helps to minimize the vehicle miles of travel (VMT) within a local community. A fully connected network has a higher capacity and is more economical to construct and maintain than a series of segregated neighborhoods served by arterial and bypass roadways.

Accommodate all Modes

In order to reduce passenger travel by private vehicles there must be alternative modes (including bicycle, pedestrian, bus, rail, and high occupancy auto) that can reasonably be used for a substantial proportion of trips. Conversion of truck freight to more cost-effective and less polluting modes, such as rail and water, is also a critical component (see Work Plans 8 & 9). Smart transportation makes this a primary consideration and accommodation of other modes of travel an intrinsic part of the planning process instead of an add-on to a roadway design effort.

Build Towns not Sprawl

There is a consensus that current sprawl development, with its associated separation of land uses, necessitates the use of private auto and the absence of defined communities does not readily accommodate or support other forms of transportation. Building towns, whether as independent rural communities or as neighborhoods in a larger urban context encourages people to remain local and as such opens up the opportunity to use other forms of transportation. The subcommittee feels this will directly impact greenhouse gas emissions and should be fully pursued.

Using Transportation to Encourage Sound Planning Practices

It has long been argued that the "car culture" has resulted in the current planning paradigm which necessitates the use of private auto for the majority of passenger trips and results in the excess consumption of land and fuel. However, just as the current transportation planning practices tend to encourage sprawling development, a shift towards transportation projects that support smart growth can help drive residential and commercial/ industrial development into more compact and integrated forms. PennDOT's emphasis on smart transportation supports this shift. Local land use and transportation planning are critical components to success.

Focusing funding on smart growth supportive transportation projects discourages the adoption of projects that might otherwise result in increased sprawl. An example of this is NJDOT's "right sizing" approach, which seeks to encourage projects focusing on connectivity to increase capacity, rather than bypassing congested areas, as well as focusing on improvements for local access and avoiding constructing restricted access roads which tend to favor regional trips. A renewed focus on the local community fosters smart growth, which leads to reduction in the number of trips, vehicle miles of travel and GHG emissions.

PennDOT's 2008 *Sound Land Use Implementation Plan, Building a Strategic Agenda for Smart Transportation (PennDOT, 2004),* The Keystone Principles, and other existing statewide initiatives provide a focused approach to the types of policies that can be adopted at the local level to encourage smart growth within existing laws, regulations, and codes. Redevelopment of an existing site, redevelopment of a corridor in a more context-sensitive manner, neighborhood redevelopment, infill, or a new construction on a greenfield site all offer the opportunity for local agencies to influence how their communities will grow. PennDOT and other state agencies have a role to play by prioritizing infrastructure investments on those projects that support local smart growth efforts and help communities realize the savings involved in adopting these principles.

Building on the programs already in place, local officials and decision makers need to have the tools and knowledge available to help guide the growth of their communities in more sustainable ways. By providing communities with the support needed in moving toward a smart growth planning approach, state agencies can help ensure that new growth can be accommodated in ways that minimize and even reduce GHG emissions while also being more cost-effective.

2. Develop an incentive-based funding program to link land use and multimodal community investments through collaboration with partners including Municipalities, Metropolitan Planning Organizations, Rural Planning organizations, and other interested parties.

Sound land use policies that seek to reduce private vehicle travel and limit GHGs can only succeed with the support of the local communities who guide development within their regions. The decentralized nature of development planning within the commonwealth limits the impact that state agencies can have on local decisions, in particular PennDOT.

There is growing support at the local level to change the business-as-usual approach to development. Pennsylvania state agencies have limited authority regarding local and regional land-use and transportation decisions. However, PennDOT can and should focus its limited funds on projects that encourage more sustainable development patterns. Local projects tend to focus capacity increases where they are needed most. If carried out in light of the local context, the projects will generate maximum return for a given investment. By fostering smart growth through available funding mechanisms, PennDOT maximizes the return on its investment and helps support development that reduces GHGs. In conjunction with transportation measures, policies involving other infrastructure investments, such as water and sewer infrastructure, could be developed to ensure that these services are expanded in a way that encourages and supports smart growth.

This, in particular, applies to passenger modes other than private autos. Transit services are not only more successful in compact communities, but also require fewer subsidies to operate, with more passengers attracted to a system served by a more compact route network. Compact development also means that non-motorized trips become increasingly viable, and investments in facilities to support these trips (trails, sidewalks, expanded shoulders, etc.) are better patronized and more cost-effective.

Agencies such as PennDOT also have a role in educating communities on the preferred development patterns and how this can benefit the local area. Communities often see compact development in the negative light of blighted urban communities. PennDOT has the opportunity to not only support smart growth through funding decisions, but also provide examples of vibrant, livable, smart growth communities. PennDOT is also in a position to demonstrate how the return on the investment is higher for the smart growth projects and the long-term costs substantially less. By implementing the concept of smart growth at the local level, communities can be encouraged to make land-use decisions that reduce transportation needs and maximize benefits to the community, including the reduction in GHG emissions.

Finally, compact development and smart growth reduce the need to develop new areas and help protect and expand wooded and other natural spaces that act as carbon sinks. State agencies have an additional role to play in the preservation and expansion of these areas. Natural settings enhance the neighboring communities and can provide an opportunity to attract tourism. Assisting communities in preserving natural areas through planning support, making focused transportation investments that do not encourage the development of new land, and supporting local community conservation efforts can further build local support for smart growth efforts.

Using an approach that directs funds into successful, smart growth supportive initiatives and partnering with local communities can advance compact, context-sensitive projects that will improve the livability of towns and cities, reduce transportation demands and the associated costs, and in turn reduce GHG emissions.

Potential GHG Reductions and Economic Costs:

GHG reductions for Work Plans T-10 and T-11 are combined and presented in Table 10-1.

Table 10-1. Estimated GHG Reductions and Cost-effectiveness

GHG emission savings (2020)	0.76-1.84	$MMtCO_2e$
Net present value (2009–2020)	<$0	$million
Cumulative emissions reductions (2009–2020)	3.79-9.18	$MMtCO_2e$
Cost-effectiveness (2009–2020)	<$0	$/$tCO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate costs savings.

Cost and savings data in the literature for statewide application are limited. The subcommittee agrees that net costs will be zero or negative, with a likelihood of net savings to the commonwealth.

Cost to Regulated Entities:

If any, costs and/or cost savings will vary based on the specific policies being implemented.

Cost to State:

This will also vary depending on the specific policy being implemented, but there is potential for cost savings, as limited transportation and other infrastructure costs are minimized by focusing on more compact areas, where maximum benefits can be realized.

There will be front-end costs of program development and implementation. Also, a successful program will likely require ongoing incentives and similar actions to ensure continued success.

In general, research supports the assertion that similar land-use measures result in net economic benefits that outweigh any associated costs to implement.

Other Potential Benefits and Disbenefits:

Additional potential benefits of promoting smart growth and transportation include:

- Decreased emissions of ozone precursors (VOC and NO_x), CO, and PM.
- Enhanced mobility for citizens, goods, and visitors.
- Reduced congestion.
- Increased urban redevelopment.
- Financial stabilization of declining towns and cities.
- Increased tourism revenue to revitalized communities and preserved natural areas.
- Increased density reduces infrastructure costs for related services, such as water and sewer lines. The capital and ongoing costs for roadways serving denser development also tend to be lower.
- Retaining urban professionals attracted to smart growth communities.
- Reduced infrastructure costs.

Ease of Implementation

The redistribution of development among regions, the costs associated with the preparation of brownfield sites, the home-rule nature of the commonwealth, the costs of new transit, and the potential need to offset tax revenues make these policies challenging to implement.

Implementation Steps

These will vary by the specific measure, but several initial steps are described in above sections.

Key Assumptions

Key assumptions are outlined in the quantification section, below.

Quantification

The impacts of this work plan (T-10) were analyzed in conjunction with the actions proposed in T-11—Transit Oriented Design, Smart Growth Communities, & Land Use Solutions. Both T-10 and T-11 speak to the issue of land use and development. Quantification methods for land-use impacts at the state level are general in nature and implicitly include TOD as a general policy. As specific information on TODs in the commonwealth could not be obtained or synthesized, the impacts of these two measures were analyzed together.

An extensive review of land-use measures as they appear in existing climate action plans, as well as other related sources, was undertaken (see references below.) Although no one methodology was identified as a preferred approach or state of the practice, the results reported provided guidance for this effort. The studies have estimated the VMT reductions that can be achieved by land-use measures, and in turn calculated the associated GHG reductions. Again various approaches have been employed in this regard, with reduction goals being applied to specific categories of VMT:

- Overall VMT (statewide).
- Urban VMT only.
- Light-duty (auto) VMT.
- VMT in specific urban areas (generally quoting earlier studies).

The vast majority of the climate action plans reviewed consider VMT reductions from baseline projected VMT levels, while a small number of more recent plans have included ambitious GHG targets specific to land use and will require per-capita decreases in VMT from current conditions. However, it was felt that for the commonwealth, impacts closer to those found in the majority of the studies were more appropriate.

VMT projections from PennDOT's Roadway Management System (RMS)/Highway Performance Monitoring System (HPMS) database, including both current estimates and estimates for 2020, formed the basis of this analysis. For the purpose of this work, the VMT estimates were segregated into the following area type categories:

- *Urban Areas:* Urban areas consist of a central city and surrounding areas whose combined population is greater than 50,000. Other towns outside of urban areas whose populations exceed 2,500 are also included in the urban population.
- *Small Urban Areas:* Small urban areas are those urban places, as designated by the Bureau of the Census, having a population of 5,000 or more that are not located within any urban area.
- *Rural Areas:* Rural areas are any area not falling within either of the above categories.

The data were further stratified by county, with the VMT estimates in these databases provided for 2005 as well as the projections provided in 5-year increments to 2035.

While a general VMT reduction factor could have been applied statewide, it was felt that attention to factors specific to both the area type and the county was appropriate. The research undertaken indicated that land-use measures have the greatest impact in urbanized areas and minimal impact in rural areas. Also, a number of counties within the commonwealth are not expected to grow significantly prior to 2020 (the analysis year of this effort); as such, the opportunities to incorporate smart growth into new and redeveloped areas would be limited. A review was done to classify VMT in the state as occurring in areas with significant, intermediate, and minimal land use/VMT reduction potential, as well as by urban, small urban, and rural areas. The thresholds between these categories were determined by inspection and were based on the expected growth between 2005 and 2020. Table 10.2 summarizes the thresholds that were used in these calculations.

Table 10-2. Thresholds Used for Determining VMT Reduction Potential

Potential for Land Use to Impact VMT	2005–2020 VMT Growth Thresholds by Area Type		
	Urban	Small Urban	Rural
Significant	>50%	>50%	>15%
Intermediate	2%–50%	25%–50%	10%–15%
Minimal	<25%	<25%	<10%

The total VMT for the state was disaggregated into these categories and is summarized in Table 10-3, below. In addition, based on the research of other state plans and related studies, high and low estimates of the VMT reduction that could be reasonably expected were extrapolated for each category and are summarized in Table 10-4.

Table 10-3. VMT by Potential Land Use Impact and Area Type

Potential for Land Use to Impact VMT	Annual Vehicle Miles of Travel		
	Urban	Small Urban	Rural
Significant	16,926,742,505	4,178,175,075	12,229,722,850
Intermediate	30,905,392,420	2,219,319,355	9,697,073,260
Minimal	34,187,051,940	3,384,394,610	20,987,317,500

Table 10-4. VMT Reduction Targets by Potential Land Use Impact and Area Type

Potential for Land Use to Impact VMT	VMT Reduction Goals		
	Urban	Small Urban	Rural
Significant	7%–10%	5%–10%	1%–2%
Intermediate	5%–7%	2%–5%	0%
Minimal	2%–5%	0%	0%

The estimated annual VMT reduction ranged from 2,616,451,748 to 6,338,782,249 vehicle miles. This was used to proportion out the benefits from the overall GHG emissions for on-road gasoline vehicles as found in the PA GHG inventory. The total estimated emission reductions ranged from 1.94 percent to 4.71 percent annually in 2020 Total GHG emission reductions ranged from 0.76 to 1.84 $MMtCO_2e$ annually in 2020. Benefits (VMT and GHG reduction) were assumed to begin in 2010, and increase linearly to 2020, resulting in cumulative benefits over the period of analysis ranging from 3.79 to 9.18 $MMtCO_2e$.

Key Uncertainties

The ability to meet the targets outlined above remains in question, and growth estimates used in the RMS are questionable, in particular given current economic conditions.

Additional Benefits and Costs

Additional potential benefits of expanding smart growth initiatives include:

- Enhanced mobility for citizens and visitors.
- Reduced congestion.
- Increased urban redevelopment.
- Financial stabilization of declining towns and cities.
- Increased tourism revenue to revitalized communities and preserved natural areas.
- Increased density reduces infrastructure costs for related services, such as water and sewer lines. The capital and ongoing costs for roadways serving denser development also tend to be lower.
- Retaining urban professionals attracted to smart growth communities.
- Reduced infrastructure costs.

Potential Interrelationships With Other GHG Reduction Measures:

This initiative recognizes that transit is a key factor in influencing the success of smart growth principles in urban areas. In less developed regions, smart growth leads directly to the preservation of farmlands and natural spaces, which in turn act as carbon sinks and, in the case of agriculture, provide a potential for supporting the alternative fuels industry.

See Work Plans T-6, T-7, and T-11.

Synergistic:

- Transit enhancements both support smart growth and require this type of development in order to be successful.
- Compact development is a more supportive environment for TDM measures.
- Compact development and smart growth tend to be supportive of passenger non-motorized (bicycle, pedestrian) and more efficient freight (e.g., rail) modes.

Other:

- Creation and preservation of GHG sinks.
- Production of alternative fuels.

Drawbacks

The movement to more compact forms of development will limit the distribution of new development, and locations that would have been attractive under the current paradigm may no longer be attractive for new projects. This seeming disparity will need to be addressed.

Subcommittee Comments

The quantified GHG benefits of the combined T-10 and T-11 work plan are smaller than some work plans (3–9MMtCO2E for 2009-2020), but, much like transit improvements, the full benefits of smart growth and land use policies will take longer to be realized than measures in other sectors. But the longer the state delays embracing these measures, the longer we'll have to wait to realize the long term substantial benefits.

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Transportation 11. Transit-Oriented Design, Smart Growth Communities, & Land-Use Solutions

<u>Summary</u>: This initiative advocates the creation of localized, small-scale areas developed using smart growth principles to create neighborhoods that generate fewer private auto trips, promote the use of transit and non-motorized modes, protect open spaces, and minimize the generation of associated GHGs. This measure is envisioned as denser centers incorporating smart growth as the fundamental design principle. These developments will be created both within the context of larger urbanized areas where they are particularly successful, as well as in less developed areas where smart growth can lead to more support for non-motorized modes, conserve land, and reduce VMT. TODs—smart growth areas having direct access to fixed-guideway transit such as subway/metro, commuter rail, light-rail transit, or BRT—will be of particular interest, as these projects tend to result in the greatest overall benefit. This initiative envisions the development of multiple TOD communities that would relate to other TOD and major destinations within the urban area in a synergistic way.

TOD and smart growth communities have already been built or proposed in various locations within the commonwealth, and existing policy promotes these investments. This measure would seek to increase the number of TOD neighborhoods and smart growth communities, provide incentives for their development, and extend the concept to other urbanized regions as appropriate. This measure would also support infill projects, which will help increase density in support of transit services, and would help further reduce the consumption of undeveloped land outside the current urbanized area, allowing for reforestation projects and the preservation of farmland. Denser developments by their nature require less infrastructure for a given population/employment base, leading to reduction of other infrastructure, including sewers, water, and electric and gas utilities.

Smart growth land-use approaches and incentives need to be initiated as soon as possible and as aggressively as possible to secure early GHG reductions, which are then cumulative through the 2020 analysis year. Early, successful implementations also encourage other parties to implement similar approaches, and yield earlier state and local infrastructure investments that are more efficient and cost-effective.

Quantification of this work plan is presented in Table 10-1 of Work Plan T-10.

<u>Other Agencies Involved:</u> PennDOT, DCED, MPOs, local transit operators, local governments, DEP, Department of Conservation and Natural Resources (DCNR), commonwealth Financing Authority (CFA), Pennvest.

<u>Possible New Measures:</u>

The concept of smart growth has been widely accepted as a measure to help mitigate traffic and promote development that reduces vehicle travel, encourages use of transit and non-motorized (bicycle and pedestrian) travel modes, reduces land consumption, and reduces initial and ongoing infrastructure costs. The maximum benefit of smart growth development will be realized in urban areas with access to high-quality transit, but some benefit will be realized if elements of smart growth become the preferred approach to development throughout the commonwealth.

Smart growth by definition addresses the needs of pedestrians and bicyclists to ensure these modes are safe, viable alternatives. Smart growth results in development that is more suited to future transit projects and in more developed areas that can capitalize on transit access to other major destinations. Smart growth consumes less land, results in shorter runs for utilities, and may help reduce VMT by reducing distances between destinations.

The benefits of smart growth, including the associated reductions in GHG emissions, may be realized on a small scale through the creation of TODs that capitalize on existing and proposed transit infrastructure. TOD is characterized as mixed-use development focused on transit access, generally with reduced parking requirements and active TDM programs to assist employees and residents in utilizing travel modes other than private autos.

TODs have already been realized in other states, with New Jersey's Transit Villages program being a prime example (currently with 19 designated mixed-use transit villages centered on NJ Transit commuter rail stations).[24] Other examples of state policies, programs, and guidelines that encourage the creation of TOD and compact communities include:

- The Pennsylvania and New Jersey Departments of Transportation *Smart Transportation Guidebook*,[25] which provides planning, design, and other information relative to the transportation elements of smart growth-type projects, including TODs.
- The SPC actively promotes TOD in its region as a congestion mitigation strategy.[26]
- The DVRPC has inventoried current TODs.[27]
- California is actively exploring the linkage between land use and GHG emissions. The passage of Senate Bill 375 requires that this issue be studied and recommendations provided by the summer of 2009.
- California requires[28] counties and localities to consider the GHG impacts of comprehensive plans, building and zoning codes, and waivers. Developers are required to demonstrate a 20 percent reduction, from all sources combined, in GHG emissions from activities at all new and re-development sites.
- Oregon's GHG plan suggests that cities and municipalities require developers or planners to include VMT and/or GHG estimates in proposals and award development credits based on reductions achieved.[29]
- In Pennsylvania, the Transit Revitalization Investment District (TRID) state legislation, Act 238 of 2004, gives state support to municipalities and transit agencies that partner to establish TRIDs to achieve TOD, redevelopment, and community revitalization.

[24] New Jersey Transit Villages Initiative Website: http://www.nj.gov/transportation/community/village/
[25] *Smart Transportation Guidebook, Planning and Designing Highways and Streets that Support Sustainable and Livable Communities*, Pennsylvania and New Jersey Departments of Transportation, March 2008. Available at http://www.smart-transportation.com/guidebook.html
[26] Southwestern Pennsylvania Commissions Website: http://www.spcregion.org/trans_cong_mon_dem2.shtml
[27] Delaware Valley Regional Transportation Planning Commission website: http://www.dvrpc.org/planning/community/tod.htm
[28] By 2007 order of the CA Attorney General and pending final legislative action on related bill(s).
[29] The Governor's Climate Change Integration Group, *Final Report to the Governor: A Framework for Addressing Rapid Climate Change.* State of Oregon, January, 2008.

- Both DVRPC and SPC have policies that encourage the creation of TOD within their regions, though their resources are limited. Transit agencies are positioned to help initiate these types of developments and could take a more proactive role in identifying suitable locations and advancing plans. Ultimately, it is the local community that will decide on whether to investigate and advance TOD initiatives. However the state, MPOs, and to some degree the municipalities could put funding mechanisms in place that would allow them to offset the costs involved in the development of TOD plans. Doing so could provide incentives for communities to examine the potential for TODs in their regions. Also there is an educational role for the transit agencies, state, RPOs, and MPOs to provide communities with access to information that would help promote these types of developments.
- On a more active level, PennDOT could continue to advance the policy found in the 2008 Sound Land Use Implementation Plan[30] of not supporting projects in the vicinity of candidate locations for TODs if the project is not supportive of smart planning principles. Consideration of smart planning, smart transportation, and context-sensitive design principles could be used in the project evaluation process when PennDOT and its planning partners are developing plans and project lists and when ranking projects competing for funding.

Summary of Initiative

- Encourage the continued promotion of smart growth as the preferred framework for future development throughout the commonwealth.
- Seek to promote the creation of TOD projects within existing urban areas where current and planned transit services are or will be available.
- In areas where TOD is not appropriate, encourage the consideration of smart growth principally in support of non-motorized modes and to achieve some reduction in VMT.
- Fund ongoing studies in the DVRPC and SPC MPOs and transportation management agencies statewide to investigate and promote TOD centers in their regions.
- Encourage the regional transit authorities to develop lists of stations and other locations most suitable for TOD projects.
- Have the MPO and/or state develop or expand training for communities on smart growth, including TOD.
- Alter the project selection process for PennDOT and its planning partners to include consideration of smart growth measures and, in particular, the advancement of projects.
- Provide funding to regional authorities to assist in planning TOD projects.
- Investigate and publicize tax advantages that could be extended to TOD projects to help promote development and attract residents/employers/commercial development.

[30] PennDOT's 2008 Sound Land Use Implementation Plan: Building a Strategic Agenda for Smart Transportation. PennDOT Smart Transportation website: http://www.smart-transportation.com/presentations.html

Though not incorporated into the quantification included in T-10, several other potential measures could aid in the promotion of smart growth and the preservation of open spaces, helping to decrease emissions and preserve areas that can act as carbon sinks:

Expand DCNR's TreeVitalize Program: This program supports the planting of trees in urban areas. It was started in southeastern Pennsylvania in 2004, expanded to the Pittsburgh region, and is now branching out throughout the state. Its current goal is to plant one million trees across Pennsylvania in the next 5 years. With increased funding and resources, this number could be even higher, meaning that an even greater amount of GHG emissions could be captured.

Expand "Main Street" and "Elm Street" Programs*:* These state-run programs offer financial support for commercial-corridor and residential-corridor redevelopment, respectively. Healthy downtown communities help to prevent sprawl and thus cut down on GHG emissions. Increasing funding for these programs could help to further strengthen downtown communities throughout Pennsylvania.

Reauthorize and Increase Funding for Growing Greener II*:* The largest preservation program in Pennsylvania, Growing Greener II has helped to protect thousands of acres of open spaces, woodlands, and family farms throughout Pennsylvania since its original enactment. Its funding is due to run dry in 2011. Renewing this program, *and* providing a dedicated funding source for it moving forward would help to ensure the program can continue its good work for years to come.

Consider GHG Emission Impact Studies and Fees: Similar to when developers have to include impact fees for infrastructure like new roads and sewage lines that are needed to support their new development, the GHG emissions impact of a new development should also be considered. A first policy could involve simply quantifying the GHG emissions impact, including both the loss of carbon sinks due to destroyed woodlands or farmlands *and* the new GHG emissions that will be created by the new structures, the travel by its inhabitants, and the infrastructure necessary to support the development. The potential for fragmentation of intact forestland to lead to future conversion of those fragmented sections to non-forested land should ideally be included in these studies. A second policy could involve incorporating these costs into the price of the development, and/or state distribution of funds to municipalities taking into account whether the municipality requires such GHG emission impact studies.

Offset the Global Warming Pollution of New Development*:* Related to the concept of GHG emission fees, developers could be required or encouraged to purchase "offsets" for the new global warming pollution that would be created from their development.

Provide State-Level Incentives for Smart Growth Development: Tax incentives or expedited permitting could be granted to developers who demonstrate that their projects adhere to the Keystone Principles.

Support Regional Urban Growth Boundaries: To prevent sprawling development, local governments should be given the option of implementing regional boundaries beyond which they can forbid any additional development. Such boundaries can help to protect existing open spaces, and instead direct development to already developed areas.

Increase Local Control Through Temporary Land-Use Restrictions*:* In the event of a municipality revising its land-use plan or zoning ordinance, or a municipality receiving an unfavorable court decision against its plan or ordinance, developers should not be allowed to seize upon these opportunities to develop in an "unregulated" state. To correct for this, the Municipalities Planning Code curative amendment process should be revised, and municipalities should be given the option of implementing temporary moratoriums on local development while a new land-use plan is being developed.

Support Urban Revitalization and Infill Housing: Impact fees and permitting processes should be used to encourage "infilling" of existing urban and developed areas, and discourage development in undeveloped areas.

Potential GHG Reductions and Economic Costs:

Table 11-1. Estimated GHG Reductions and Cost-effectiveness

GHG emission savings (2020)	Included in T-10	$MMtCO_2e$
Net present value (2009–2020)	<$0	$million
Cumulative emissions reductions (2009–2020)	Included in T-10	$MMtCO_2e$
Cost-effectiveness (2009–2020)	<$0	$/t$CO_2e$

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $/t$CO_2e$ = dollars per metric ton of carbon dioxide equivalent. Negative numbers indicate costs savings.

The impacts of Work Plan T-10—Enhanced Support for Existing Smart Growth/Transportation & Land-Use Policies—were analyzed in conjunction with the actions in this work plan. Both T-10 and T-11 speak to the issues of land use and development. Quantification methods, as they exist, are general in nature, and implicitly include TOD as a general policy. As specific information on TODs in the commonwealth could not be obtained or synthesized, the impacts of these two measures were analyzed together and are included in the documentation for T-10.

Cost to Regulated Entities:

General/Shared Costs

If transit service needs to be enhanced to serve the needs of the TOD, there may be additional capital and operating costs.

Cost to State

State costs would generally be limited to the costs associated with improvements to transit facilities and access to the site (if required).

Cost to Region

Infrastructure costs associated with improvements to services, major roadways, and transit facilities. Potential costs associated with property tax reductions if this is used as an inducement to development.

In general, research supports the assertion that similar land-use measures net economic benefits outweigh any associated costs to implement.

Other Potential Benefits and Disbenefits:

Additional potential benefits of smart growth planning include:

- Decreased emissions of ozone precursors (VOC and NO_x), CO, and PM.
- Enhanced mobility for citizens and visitors.
- Reduced congestion.
- Increased urban redevelopment.
- Increased density reduces infrastructure costs for related services, such as water and sewer lines. The capital and ongoing costs for roadways serving denser development also tend to be lower.
- Financial stabilization of declining towns and cities.
- Retaining urban professionals attracted to smart growth communities.
- Reduced infrastructure costs.

Ease of Implementation:

The implementation of a TOD project is dependent on the local community's desire or acceptance of such a development. Initial phases of a project can be realized quickly, depending on the need for permits and planning in conjunction with the proposed development and any existing planning efforts that may have been undertaken. Existing PA laws and regulations allow and encourage local implementation of these approaches. In general the initial planning can be completed within 3 years, and initial construction beginning soon thereafter. Completion of the entire TOD will depend on the phasing that a developer chooses for the project. With regard to broader land-use policies, mandates will generally be met with more resistance but will realize greater and more immediate results, while incentives will generally be met with less resistance but will realize less immediate results.

Implementation Steps:

These will vary based on the specific measure, but many are described in-depth in this work plan's previous sections.

Potential Interrelationships With Other GHG Reduction Measures:

This initiative recognizes that transit is a key factor in influencing the success of smart growth principles in urban areas. Localized efforts support regional smart growth/smart transportation plans to reduce the impacts of urban growth. Increased development in urban areas can lead directly to the preservation of farmlands and natural spaces that, in turn, act as carbon sinks and, in the case of agriculture, provide a potential for supporting the alternative-fuels industry.

See the public transit and other interrelated land use measures (T-6, T-7 and T-10).
Synergistic:

- Transit enhancements both support smart growth and require this type of development in order to be successful.
- Compact development is a more supportive environment for TDM measures.
- Compact development and smart growth tend to be supportive of non-motorized (bicycle, pedestrian) modes.

Other

- Can offset development in greenfield location, which can then considered as potential carbon sinks.

Drawbacks

In some instances, the development of a TOD may displace an existing park-and-ride lot or limit the future expansion of such facilities.

Key Assumptions

This work plan was quantified as part of T-10—Enhanced Support for Existing Smart Growth/Transportation & Land-Use Policies—and includes the key assumptions.

Key Uncertainties

This work plan was quantified as part of T-10—Enhanced Support for Existing Smart Growth/Transportation & Land Use Policies—and includes the key assumptions.

Subcommittee Comments

The quantified GHG benefits of the combined T-10 and T-11 work plan are smaller than some work plans (3–9MMtCO2E for 2009-2020), but, much like transit improvements, the full benefits of smart growth and land use policies will take longer to be realized than measures in other sectors. But the longer the state delays embracing these measures, the longer we'll have to wait to realize the long term substantial benefits.

References: See text.

B APPENDIX H
Industry Sector Work Plans

Summary of Work Plan Recommendations

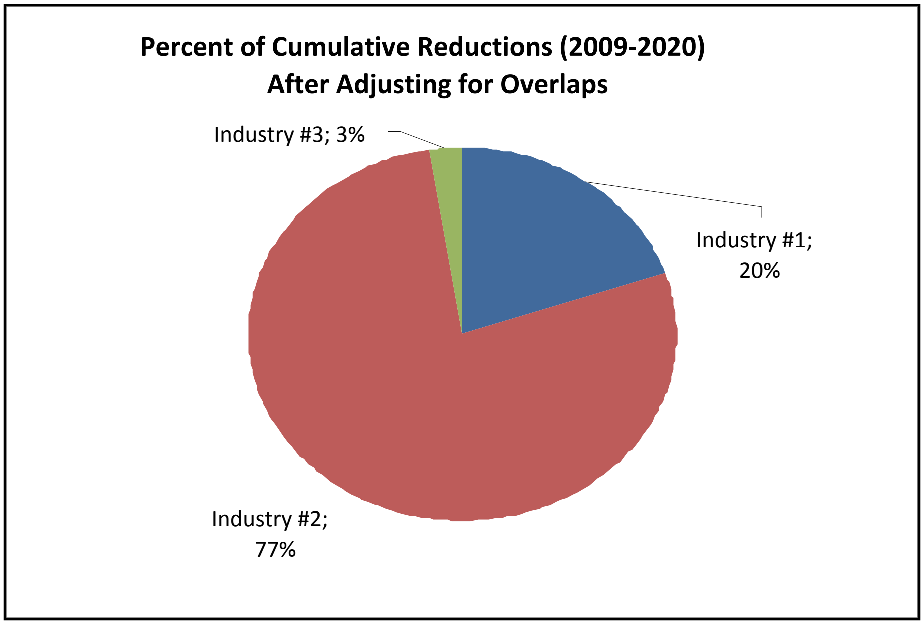
Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)	
1	Coal Mine Methane (CMM) Recovery	0.57	-$5.9	-$10.3	6.38	-$51.8	-$8.03	21 / 0 / 0
2	Industrial Natural Gas and Electricity Best Management Practices	5	-$348	-$68	25	-$972	-$38	18 / 3 / 0
3	Reduce Lost and Unaccounted for Natural Gas	0.1	-$11	-$84	1	-$48	-$55	21 / 0 / 0
Sector Total After Adjusting for Overlaps		**6**	**-$365**	**-$62**	**33**	**-$1,072**	**-$33**	
Reductions From Recent State and Federal Actions		0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Sector Total Plus Recent Actions		**6**	**-$365**	**-$62**	**33**	**-$1,072**	**-$33**	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

Figure 1. Contribution by Each Work Plan to Total Emission Reductions Associated with the Work Plans Combined for the Industry Sector



The percent contribution by each work plan is calculated by dividing the cumulative reduction (2009-2020) for the work plan by total cumulative reductions for all work plans combined (i.e., 33 $MMtCO_2e$). The numeric values used to calculate the percentages shown in this figure are provided in the summary table on page 1 of this appendix.

Industry 1. Coal Mine Methane Recovery

<u>Initiative Background</u>: The release of methane gas to the atmosphere is a major component of Greenhouse Gas emissions. Methane gas is a fossil fuel and energy source, commonly known as natural gas, which occurs in various geologic formations in Pennsylvania, including coal formations. When coal is mined and processed for use, substantial amounts of methane gas are released. Coal bed methane (CBM) is methane contained within coal formations and may be extracted by gas exploration methods or released as part of coal mining operations. This work plan deals with coal mine methane (CMM), the methane within the coal that can be vented or recovered prior to mining the coal, during mining, and immediately after mining as some gas escapes to the surface through post-mining vents or boreholes. Methane gas that remains sequestered within an abandoned underground coal mine does not contribute to Greenhouse Gas emissions, but could be and sometimes is recovered by subsequent gas exploration operations.

The federal Mine Safety and Health Administration (MSHA) definition of a gassy mine, as defined in 30 CFR § 27.2 (g), is that a "*Gassy mine or tunnel* means a mine, tunnel, or other underground workings in which a flammable mixture has been ignited, or has been found with a permissible flame safety lamp, or has been determined by air analysis to contain 0.25 percent or more (by volume) of methane in any open workings when tested at a point not less than 12 inches from the roof, face, or rib." MSHA records coal mine methane readings with concentrations of greater than 50 parts per million (ppm) methane. Readings below this threshold are considered non-detectable.

Currently and in recent years approximately 85 percent of the methane gas released during the mining of coal in Pennsylvania occurs from mining in longwall underground mines. The five large longwall underground coal mines now operating in Pennsylvania extract approximately 60 percent of the 68 million tons of coal mined each year within Pennsylvania. These high amounts of longwall mine production and the fact that the longwall mines recover coal from greater depths than other mines make longwall mining the predominant current source of coal mine methane release and an important contributor to Greenhouse Gas emissions. In recent years several mining companies have begun to capture and utilize methane gas within longwall underground mines, resulting in a reduction of methane Greenhouse Gas emissions.

Surface mining of coal currently releases about 9 percent of all coal mine methane emissions in Pennsylvania. However, with the continuing decline in surface mining production as recorded over the past two decades and the ultimate depletion of the state's shallow coal reserves, it is possible that by 2025 there could be a 70 percent reduction of surface coal mine methane emissions simply as a result of lower production.

<u>Other Involved Agencies:</u> Not applicable

Possible New Measures:

Surface Mines and Nongassy Underground Mines

There are no specific measurements of methane gases released from mining at individual surface coal mines in Pennsylvania. This analysis uses the most recently published U.S. EPA emission factors for surface mining of coal in Pennsylvania. In this analysis the same emission factors used for surface mines are also used for low-methane nongassy room and pillar underground coal mines. These are underground coal mines that have no methane levels routinely reported by MSHA. The U.S. EPA emission factor is 119.0 cubic feet of methane released per ton of coal mined and an additional 19.3 cubic feet of methane released from post-mining processing of the coal. These factors are published within Annex 3 Section 3.3 *"Methodology for Estimating CH4 Emissions from Coal Mining"* of the U.S. EPA report *"Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2007,"* published April 15, 2009, as document EPA 430-R-09-004, and is available on the Internet at the website:
http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Gassy Underground Mines

Methane levels reported by MSHA for gassy underground mines indicate two basic categories: gassy room and pillar mines and gassy longwall mines. Emission factors developed for these two types of gassy underground mines represent an estimate of the total methane released from the entire mining process, including pre-mining degassing and post-mining venting, as well as that liberated by ventilation systems. For both types of gassy underground mines this analysis uses the U.S. EPA emission factor of 45.0 cubic feet of methane per ton of coal to account for methane released as a result of post-mining processing of the coal on the surface. This post-mining factor is published in the 2009 EPA Report referenced previously. The total emission factor used for gassy room and pillar underground mines is 165 cubic feet of methane per ton of coal mined and processed on the surface. During the past few years, approximately 20 percent of Pennsylvania's room and pillar mines have been gassy, with these mines accounting for approximately 33 percent of the total coal production from room and pillar mines. The average methane concentrations reported for these mines during the past few years, when compared to tons of coal mined, is 120 cubic feet of methane per ton of coal mined. Room and pillar underground mines were assumed, on average, to operate 310 days per year and longwall mines to operate 330 days per year. These emission factors represent an estimate for all methane released before, during, and after the mining of coal in these gassy underground mines. The total longwall underground mine emission factor is 445 cubic feet of methane per ton of coal mined and processed on the surface. Estimates of coal mine methane released during longwall mining are based on methane liberation and capture measurements, on horizontal degassing and capture measurements, and on pre-mining and post-mining surface drill hole degassing measurements recorded and provided by the coal industry and by MSHA. These methane concentration measurements were correlated with tonnages of coal mined. The average coal mine methane emission level reported for the five active longwall mines, when compared to tons of coal mined, is 400 cubic feet of methane per ton of coal mined. This is an average of measurements made over several years. CONSOL provided data for three longwall mines for the years 2000 through 2006 and Foundation Coal provided data for two longwall mines for the years 2004 through 2008.

This Coal Mine Methane Recovery Initiative would encourage owners/operators of current longwall mines, and of any new gassy underground coal mines that are mined by any method, to capture 10 percent of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations. At this time it is not feasible to capture methane liberated by high velocity ventilation systems, therefore the proposed and encouraged 10 percent capture of total coal mine methane from gassy underground coal mines would have to be realized from pre-mining surface drill holes, horizontal drill holes within the mine, or for a brief time from surface drill holes into the post-mining gob area.

Projected 2025 Reduction (Million Metric Tons of CO_2 Equivalents):
Concentrations of released methane are expressed as cubic feet per ton (2,000 lbs) of coal mined. This analysis considers methane to be 21 times more powerful than CO_2 in warming the atmosphere as a Greenhouse Gas. One million cubic feet of methane is equal to 404.5 metric tons of CO_2 equivalent Greenhouse Gas. Estimates of coal mine methane released during mining are based on methane liberation and capture measurements recorded and provided by the coal industry and by the federal Mine Health and Safety Administration (MSHA), and on emission factor estimates published in the 2009 U.S. EPA report "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007." For all types of coal mines, the release of methane determined and predicted in this analysis is expressed as cubic feet of methane per ton of coal mined. Total annual methane concentrations are also expressed as metric tons of CO_2 equivalent.

Coal mine production for the years 2000 through 2008, and also for years 1985-1999 used to determine 2025 estimates through trend analysis, are based on actual tonnages reported quarterly and annually to the Pennsylvania DEP Bureau of Mining and Reclamation. Coal mine production information is available to the public for the years 1980 through 2008 on the DEP Bureau of Mining and Reclamation website:
http://www.dep.state.pa.us/dep/deputate/minres/bmr/historicalminingreports/index.html

Trend charts for annual coal production and mining permits issued are presented on the DEP Bureau of Mining and Reclamation website:
http://www.dep.state.pa.us/dep/deputate/minres/bmr/annualreport/2008/Coal_Mining_Trend_Charts_001.htm.

(Tables of Estimates and Projections for 2000 and 2025 are presented at end of this document.)

- Year 2000 Estimated Emissions (no Methane Capture): 10,347,409 metric tons CO_2 equivalent

- Year 2025 Estimated Emissions (no Methane Capture): 8,092,018 metric tons CO_2 equivalent (21.8 percent decrease)

- Year 2025 Estimated Emissions (with 10 percent Methane Capture in Gassy Underground Coal Mines): 7,372,008 metric tons CO_2 equivalent (28.8 percent decrease)

0.72 $MMtCO_2e$ Reduction (with 10 percent Methane Capture in Gassy Underground Coal Mines)

Economic Cost: This initiative would be purely industry driven.

Implementation Steps: This Coal Mine Methane Recovery Initiative would encourage owners/operators of current longwall mines, and of any new gassy underground coal mines that are mined by any method, to capture 10 percent of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations. This could be accomplished by pre-mining gas exploration into the coal formation to be mined, capturing methane from pre-mining vertical degas holes, capturing methane by horizontal drilling within active underground mines, or possibly capturing methane from post-mining areas of underground mines, where for a brief period of time gas is still making its way to the surface through existing boreholes. PA DEP annual coal production numbers and MSHA gas liberation numbers will be reassessed annually, as well as new technological developments, with changes made to trend forecasts on future coal production and revisions to estimates of methane gas released per ton of coal mined.

Table 1-1. Summary of Estimated and Projected Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2000 Levels with No Capture in Gassy Underground Mines

	Methane Emission Factor (ft^3/t)	2000 (tons)	2000 (ft^3 CH_4)	2000 $MMtCO_2e$
Anthracite Underground Mines	138.3	220,462	30,489,895	12,333
Anthracite Surface Mines	138.3	2,332,828	322,630,112	130,504
Bituminous Surface Mines	138.3	14,936,924	2,065,776,589	835,607
Room & Pillar Bituminous Underground Mines		8,665,475		
Room & Pillar Mines with Low Methane	138.3	5,805,868	802,951,579	324,794
Room & Pillar Mines with High Methane	165.0	2,859,607	471,835,114	190,857
Longwall Bituminous Underground Mines	445.0	49,184,398	21,887,057,110	8,853,315
Totals for Coal Mining in Pennsylvania		75,340,087	25,580,740,399	**10,347,409**

*All methane emission factors include U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.

Table 1-2. Summary of Estimated and Projected Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2025 Levels with No Capture in Gassy Underground Mines

	Methane Emission Factor (ft^3/t)	2025 (tons)	2025 (ft^3 CH_4)	2025 $MMtCO_2e$
Anthracite Underground Mines	138.3	100,000	13,830,000	5,594
Anthracite Surface Mines	138.3	800,000	110,640,000	44,754
Bituminous Surface Mines	138.3	4,400,000	608,520,000	246,146
Room & Pillar Bituminous Underground Mines		*10,000,000*		
Room & Pillar Mines with Low Methane	138.3	6,666,667	922,000,046	372,949
Room & Pillar Mines with High Methane	165.0	3,333,333	549,999,945	222,475
Longwall Bituminous Underground Mines	445.0	40,000,000	17,800,000,000	7,200,100
Totals for Coal Mining in Pennsylvania		**55,300,000**	**20,004,989,991**	**8,092,018**

*All methane emission factors include U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.

Table 1-3. Summary of Estimated and Projected Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2025 Levels with 10 percent Capture In Gassy Underground Mines

	Methane Emission Factor (ft^3/t)	2025 (tons)	2025 (ft^3 CH_4)	2025 $MMtCO_2e$
Anthracite Underground Mines	138.3	100,000	13,830,000	5,594
Anthracite Surface Mines	138.3	800,000	110,640,000	44,754
Bituminous Surface Mines	138.3	4,400,000	608,520,000	246,146
Room & Pillar Bituminous Underground Mines		*10,000,000*		
Room & Pillar Mines with Low Methane	138.3	6,666,667	922,000,046	372,949
Room & Pillar Mines with High Methane	165.0	3,333,333	549,999,945	222,475
Longwall Bituminous Underground Mines	445.0	40,000,000	16,020,000,000	6,480,090
Totals for Coal Mining in Pennsylvania		**55,300,000**	**18,244,989,991**	**7,372,008**

*All methane emission factors include U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.

Table 1-4. Summary of Estimated and Projected Coal Mine Methane Emissions from Pennsylvania Coal Mines* - CONSOL's PA Longwall Coal Mines

5/6/09 DAK, rev 5/19/09 RAW	Methane Emissions from CONSOL's PA Longwall Coal Mines							
				Bailey				
Year	2000	2001	2002	2003	2004	2005	2006	Average
Ventilation air methane, mcf	2,755,013	3,068,453	2,572,155	2,022,434	2,396,590	2,501,345	2,725,482	
Degasification methane								
horizontal, mcf								
vertical gob, mcf		17,345	29,200	27,068	8,640	25,754	19,042	
subtotal. mcf		17,345	29,200	27,068	8640	25,754	19,042	
Capped shafts methane, mcf								
Post-mining methane, mcf	127,233	133,221	124,626	121,148	130,725	142,889	131,252	
Total methane emitted, mcf	2,882,245	3,219,019	2,725,981	2,170,650	2,535,955	2,669,988	2,875,776	2,725,659
Clean coal produced, tons	9,863,000	10,327,224	9,660,905	9,391,318	10,133,685	11,076,662	10,174,574	10,089,624
Methane emissions, cf/ton clean coal	292	312	282	231	250	241	283	270
				Enlow Fork				
Year	2000	2001	2002	2003	2004	2005	2006	Average
Ventilation air methane, mcf	4,015,055	4,191,134	3,292,102	3,390,376	4,540,600	3,496,913	3,568,374	
Degasification methane								
horizontal, mcf								
vertical gob, mcf		36,266	36,000	10,585	12,078	1,231	10,414	
subtotal. mcf		36,266	36,000	10,585	12,078	1,231	10,414	
Capped shafts methane, mcf								
Post-mining methane, mcf	122,821	133,207	123,450	127,562	131,825	126,083	138,072	
Total methane emitted, mcf	4,137,876	4,360,608	3,451,552	3,528,523	4,684,503	3,624,227	3,716,860	3,929,164
Clean coal produced, tons	9,521,000	10,326,125	9,569,786	9,888,511	10,218,960	9,773,883	10,703,231	10,000,214
Methane emissions, cf/ton clean coal	435	422	361	357	458	371	347	393
				Blacksville #2				
Year	2000	2001	2002	2003	2004	2005	2006	Average
Ventilation air methane, mcf	1,705,969	2,463,948	3,170,629	2,374,135	2,104,500	2,266,650	1,805,655	
Degasification methane								
horizontal, mcf	73,000	73,000	65,700					
vertical gob, mcf	1,505,725	599,457	674,885	389,165	521,269	543,704	904,470	
subtotal. mcf	1,578,725	672,457	740,585	389,165	521,269	543,704	904,470	
Capped shafts methane, mcf	147,095							
Post-mining methane, mcf	66,513	64,939	62,138	70,302	73,771	67,845	65,009	
Total methane emitted, mcf	3,498,302	3,201,345	3,973,352	2,833,602	2,699,540	2,878,199	2,775,134	3,122,782
Clean coal produced, tons	5,156,047	5,034,039	4,816,887	5,449,779	5,718,668	5,259,338	5,039,423	5,210,597
Methane emissions, cf/ton clean coal	678	636	825	520	472	547	551	599
Average total clean coal production ton/year								25,300,435
Average total methane emissions, mcf/year								9,777,605
Global average methane emissions, cubic feet methane/ton of clean coal produced								386
Source: These are the methane emission data reported by CONSOL under the Voluntary Greenhouse Gas Emissions Reporting program.								

*All methane emission factors include U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.

Quantification Approach and Assumptions

The following inputs were used in the analysis of coal mine methane GHG reductions and costs. Three cost & performance sensitivities were conducted (the summary table able only report the central estimate).

PA specific data inputs were used for the following parameters

- Coal mining emissions for longwall mining (ft^3 CH_4 per ton coal mined)
- Number of CONSOL's PA longwall mines
- Gob gas production shares from CONSOL's and Foundation Coal longwall mines
- Methane capture target from longwall mines

National data inputs were used for the following parameters:

- Natural gas wellhead price in the Northeast (source: EIA's AEO2009 supplemental tables)
- Cost and performance assumptions (source: USEPA as noted below)
- Share of methane as a fraction of gob gas (source: USEPA as noted below)

Table 1-5. Quantification Assumptions

Source for cost and performance assumptions noted below

USEPA, 1997. "Technical and Economic Assessment of Potential to Upgrade Gob Gas to Pipeline Quality", Air and Radiation, 430-R-97-012, December

Coal mining emissions	
Units: ft3 CH4 per ton coal mined	
Longwall method	400.4
Other methods (weighted average)	227.3

Emission factor		
Units: tons of CO2e per million ft3 of CH4	Workplan	IPCC
CO2e (oxidized CH4)	63.9	63.9
CO2e (non-oxidized CH4)	404.5	438.8

IPCC Comparison for vented CH4 from coal mines	
21	GWP of CH4
0.67	Gg CH4 per million m3 of CH4
737.9	tons CH4 per million m3 of CH4
20.9	tons CH4 per MMscf of CH4
438.8	tons CO2e per MMscf of CH4

IPCC factors for combusted CH4	
3.7	tCO2e/tC
16.9	ton C/TJ of CH4
61.8	ton CO2e/TJ of CH4
63.9	ton CO2e/MMscf of CH4

Energy density	
Units: btu/scf	
Processed methane	980

Deflator													
Units: dimensionless		1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
1996 to 2007	1.2746	93.328	95.054	96.089	97.328	99.317	101.478	103.568	105.724	108.175	111.765	115.533	118.956

Sensitivity	
Units: dimensionless	
1=central (default); 2=low; 3=high	1

Methane capture	
Units: dimensionless	
Start year	2010
Target (share in 2025 captured relative to 2000)	10%

Plant size	
units: MMscf per day of gob gas	
Size option #1	3.0
Size option #2	4.0
Size option #3	5.0

Design capacity factor of gob gas enrichment plant	
units: %	90%

Gob gas production shares in all years			2006-08 characteristics		
units: % of total gob gas produced across all longwell mines			coal mined (ton)	methane (Mcf)	Share
Baily	27%		70,627,368	27,780,058	27%
Enlow Fork	27%		70,001,496	27,504,348	27%
Balcksville #2	21%		36,474,581	21,859,473	21%
Cumberland	14%		58,095,123	14,669,019	14%
Emerald	10%			10,137,599	10%
Mine #6	0%		0	0	0%
Total	100%	OK	235,198,368	101,820,297	100%

Captured Methane		
units: % of gob gas		
50% methane inlet gas	50%	Range is between 40% and 53%. Source: http://www.epa.gov/ttnchie1/ap42/ch14/related/mine.pdf (page 11) for national data on gob wells

Methane for compressor fuel	3 MMscf unit			4 MMscf unit			5 MMscf unit		
units: % of input methane	Low	High	Central	Low	High	Central	Low	High	Central
50% methane inlet gas	22%	15%	19%	31%	26%	28%	20%	15%	18%

Processed methane gas for sale @ 90% plant capacity factor	3 MMscf unit			4 MMscf unit			5 MMscf unit		
units: MMscf	Low	High	Central	Low	High	Central	Low	High	Central
50% methane inlet gas	1.17	1.27	1.22	1.39	1.48	1.44	1.99	2.12	2.06

Capital cost	3 MMscf unit					4 MMscf unit					5 MMscf unit				
units: million $ per unit	1996$		2007$			1996$		2007$			1996$		2007$		
	Low	High	Low	High	Central	Low	High	Low	High	Central	Low	High	Low	High	Central
50% methane inlet gas	$3.55	$4.32	$4.52	$5.50	$5.01	$3.74	$4.51	$4.77	$5.75	$5.26	$5.19	$6.00	$6.61	$7.65	$7.13

Fixed O&M cost @ 90% capacity factor	3 MMscf unit					4 MMscf unit					5 MMscf unit				
units: million $/year	1996$		2007$			1996$		2007$			1996$		2007$		
	Low	High	Low	High	Central	Low	High	Low	High	Central	Low	High	Low	High	Central
50% methane inlet gas	$0.27	$0.37	$0.34	$0.47	$0.40	$0.27	$0.38	$0.35	$0.48	$0.42	$0.36	$0.50	$0.46	$0.64	$0.55

NG price															
units: 2007$/mmbtu	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Well price in Northeast	$7.23	$6.94	$8.92	$4.56	$5.15	$5.59	$5.72	$5.82	$5.98	$6.21	$6.39	$6.59	$6.83	$7.09	$7.39

Financial parameters		
units: as indicated		
Book life	20	years
Real discount rate	5.0%	%
Capital recovery factor	8.02%	%

Workplan Cost and GHG Reduction:

Table 1-6. Quantification Results

	GHG Reductions (million tons					
	Annual	Cumulative	NPV of Costs	2007$/ton of		
Grand Summary	in 2020	through 2020	(E6 2007$)	CO2e avoided		
50% methane inlet gas	0.57	6.38	($51.2)	-8.03		
	Gob gas	Methane				
Production Summary (in 2020)	(MMscf/day)	(MMscf/day)				
50% methane inlet gas	9.24	4.62				
	Number of plants sized as:					
Plant Build Summary	3 MMscf/day	4 MMscf/day	5 MMscf/day			
50% methane inlet gas	5	0	0			
Plant Performance Summary (in 2020)	Capacity factor in 2020 (%)					
3 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	75%	75%	59%	40%	28%	0%
	Capacity factor in 2020 (%)					
4 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0%	0%	0%	0%	0%	0%
	Capacity factor in 2020 (%)					
5 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0%	0%	0%	0%	0%	0%
Outlet Fuel Summary (in 2020)	Outlet gas for sale (MMscf/day)					
3 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	1.02	1.01	0.81	0.54	0.37	0.00
	Outlet gas for sale (MMscf/day)					
4 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Outlet gas for sale (MMscf/day)					
5 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Outlet gas for sale (MMscf/day)					
All plants	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	1.02	1.01	0.81	0.54	0.37	0.00
Capital Cost Summary (in 2020)	Annualized capital costs (million 2007$)					
3 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.40	0.40	0.40	0.40	0.40	0.00
	Annualized capital costs (million 2007$)					
4 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Annualized capital costs (million 2007$)					
5 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Annualized capital costs (million 2007$)					
All plants	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.40	0.40	0.40	0.40	0.40	0.00
O&M Cost Summary (in 2020)	Fixed O&M costs (million 2007$)					
3 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.40	0.40	0.40	0.40	0.40	0.00
	Fixed O&M costs (million 2007$)					
4 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Fixed O&M costs (million 2007$)					
5 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Fixed O&M costs (million 2007$)					
All plants	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.40	0.40	0.40	0.40	0.40	0.00

Outlet gas sales Cost Summary (in 2020)	Outlet gas sales O&M costs (million 2007$)					
3 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.81	0.81	0.81	0.81	0.81	0.00
	Outlet gas sales O&M costs (million 2007$)					
4 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Outlet gas sales O&M costs (million 2007$)					
5 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Outlet gas sales O&M costs (million 2007$)					
All plants	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.81	0.81	0.81	0.81	0.81	0.00
Outlet Gas Sale Benefit Summary (in 2020	Outlet gas sales (million 2007$)					
3 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	2.71	2.68	2.13	1.43	0.99	0.00
	Outlet gas sales (million 2007$)					
4 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Outlet gas sales (million 2007$)					
5 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Outlet gas sales (million 2007$)					
All plants	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	2.71	2.68	2.13	1.43	0.99	0.00
Net Cost Summary (in 2020)	Net costs (million 2007$)					
3 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	-1.90	-1.88	-1.33	-0.62	-0.18	0.00
	Net costs (million 2007$)					
4 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Net costs (million 2007$)					
5 MMscf	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.00	0.00	0.00	0.00	0.00	0.00
	Net costs (million 2007$)					
All plants	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	-1.90	-1.88	-1.33	-0.62	-0.18	0.00
Annual CO2e Summary (in 2020)	CO2e emissions (million tons CO2e)					
Reference Case	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.19	0.18	0.15	0.10	0.07	0.00
	CO2e emissions (million tons CO2e)					
Reduction	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.16	0.16	0.12	0.08	0.06	0.00
	CO2e emissions (million tons CO2e)					
Mitigation Case	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.03	0.03	0.02	0.02	0.01	0.00
Cumulative CO2e Summary (in 2020)	Cumulative CO2e emissions (million tons CO2e)					
Reference Case	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	2.06	2.04	1.62	1.09	0.75	0.00
	Cumulative CO2e emissions (million tons CO2e)					
Reduction	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	1.74	1.72	1.37	0.92	0.63	0.00
	Cumulative CO2e emissions (million tons CO2e)					
Mitigation Case	Baily	Enlow Fork	Balcksville #2	Cumberland	Emerald	Mine #6
50% methane inlet gas	0.33	0.32	0.26	0.17	0.12	0.00

Subcommittee Comments
As with other work plans there was substantial input from outside parties invited by the subcommittee to participate. Some changes were made to the work plan from that presented originally by the department. These changes were made by the department. As revised the subcommittee felt that based on the information available, some GHG reductions would be realized in a cost effective manner.

Industry 2. Industrial Natural Gas and Electricity Best Management Practices Work Plan for Potential GHG Reduction Measure

Summary: Implement DOE Industrial Technology Program (ITP) Best Management Practices (BMPs) to process heating and steam system operation to reduce the consumption of natural gas or other fossil fuels, such as coal and oil by 5-15 percent per year for industrial steam systems, and 5-25 percent for process heating systems. Electricity efficiency reductions are targeted for 20 percent of sales by 2031, consistent with the supply of industrial electricity efficiency resources identified in the ACEEE (2009) report.

Programs are assumed to begin in January 2012. Implementation of energy efficiency is assumed to occur at a rate of 1 percent of sales per year for both natural gas and electricity measures.

Other Involved Agencies: U.S. DOE and PADEP

Background: Industrial gas and electricity consumption in Pennsylvania are expected to increase by 1.2 percent and 0.9 percent per year from 2008-2024 respectively.[1] This change in consumption is also influenced by the relative growth and decline in particular industries over the planning period. Industries that show a relative increase in electricity and natural gas consumption between 2008 and 2025 are chemical manufacturing and petroleum and coal products manufacturing. The largest declines are expected in primary metal manufacturing.[2]

[1] Source: ACEEE et al. (2009). Energy Efficiency, Demand Response, and Onsite Solar Energy Potential in Pennsylvania. April. Pp. 9-10. http://www.aceee.org/pubs/e093.htm
[2] Source: Ibid. P. 29.

Figure 2-1. Industrial Electricity Consumption Forecast

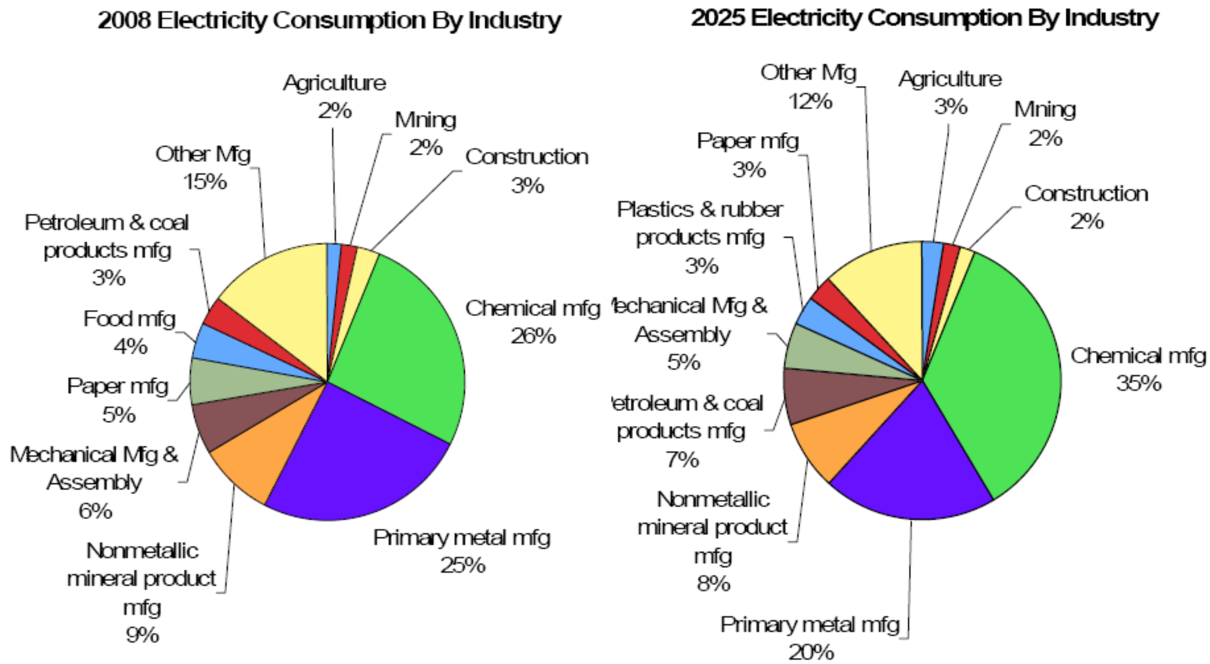
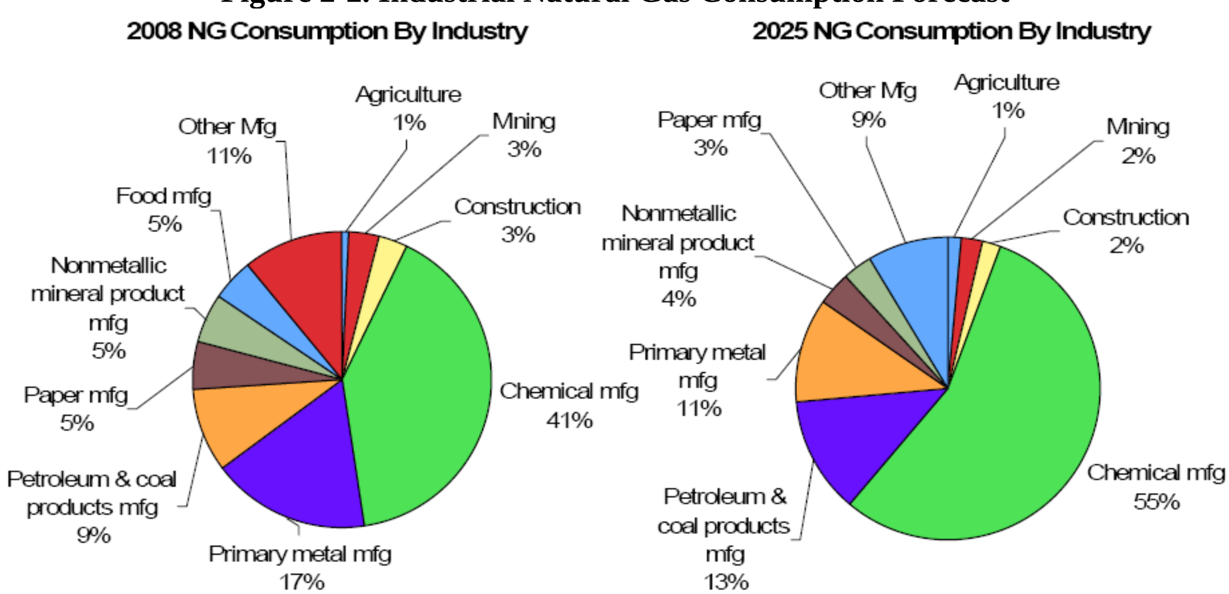


Figure 2-2. Industrial Natural Gas Consumption Forecast



Savings Identified by ACEEE Energy Assessment

The ACEEE et al (2009) report identifies significant energy efficiency opportunities in Pennsylvania's industrial sector. Industrial electricity supplies are estimated at 16 percent of 2025 sales, and industrial gas supplies are estimated at 17 percent (pp. 30-31). These estimates do not include site specific process heating measures, on which ACEEE states:

> We anticipate an additional economic savings of 5–10 percent, primarily at large energy-intensive manufacturing facilities. The overall economic industrial efficiency resource opportunity is on the order of 22–27 percent. Therefore, the total economic potential for natural gas savings in the industrial sector in 2025 would be about 52,660 Btu. P. 31.

The ACEEE report is somewhat contradictory on the supply of industrial GWh electricity reductions available to the state in 2025. On page 14 these are estimated for non-CHP measures at ~13,000 GWh, but on page 30 supplies are estimated at 9,297 GWh in 2025. This workplan targets approximately 7,900 GWh electricity reductions by 2025 which is less than both of the ACEEE estimates. CHP measures pose an additional ~11,000 GWh reductions.

Possible New Measures[3]: By implementing DOE BMPs, the DEP expects efficiency improvements between 5 percent to 25 percent and between 5 percent to 15 percent can be achieved in industrial process heating and steam systems, respectively.

The direct combustion of fossil fuel such as natural gas, fuel oil, and coal comprise 92 percent of the energy used in industrial process heating systems. The thermal efficiency of process heating equipment varies broadly between 15 percent and 80 percent. This large range in efficiency allows fuel reduction opportunities between 5 percent to 25 percent through the application of ITP best operational practices[4].

The direct combustion of fossil fuels such as natural gas, fuel oil, and coal comprise at least 71 percent of the boiler fuels used to raise steam for industrial processes. The inclusion of propane and waste fuels is estimated to increase this percentage to at least 85 percent. The thermal efficiency of industrial steam systems reportedly range from 65 percent to 85 percent. This range in efficiency allows fuel reduction opportunities between 5 percent and 15 percent through the application of ITP BMPs[5].

[3] Statistics taken from U.S. DOE Energy Information Administration
[4] See http://www1.eere.energy.gov/industry/bestpractices/pdfs/em_proheat_bigpict.pdf
[5] See http://industrial-energy.lbl.gov/files/industrial-energy/active/0/Steam%20Sourcebook.pdf.

Table 2-1. Industrial Electricity Measure Savings and Costs

Measures	Savings Potential in 2025 (GWh)	Savings Potential in 2025 (%)	% of Efficiency Potential	Levelized Cost of Saved Energy ($/kWh)
Sensors & Controls	237	0.4%	0%	$0.014
EIS	67	0.1%	0%	$0.061
Duct/Pipe insulation	1,587	2.8%	3%	$0.052
Electric Supply	1,710	3.0%	3%	$0.010
Lighting	550	1.0%	1%	$0.020
Motors	2,240	3.9%	4%	$0.027
Compressed Air	1,030	1.8%	2%	$0.000
Pumps	1,523	2.7%	3%	$0.008
Fans	231	0.4%	0%	$0.024
Refrigeration	123	0.2%	0%	$0.003
Total	9,297	16%	100%	$0.021

Table 2-2. Natural Gas Measure Savings and Costs

Measures	Savings Potential in 2025 (BBtu)	Savings Potential in 2025 (%)	% of Efficiency Potential	Levelized Cost of Saved Energy ($/MMBtu)
Load control	2,809	1.3%	8%	$0.13
Improved insulation	5,618	2.6%	15%	$0.63
Steam trap maintenance	4,389	2.0%	12%	$0.45
Automatic steam trap monitoring	1,756	0.8%	5%	$0.33
Other Boiler measures	5,255	2.4%	14%	$0.15
HVAC Measures	622	0.3%	2%	$4.47
Process Controls & Management	3,679	1.7%	10%	$0.51
Efficient burners	2,929	1.4%	8%	$1.85
Process integration	4,346	2.0%	12%	$8.39
Other Process Heat measures	5,359	2.5%	15%	$3.41
Total	36,759	17%	100%	$1.96

Workplan Cost and GHG Reduction:

Table 2-3. Quantification Results

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($/tCO_2e$)
Industry 2	Industrial Natural Gas and Electricity Best Management Practices	5.3	-$377	-$71	26.3	-$1,180	-$45

The 2020 GHG reduction of 5.3 $MMtCO_2e$ are estimated to be split between gas at 0.90 and electricity at 4.4 $MMtCO_2e$.

Notes: The cost estimates (colums 3 and 6) are incremental costs of energy efficient measures including capital cost, operating and maintenance, and labor, above baseline measure costs. The cost estimates are calculated as the costs less avoided energy expenditures. Also, the difference between the 2020 cost effectiveness (column 4) and the cumulative cost effectiveness (column 7) is due, in part, to the effects of discounting the net cash flows over the analysis period of 2009-2020.

- Efficiency improvement costs (that result in fuel savings up to 10 percent) are very low and often part of routine maintenance costs
- 10 percent to 15 percent fuel savings may result from small to medium cost system improvements
- Fuel savings greater than 20 percent may result from medium to high cost system improvements
- Energy savings pay back time frames are typically very good.

<u>Quantification Approach and Assumptions</u>

- Reductions from the workplan are assumed to begin in 2012 and are implemented at a rate of 1 percent of sales each year through the end of the planning period.
- Energy efficiency costs are expressed as levelized costs over the life of the energy efficiency options. The incremental costs (typically incurred in the first year of program implementation) are spread over all future years of the life of the energy efficiency measures.
- The costs of the workplan are calculated by estimating the annual costs of energy efficiency (capital, O&M, labor) less avoided fuel savings.
- These cash flows are then discounted at a real rate of 5 percent.
    - The net present value of cash flows is calculated beginning in 2009 through 2020.
- All prices are in $2007 as per the Center for Climate Strategies Quantification Memo.
- The levelized cost of electric efficiency measures is $26.03/MWh, the levelized cost of natural gas efficiency measures is $2.11 MMBTU.[6]
    - This figure includes all utility and participant costs as commonly performed in a total resource cost test.
    - Program fixed costs are assumed to be part of each measure's capital cost, These include administrative, marketing, and evaluation costs of 5 percent.[7]
- Avoided electricity prices are $70 over the planning period, and avoided fuel costs are $11.72 MMBTU.[8] [placeholder]
- The GHG savings potential does not evaluate differentiate between natural gas utility and transporter distribution.

[6] Source: ACEEE et al. (2009).
[7] Source: ACEEE et al. (2009) p. 49.
[8] Source: Placeholder values from ACEEE et al (2009) report

- Electricity transmission and distribution losses are assumed to be 7 percent over the analysis period. Natural gas transmission and distribution losses are assumed to be immaterial for this workplan but rather are quantified under Industry #3.
- To estimate emission reductions from workplans that are expected to displace conventional grid-supplied electricity (i.e., energy efficiency and conservation) a simple, straightforward approach is used. We assume that these policy recommendations would displace generation from an "average thermal" mix of fuel-based electricity sources of coal and gas. This mix is based on the sources of forecasted generation in PA over the planning period. 90 percent coal, 10 percent gas for all years 2009-2030 based on EIA 2006 State Electricity Profile data.
    - The average thermal approach is preferred over alternatives because sources without significant fuel costs would not be displaced—e.g., hydro, nuclear, or renewable generation.
        - Similarly, a "marginal" approach is not possible in Pennsylvania because the natural gas share of the annual generation portfolio (13.5 million MWh) of total generation (218 million MWh in 2006) is only about 6 percent. This small amount does not provide enough be "backed down" due to the energy efficiency deployment in the workplan.
    - This approach provides a transparent way to estimate emission reductions and to avoid double counting (by ensuring that the same MWh from a fossil fuel source are not "avoided" more than once). The approach can be considered a "first-order" approach; it does not attempt to capture a number of factors, such as the distinction between peak, intermediate, and baseload generation; issues in system dispatch and control; impacts of nondispatchable and intermittent sources, such as wind and solar; or the dynamics of regional electricity markets. These relationships are complex and could mean that policy recommendations affect generation and emissions (as well as costs) in a manner somewhat different from that estimated here. Nonetheless, this approach provides reasonable first-order approximations of emission impacts and offers the advantages of simplicity and transparency that are important for stakeholder processes.

Implementation Steps

- Conduct DOE workshops that advance best practice implementation for process heating and steam systems.
- Advance the use of DOE process heating and steam system analysis tools.
- Encourage assessment and benchmarking of all process heating and steam systems utilizing state and federal assessment resources.
- Encourage review, and implementation when cost effective, of best practices for all large natural gas systems.
- Partner with utilities to develop energy use reduction programs for large energy users.

Potential Overlap

- Lost and Unaccounted for Natural Gas, Landfill Methane Capture, Recycling, Solid Waste, etc.
- Act 129, Reduced and Stabilized Load Growth workplans

Subcommittee Comments
Although this work plan will likely overlap significantly with work plans from the Electricity subcommittee and that overlap should be accounted for in this final Action Plan document, the subcommittee felt that it should include this work plan since the reductions were fairly large relative to other industry work plans and were cost effective.

Industry 3. Reduce Lost and Unaccounted for Natural Gas Work Plan for Potential GHG Reduction Measure

Summary: Reduce lost and unaccounted (L&U) for natural gas from retail operations by 15 percent by the year 2020. The program begins in January, 2010 and fugitive emissions are assumed to be implemented linearly at a rate of 1.5 percent per year until the 15 percent target is reached in 2019.

Other Involved Agencies: PUC, U.S. Department of Transportation, and EPA Gas STAR Program

Baseline Activities and Assumptions

Natural Gas Consumers in Pennsylvania in 2005[9] – 2,839,282

- Residential – 2,600,574 (91 percent)
- Commercial – 233,132 (8 percent)
- Industrial – 5,576 (0.2 percent)

Pennsylvania Natural Gas Consumption by End User in 2005:

- Residential – 245 Bcf (40 percent)
- Commercial – 145 Bcf (24 percent)
- Industrial – 185 Bcf (30 percent)
- Electric Power Generation – 33 Bcf (6 percent)

Natural gas (NG) companies report L&U natural gas to the Public Utility Commission. The American Gas Association defines L&U as the difference between the total gas available from all sources, and the total gas accounted for as sales, net interchange, and company use. It is important to reduce natural gas losses because natural gas (methane) is approximately 21 times more powerful greenhouse gas emission than carbon dioxide.

NG is released to the atmosphere through fugitive and vented emissions. Fugitive emissions are methane leaks often through pipeline and system components (such as compressor seals, pump seals, and valve packing). Vented emissions are methane leaks from a variety of equipment and operational practices directly attributed to an organization's actions (e.g., purge and blow down activities from operation) or accidental line breaks/thefts.

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[9] Gas Consumers and Gas Consumption information was provided through an American Gas Association query - 2005 Data.

Table 3-1 indicates that reported L&U natural gas in 2005 was 19.6 billion cubic feet.

Table 3-1. Lost & Unaccounted-for Natural Gas for Major Pennsylvania Gas Distribution Utilities+

Company	Total Lost & Unaccounted-for (mcf)	Total Deliveries (mcf)	Percent L & U		Assume 15 percent of L & U is Preventable
Columbia	1,252,493	112,953,730	1.1 percent	15 percent	2,939,754.90
Dominion - Peoples	4,767,103	93,059,502	5.1 percent	$MMtCO_2e$**	161,143
Equitable	6,871,103	67,142,740	10.2 percent		
National Fuel	163,550	53,079,559	0.3 percent	** At equivalent 120.593 lb/mcf	
PECO Gas	2,493,685	87,908,874	2.8 percent		
PG Energy *	119,512	48,117,054	0.2 percent		
Phila. Gas Works	3,106,403	91,469,723	3.4 percent		
PPL Gas	1,203,005	27,642,650	4.4 percent		
UGI - Gas*	-378,488	95,817,773	-0.4 percent		
Totals	19,598,366	677,191,605	2.9 percent		

+ There are no PUC standards for lost and unaccounted for gas

* Both companies, owned by UGI, report in a way that results in little or even negative lost gas. The PUC staff has proposed that reporting be standardized.

However, the reported L&U values are not accurately estimating gas companies' individual contributions to fugitive or vented emissions for the following reasons:

1) End-use consumer meters (likely to be residential sector meters) do not accurately measure delivered volumes. This is because some meters do not accurately account for temperature and pressure sensitivities. It is thought that consumer meters are approximately + or - 3 percent in measurement accuracy.
2) Natural gas companies use a portion of their product in various stages of the transmission process (i.e. compressors), which is not separately quantified.
3) Gas theft may also be occurring, although it is assumed to be a relatively minor loss with regard to L&U reporting.
4) The PUC does not have standardized calculation/reporting procedures for L&U. Some utilities report gains instead of losses in L&U. This means that it is not possible to draw conclusions from the PUC's statewide L&U statistics.
5) The PUC indicates there are approximately 6,000 line breaks per year due to accidents (i.e. digging-up a line during construction). These individual accidents that cause releases have not been quantified.

Therefore there are three primary areas that need to be addressed to improve our understanding L&U natural gas:

- Accurate measurement and reporting;
- Operations and maintenance improvements (or replacements) to lines and aging parts; and
- Minimization of accidental losses through line breaks.

The table below indicates there is not a direct relationship between cast iron and unprotected steel pile with Lost and Unaccounted for Gas. For this workplan, pipeline replacements are not assumed to be performed solely due to the GHG benefits under this measure, but rather due to other regulatory requirements and business operations decisions.

Table 3.2: Pennsylvania Distribution Sector – Report on Cast Iron and Unprotected Steel[10]

Company	Miles of Cast Iron	Miles of Unprotected Bare Steel	Total Miles Distribution	percent of Statewide Total Cast Iron	percent of Statewide Total Unprotected Bare Steel
Columbia Gas of PA	74	2,188	7,260	2.3 percent	25 percent
Dominion Peoples	66	1,908	6,566	2.0 percent	21 percent
Equitable Gas	47	830	3,307	1.4 percent	9 percent
National Fuel Gas	93	1,051	4,916	2.8 percent	12 percent
PECO	836	369	6,614	25.5 percent	4 percent
UGI Penn Natural	82	305	2,562	2.5 percent	3 percent
PGW	1,624	-	3,019	49.5 percent	0 percent
PPL Gas	28	661	3,619	0.9 percent	7 percent
T.W. Phillips	-	1,295	2,955	0.0 percent	15 percent
UGI	428	300	5,012	13.1 percent	3 percent

GHG Emissions Reductions from Lost and Unaccounted For Emissions

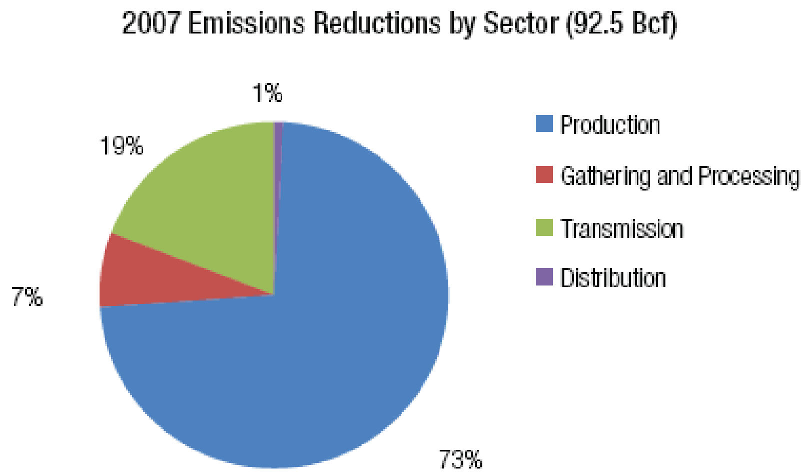
Reduce lost and unaccounted for natural gas from retail operations by 15 percent through various actions such as: improved operation and maintenance, replacement of inaccurate metering, reducing the number of accidental line breaks and thefts, and requiring more accurate reporting of L&U natural gas.[11]

The US EPA Gas Star program is a voluntary initiative to reduce fugitive emissions from all aspects of natural gas production, transmission and distribution. Much of the industry's knowledge regarding the supply and costs of mitigating fugitive methane emissions comes from this program. The 2007 results from this program indicate that the preponderance of the emissions reductions occurred at the production level, leaving plenty of low hanging fruit for Pennsylvania's transmission and distribution firms.

[10] Developed by the PUC using U.S. Department of Transportation Data

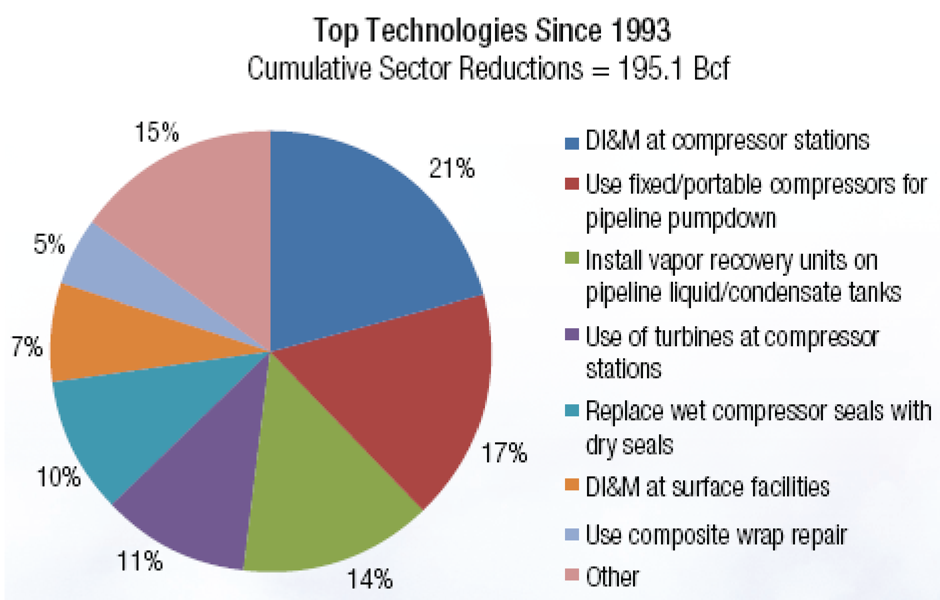
[11] US EPA. (2007). *Project Opportunities Study for Partner X*. Natural Gas Star Program.

Figure 3.1: Reductions from Natural Gas Star partners by sector[12]



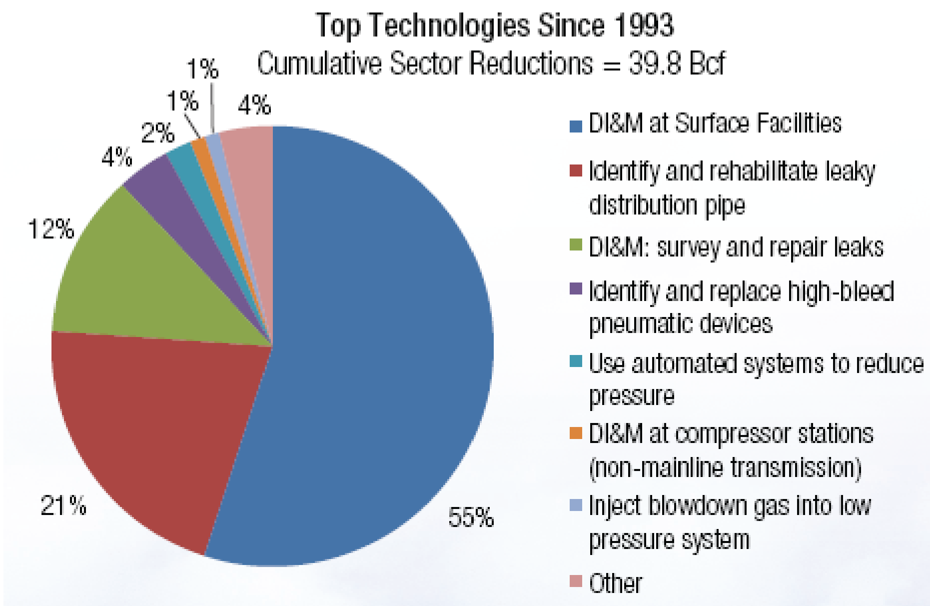
The types of technologies used to reduce fugitive emissions vary by sector. The following two graphs highlight these differences fore the transmission and distribution sectors.

Figure 3.2: Natural Gas Star Transmission Sector Reductions



[12] EPA. (2007). Natural Gas STAR Program Accomplishments. http://www.epa.gov/gasstar/documents/ngstar_accomplishments_2007.pdf

Figure 3.3: Natural Gas Star Distribution Sector Reductions



Residential measures for Pennsylvania include replacing all customer meters with "temperature and pressure compensated" meters may cost $100 per meter (PUC estimate). There are about 2.6 million households using natural gas (not including commercial and industrial consumers which may have temperature/pressure meters). This will result in improved metering and a reduction in the measuring of L&U.

Other measures include:

- Improved reporting requirements from all utilities on L&U losses. This would require PUC staff to develop standardized accurate reporting methods.
- Reduce accidental line breaks throughout Pennsylvania. Stricter enforcement of the Pennsylvania One Call System could help reduce these losses. This could require additional staff time to enforce, but may be offset by fines and penalties.
- Encourage utilities to participate in existing voluntary industry programs. EPA's Natural Gas STAR Program is focused on reducing methane emissions through technology transfer using best practices in operation and maintenance. Natural Gas STAR provides analytical tools and services to assist in calculating companies methane emissions.

Quantification Approach and Assumptions

The actual mitigation projects undertaken by Pennsylvania gas distributors will vary depending on the types and age of equipment installed, existing monitoring and reporting protocols, etc. To quantify the costs and reductions associated with this workplan, the representative mitigation approaches are taken from actual Natural Gas Star partner experiences. Of the many possible projects possible, three are taken as representative. These are chosen because they are among the largest mitigation sources listed in Figures 3.2 and 3.3 above. The technologies or practices include:

- Direct inspection at gate stations and surface facilities-- Implementing a directed inspection and maintenance (DI&M) program is a proven, cost-effective way to detect, measure, prioritize, and repair equipment leaks to reduce methane emissions. A DI&M program begins with a baseline survey to identify and quantify leaks. Repairs that are cost-effective to fix are then made to the leaking components. Subsequent surveys are based on data from previous surveys, allowing operators to concentrate on the components that are most likely to leak and are profitable to repair.[13]
- Replace wet seals with dry Seals in centrifugal compressors-- Centrifugal compressors are widely used in production and transmission of natural gas. Seals on the rotating shafts prevent the high-pressure natural gas from escaping the compressor casing. Traditionally, these seals used high-pressure oil as a barrier against escaping gas. Natural Gas STAR partners have found that replacing these "wet" (oil) seals with dry seals significantly reduces operating costs and methane emissions.[14]
- Connecting the blowdown vent lines to the fuel gas system for baseload compressors when offline--This option involves adding piping and valves to bleed gas from an idle compressor into the compressor station's fuel gas system. Facility modification costs range between $900 and $1,600 per compressor. Reduces fugitive methane losses by 1.275 Mcf/hr (91 percent). [15]

[13] http://www.epa.gov/gasstar/documents/ll_dimgatestat.pdf
[14] http://www.gastool.methanetomarkets.org/m2mtool/files/docs/ll_wetseals.pdf
[15] http://www.gastool.methanetomarkets.org/m2mtool/files/docs/ll_compressorsoffline.pdf

The cost and performance assumptions for the three technologies are listed in Table 3.3:

Table 3.3 Technologies to Reduce Lost and Unaccounted for Natural Gas Emissions

Direct Inspection at Gate Stations and Surface Facilities	
Expected Life Yrs	1
Annual Cost of Inspections	$20,413
Net O&M costs (savings)	$0
Net Cost/ yr	$ 20,413
Fuel Savings/yr MMBTU	123,289,042
$/MMBTU Saved	$0.0002
Replace Wet Seals with Dry Seals	
Initial Incremental Capital Cost	$180,000
Expected Life Yrs	5
Levelized Capital Cost	$43,167
Net O&M costs (savings)	-$63,000
Net Cost/ yr	-$19,833
Fuel Savings/yr MMBTU	46,518,720
$/MMBTU Saved	-$0.0004
Connecting blowdown vent lines to the fuel gas system	
Initial Incremental Capital Cost	$1,250
Expected Life Yrs	5
Levelized Capital Cost	$300
Net O&M costs (savings)	$0
Net Cost/ yr	$300
Fuel Savings/yr MMBTU	213,417
$/MMBTU Saved	$0.0014
Weighted Average Costs	**$0.0004**

- The cost of conserved gas is calculated by: 1) estimating the annual financial costs (savings) of each measure and dividing this by annual natural gas savings to estimate a $/MMBTU cost. 2) The costs of the three measures are then averaged (unweighted) to arrive at a workplan level cost in MMBTU.
- The weighted average cost for the suite of three efficiency measures is estimated at $.0004/MMBTU over the planning period.
- The NET cost of the workplan is calculated by subtracting the assumed wholesale price of natural gas from the cost of the efficiency measures.
    - The wholesale prices of natural gas are assumed to be $4.29 over the planning period. This figure comes from the May 18th, 2009 settlement price for natural gas on the NYMEX futures exchange.[16]
- These cash flows are then discounted at a real rate of 5 percent.
    - The net present value of cash flows is calculated beginning in 2009 through 2020.
- All prices are in $2007 as per the Center for Climate Strategies Quantification Memo.

[16] For the July, 2009 futures contract. http://www.nymex.com/ng_fut_cso.aspx

Table 3.4 Quantification Results

Work Plan No.	Work Plan Name	Annual Results (2020)			Cumulative Results (2009-2020)		
		GHG Reductions ($MMtCO_2e$)	Costs (Million $)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $)	Cost-Effectiveness ($\$/tCO_2e$)
Industry 3	Reduce Lost and Unaccounted for Natural Gas	0.1	-$11	-$84	0.9	-$48	-$55

Notes: The cost estimates (colums 3 and 6) are incremental costs of energy efficient measures including capital cost, operating and maintenance, and labor, above baseline measure costs. The cost estimates are calculated as the costs less avoided energy expenditures. Also, the difference between the 2020 cost effectiveness (column 4) and the cumulative cost effectiveness (column 7) is due, in part, to the effects of discounting the net cash flows over the analysis period of 2009-2020.

Implementation Steps:

- Encourage utilities to regularly perform self-assessments and report (to the PUC) operation and maintenance practices that have resulted in environmental savings.
- Require improved and standardized reporting to the PUC on L&U, so that atmospheric system losses can be better understood and separated from non-atmospheric losses.
- Investigate the savings from increased enforcement of the Pennsylvania One Call system.
- Possible phase-out of older metering devices with more accurate “pressure and temperature compensated” metering.

Potential Overlap:

- Demand Side Management – Natural Gas
- Increased Use of Landfill Methane

Subcommittee Comments

At least two members of the subcommittee commented that there is little meaningful reduction from the work plan. However, the implementation steps seem sensible so we resolved to include it for whatever value the department may see in it.

APPENDIX H1 Workplan Design Memo

Memorandum

To: CCAC Industry and Waste Subcommittee
From: Center for Climate Strategies, Hal T. Nelson, Ph.D.
Re: Industrial Energy Efficiency Best Practices Workplan Design
Date: April 24, 2009

On the April 17, 2009 call, I was asked to bring forward information about recommendations for optimizing the design elements of the industrial gas efficiency program. There was interest during the call for information on natural gas efficiency supplies. Also requested was information on public/private relationships and the ramp-in time for the workplan. The following summarizes research based on comments from that call as well as information on exemplary industrial efficiency programs nationwide.
On the April 24th call the Industry and Waste Subcommittee decided that electricity efficiency should also be included in the workplan. This memo was revised to include electricity and to update the potential implementation schedule at the end of the document.

Supplies of Industrial Energy Efficiency

Energy efficiency opportunities in the industrial sector include the implementation of technologies and best practices that are cost effective. For a technology or best practice to be cost effective, capital costs, operation and maintenance costs, and installation costs must be less that the benefits from reduced energy use and/or more efficient production techniques. The ACEEE (2009) study recently quantified the supply of these cost effective industrial energy efficiency for natural gas usage in Pennsylvania.[17] The study estimates non-process natural gas efficiency supplies at 12 percent of 2008 sales. Process – specific measures were not estimated, but ACEEE anticipates additional cost effective efficiency supplies of 5-10 percent of sales from process – specific measures. Thus, total gas efficiency supplies for Pennsylvania are estimated at 17-22 percent (p. 164). These resource estimates are similar to those found for industrial gas users in other states. A natural gas efficiency study for NY concluded that cost effective industrial gas supplies at almost 22 percent of 2016 forecasted load. Individual measures savings range from 3 percent of end user demand to 20 percent.[18] A study for Iowa found 18 percent of industrial gas demand reductions to be cost effective.[19] For California, KEMA estimated economic potential for natural gas reductions to be 13 percent of demand.[20]

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[17] American Council for an Energy Efficient Economy. (2009). *Potential For Energy Efficiency, Demand Response, and Onsite Solar Energy in Pennsylvania*. April. ACEEE report E093.
[18] Optimal. (2006). *Natural Gas Energy Efficiency Resource Development Potential In New York*. October. Pp. 4-30 to 4-32. http://www.nyserda.org/energy_information/otherdocs.asp
[19] Quantec LLC, Summit Blue Consulting, Nextant, Inc., A-TEC Energy Corporation, and Britt/Makela Group. February 2008. *Assessment of Energy and Capacity Savings Potential in Iowa: Final Report*, vol. I. Prepared for the Iowa Utility Association. (No Web link available.)
[20]KEMA. (2006). California Industrial Existing Construction Energy Efficiency Potential Study. http://www.calmac.org/publications/PGE_PotentialStudy_Vol1_05242006.pdf

For electricity, ACEEE (2009) estimates that 16 percent of non-process industrial electricity can be cost effectively conserved in Pennsylvania. Process – specific measures were not estimated, but ACEEE anticipates additional cost effective efficiency supplies of 5-10 percent of sales from process – specific measures. Thus, total electricity efficiency supplies for Pennsylvania are estimated at 21-26 percent (p. 164).

Guiding principles for Workplan Design

Industrial energy efficiency improvements are diverse, even within the same industry because of differences in plant age, layout, process equipment, boiler efficiencies, etc.

- Industrial efficiency efforts thus need to be highly customized to the customers' needs.
- Onsite assessments are often required, which tend to be expensive
- Because of the high costs of assessments, electricity (and water) efficiency options should also be evaluated simultaneously

Best Practices Design Elements

Customized design—NYSERDA's FlexTech program provides large customers with consultants who present a detailed scope of work based on site specific customer efficiency opportunities.[21] The scope of works are evaluated and approved following staff technical review. The Energy Trust of Oregon assigns a highly skilled, industry-specific specialist with considerable expertise to develop each customer scope of work.[22]

Customized incentives—CenterPoint Energy's custom process rebate program gives rebates for the purchase of increased efficiency equipment based on the savings expected.[23] Program achieved savings at approximately $2.65/million cubic feet (mcf). FlexTech specifies the percent of funding that will come from the state systems benefit charge. The Energy Trust program funds up to 50 percent of total project costs or $0.15/kWh whichever us less, up to $500,000 annually per site.

Customer best practices dissemination—Focus On Energy's industrial program has a specialized best practice training system based on DOE guidelines and has distributed "Energy Best Practices Handbooks" to customers via relationships with state industry organizations. Program achieved energy savings at benefit cost ratio of 11.9 (total resource cost (TRC) test).[24] This program has a ½ day Practical Energy Management "starter" seminar on facilities energy management. Surveys have indicated that over 60 percent of participants have used the approach in the six months after the seminar.

Dedicated program staff—The recommendation that efficiency equipment and incentives are customizable requires that the program staff have skills to evaluate and quantify the program. Similarly, the workshops and best practices handbook, although based on DOE material, require technical skills on behalf of the program staff.

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[21] http://www.nyserda.org/programs/Technical_Assistance/flextechprocess.asp
[22] ACEEE rated honorable mention program. http://aceee.org/pubs/u081/ind-process.pdf p. 9-17+
[23] ACEEE rated honorable mention program. http://aceee.org/pubs/u081/ind-process.pdf p. 9-6+
[24] ACEEE rated exemplary program. http://aceee.org/pubs/u081/ind-process.pdf p. 9-5+

Integrated delivery—Pacific Gas and Electric's Heavy Industry and Manufacturing Energy Efficiency Program included demand response and self-generation opportunities along with energy efficiency recommendations based on particular market segments for both gas and electricity and water.[25] The program's benefits cost ratio is 3.8 (TRC test). The program also includes industrial retrocommissioning.

Workforce support—Essential to the success of the efficiency program is the development of a private sector workforce (ESCOs, utilities, etc) that can perform the assessments and benchmarking as well as vendors to install the energy efficiency equipment. Also, Focus on Energy trains and incentivizes compressed air equipment vendors to identify other energy efficiency opportunities such as leak detection and overall system analysis at the their customers' facilities.

Focus on process improvements—the Energy Trust program focuses on fundamental process changes that yield not only energy savings but also improved production efficiencies. Connecticut Light and Power's PRIME program teaches manufacturers "Lean Manufacturing" techniques that do more with existing resources by eliminating non-value add activities (Kaizen technique of continuous improvement). Benefit cost ratio for this program is 1.29.[26]

Summary and Implications for the Design of Natural Gas Efficiency Workplan

The elements above indicate that a top industrial efficiency program cannot be built overnight. Evaluating and selecting allies, training staff, developing workshop materials and best practices guidebooks, developing technology and funding protocols all take time. Most of the successful industrial efficiency programs listed above started small and grew because of their ability to deliver gas reductions. However, the Office of Energy and Technology Deployment (OETD) is already performing many of these functions as of 2009. Similarly, federal funding could help accelerate the development of this industrial energy efficiency program. Pennsylvania will receive $373 million to promote energy independence under the American Recovery and Reinvestment Act.[27]

The following is a possible timeline for workplan implementation:

- 2009-2010: Program authorization and development of training material, protocols and vendor selection.
- 2011: Pilot phase introduction
- 2012: Beginning of full program and assumption of linear implementation of program targets.

[25] ACEEE rated honorable mention program. http://aceee.org/pubs/u081/ind-process.pdf p. 9-10+
[26] ACEEE rated honorable mention program. http://aceee.org/pubs/u081/ind-process.pdf p. 9-15+
[27] http://www.recovery.pa.gov/portal/server.pt?open=514&objID=505976&mode=2

Appendix H2. Overlap Analysis

Workplan	Potentially Overlaping Workplan	Overlap Adjustment To	Notes	Resolution
Electricity -3 Stabilized Load Growth	Industry-2 Industrial Gas and Electricity	Electricity -3	Industry 2 targets 9 percent industrial efficiency by 2020 while Electricity-3 is only 7 percent. The issue for the interaction between these workplans is not overlaps, but assurance that in combination they do not exceed industrial electric efficiency supplies in PA. By 2020, the combined GWh of both workplans exceeds by approximately 350 GWh the linear implementation of the two 2025 industrial estimates in ACEEE et al (2009) of 9,900 and 13,000 GWh (pp. 14, 30).	2020 reductions of electric industrial energy efficiency are reduced by 350 GWh (10 percent of industrial electric efficiency reductions under Electricity 3).
Industry-2 Industrial Gas and Electricity	RC-10 Gas DSM	None	RC-10 applies only to residential and commercial buildings	None required
Electricity-9 Combined Heat and Power	Industry-2 Industrial Gas and Electricity	None	Industry 2 does not target CHP specifically. In addition, the ACEEE et al (2009) report identifies between 10,000-13,000 GWh of non-CHP electricity efficiency in the industrial sector by 2025. The 2025 target under Industry 2 is only 7,900 GWh. This means that the state can fulfill the targets under Industry 2 without including overlaps for CHP from the electricity CHP workplan.	None required

The natural gas demand side reductions from the Energy Independence and Security Act (EISA) of 2007 are assumed to be in the baseline forecast because the growth figures are projected from EIA Annual Energy Outlook which has accounted for the 2007 law. The electricity reductions from Industry-2 are assumed to be net of the EISA as these impacts were considered by ACEEE et al (2009) when developing the energy efficiency resource assessment.

APPENDIX I
Waste Sector Work Plans

Summary of Work Plan Recommendations

Work Plan No.	Work Plan Name	Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $)	Annual Results (2020) Cost-Effectiveness ($\$/tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $)	Cumulative Results (2009-2020) Cost-Effectiveness ($\$/tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)
1	Landfill Methane Displacement of Fossil Fuels	0.1	-$0.1	-$0.8	0.56	-$11	-$19	21 / 0 / 0
2	Statewide Recycling Initiative	5.44	-$41	-$8	34.4	-$246	-$7	21 / 0 / 0
4	Improved Efficiency at Wastewater Treatment Facilities	3.8×10^{-3}	-$0.50	-$126	0.023	-$3.2	-$143	21 / 0 / 0
5	Waste-to-Energy Digesters	0.1	$0.1	$1.0	0.6	$0.7	$1.2	21 / 0 / 0
6	Waste-to-Energy MSW	0.24	-$8.1	-$34	1.42	-$40	-$28	19 / 1 / 1
Sector Total After Adjusting for Overlaps		5.9	-$50	-$8	37	-$299	-$8	
Reductions From Recent State and Federal Actions		0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Reductions From Recent State and Federal Actions		5.9	-$50	-$8	37	-$299	-$8	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; NQ = not quantified; MSW = municipal solid waste.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

Waste-1. Landfill Methane Displacement of Fossil Fuels

Summary: Landfill methane (CH_4) resources and projects will be identified, assessed, and promoted to decrease fossil fuel use in business thermal applications, or otherwise displace the use of commercial natural gas resources. Maximizing the use of landfill CH_4 as a fuel reduces greenhouse gas (GHG) emission of CH_4 and serves to offset emissions of carbon dioxide (CO_2) from the use of fossil fuels, such as coal, oil, and natural gas.

Goals: Increase landfill gas (LFG) utilization from the current 69 percent beneficial use to 80 percent beneficial use.

The term "beneficial use" applies to LFG that is combusted for the purposes of generating energy that can be used in place of energy generated from traditional sources (i.e., fossil fuels).

Implementation Period: Achieve 80 percent beneficial use of LFG collected by 2025.

Other Involved Agencies: Pennsylvania Department of Environmental Protection (DEP), Pennsylvania Department of Transportation (PennDOT), Public Utility Commission (PUC), Department of Community and Economic Development (DCED), landfill owners and operators.

Data Sources/Assumptions/Methods for GHG:

LFG resources will be assessed to determine the degree to which fossil fuel use for the purpose of generating heat can be displaced. LFG thermal use projects include conversion to commercial-grade "pipeline-quality" methane (natural gas), and direct-use applications in industrial or commercial equipment. For the purposes of this report, the most common beneficial use of LFG (to generate electricity) projects will not be expanded.

Operating municipal waste landfills are evaluated annually. Key data collected from DEP Solid Waste Program Landfill Annual Operation Reports include:
- Site total waste capacity and the volume of waste disposed of,
- Landfill gas collection rates and gas quality relative to CH_4 content,
- Details of LFG projects, and
- Thermal energy benefits.

LFG collection system efficiency is estimated between 60 percent and 85 percent by the U.S. Environmental Protection Agency (EPA). Collection efficiencies up to 99 percent have been calculated for closed, plastic-covered cells at modern landfill operations.[1] For the purposes of this report LFG collection efficiency will be estimated at 75 percent for the following reasons:
- At any given time, only portions of operating landfills are closed, while other portions are open with limited practical means of collecting LFG.

[1] SCS Engineers, Current MSW Industry Position and State-of-the-Practice on LFG Collection Efficiency, Methane Oxidation, and Carbon Sequestration in Landfills (prepared for Solid Waste Industry for Climate Solutions, Version 2.2, January 2009) ("SWICS January 2009")

- LFG collection project investments rely on optimizing LFG volume and quality relative to methane content. Overly aggressive gas collection will result in dilution with air, which can reduce the utility of the collected gas for beneficial use.
- PA landfills are well maintained. Installed gas collection systems are relatively new.
- Improved technologies and operational practices are used in landfill construction. Gas wells are routinely monitored and calibrated.

Data Sources/Assumptions/Methods for Costs:

- Direct-use project capital costs include:
    - o $260/standard cubic foot per minute (scfm) of LFG for a gas treatment and compression system,[2] plus the cost of installing the equipment.[3]
    - o $280,000 million per mile of pipeline.[4]
    - o Retrofit costs for burners and boilers to utilize LFG for fuel approximately $30,000–300,000 depending on size and type of retrofit.[5]
  - $111/scfm of LFG for annual operation and maintenance (O&M) costs.[6]
- State permitting costs, which are not included in the analysis of this work plan, are undetermined but may include:
  - o Solid waste beneficial use permit for landfill gas utilization.
  - o Air Quality Program notifications and operational permit for LFG processing and gas end-use equipment.
  - o Stormwater permitting and/or erosion and sedimentation controls may be needed.
  - o Historic preservation or Endangered Species Act may apply to pipeline rights of way. Pipeline costs would increase accordingly.
  - o Local permitting may also apply.

Historical Inventory of Landfill Emissions: A historical GHG emissions inventory was developed based on DEP waste reports from 1990 to 2008 and historical per-capita waste generation. Historical landfilling rates were estimated by back calculating from current rates. Waste receipts were then entered into EPA's Landfill Gas Emissions Model (LandGEM) (a first-order decay model)[7] for purposes of estimating LFG generation rates for the period of interest.

Recovery and beneficial use of methane from landfills increased sharply in the United States between 1990 and 2001, with the result that estimated emissions of methane from landfills fell 38 percent from 258 million metric tons of carbon dioxide equivalent ($MMtCO_2e$) to

[2] scfm: Standard cubic feet per minute. To convert costs from $/scfm to $/MMBtu, divide by 262.8 [500 Btu/scfm X 525,600 minutes/year / 1,000,000]. Thus, $260/scfm becomes $0.99/mmBtu,
[3] USEPA's Landfill Methane Outreach Program (LMOP) LFG Energy Project Development Handbook (http://www.epa.gov/lmop/res/handbook.htm), ("LMOP Project Handbook"), Table 4-2
[4] Ibid, $53/foot X 5,280 ft/mile = $280,000/mile
[5] Data provided in original Work Plan. Not included in quantification, as it is assumed that the capital cost includes retrofits to burners and boilers.
[6] EPA's LMOP Project Handbook, op cit.
[7] USEPA's Landfill Gas Emissions Model—LandGEM, version 3.02. (http://www.epa.gov/ttn/catc/dir1/landgem-v302.xls). Methane Generation Rate k = 0.04 $year^{-1}$, Potential Methane Generation Capacity L_o = 100 m^3/Mg.

161 MMtCO_2e in that period.[8] There are several reasons for these increases in LFG collection (and corresponding decreases in GHG emissions from landfills):

- Passage of the Energy Policy Act of 1992 and President *Clinton's Climate Change Action Plan* which included four initiatives relating to LFG collection.
- Establishment of EPA's Landfill Methane Outreach Program (LMOP) in 1995.
- Promulgation in March 1996 of New Source Performance Standards by EPA under the Clean Air Act for large landfills that required LFG collection and control systems.
- Availability of tax credits under Section 29 of the Internal Revenue Code for LFG beneficial use projects constructed by 1998.

Pennsylvania has moved aggressively to require large landfills to collect and control LFG emissions, and it is believed that results at Pennsylvania landfills between 1990 and 2001 were even better than the national averages reported above. Since 2001, CH_4 emissions from landfills in the United States are estimated to have remained roughly flat, despite a growing amount of solid waste disposed to landfills.

Figure 1-1 summarizes historical landfill emissions in Pennsylvania. It assumes that 35 percent of the landfill gas generated in Pennsylvania in 1990 was collected and controlled, and that collection efficiency for LFG improved in a linear function to 75 percent by 2001 (holding steady at 75 percent thereafter).[9]

[8] Emissions of Greenhouse Gases in the United States 2007, U.S. Department of Energy, Office of Integrated Analysis and Forecasting, Energy Information Administration (DOE/EIA-0573(2007), December 2008), page 28, Table 19.
[9] Based on the EPA LandGEM model using estimates of MSW placed in Pennsylvania landfills between 1960 and the present, assuming 20% oxidation of uncollected methane and 100% destruction efficiency of collected methane.

Figure 1-1. Historical Methane Emissions From Pennsylvania Landfills

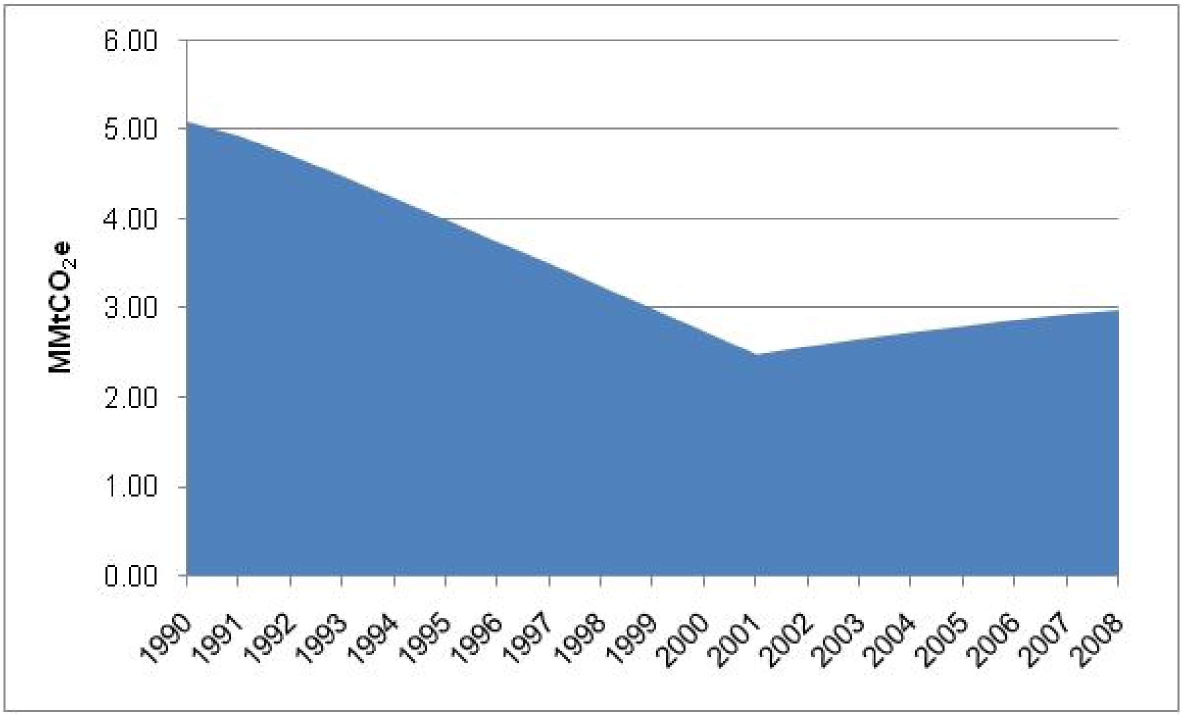

Table 1-1 summarizes emissions attributable to municipal solid waste (MSW) disposal in Pennsylvania landfills in baseline year 2000, using the approach described above.

Table 1-1. 2000 Emissions of GHGs by Pennsylvania Landfills

	Gross Methane Generation by WIP (million cubic meters CH_4)	Methane Collected for Flaring or Beneficial Use (million cubic meters CH_4)	Oxidation (million cubic meters CH_4)	Fugitive and Net Emissions after Thermal Destruction and Oxidation ($MMtCO_2e$)
All Landfills	724	516	20	2.74

(note: 1 cubic meter = 35.3 cubic feet)

In calendar year 2007, active Pennsylvania landfills reported collecting over 62,700 million standard cubic feet per year (MMscf/yr) of LFG. Assuming this LFG was 50 percent methane, this would equate to collection of about 888 million cubic meters (MMm^3) of CH_4 in 2007. The LandGEM model for Pennsylvania based upon assumed waste receipts and 75 percent collection efficiency predicted that only 663 MMm^3 of CH_4 would be collected in 2007.

This may mean that actual collection efficiency in 2007 was higher (e.g., in excess of 90 percent), or that the model underestimates the LFG generated, or some combination of factors. The model is intended to estimate only LFG generation attributable to MSW disposal, and many MSW landfills accept waste materials that are not MSW, but that would be expected to generate landfill gas. Examples include construction and demolition debris, vegetative wastes, and some sludge and residual wastes. Thus, it is likely that the reports for 2007 included collection and destruction of gas not strictly generated by decomposition of MSW.

The 2007 DEP reports provide the best measure of LFG utilization by active landfills in Pennsylvania. Based on those reports, in 2007:

- Over 11,700 MMscf (~19 percent) of collected LFG was used in thermal projects that displace fossil fuel use,
- Over 19,500 MMscf (31 percent) was flared, and
- About 31,500 MMscf (50 percent) was used to generate electricity.

The 43,200 MMscf of LFG beneficially used for thermal and electrical generation applications offset more than 1 $MMtCO_2e$ emissions that otherwise would have been produced from combustion of fossil fuels.[10]

While the volumes of LFG reported for 2007 are somewhat higher than those estimated by the LandGEM model for decomposition of MSW, the percentages reported are assumed to apply equally to LFG produced by all wastes as well as to LFG produced by MSW alone. The percentages reported for flaring and beneficial use will be used as the baseline for the business-as-usual (BAU) case.

GHG Emissions Reduction Analysis: The goal of this work plan is to increase the percentage of LFG applied to a beneficial use (rather than flaring) from 69 percent to 80 percent by 2025.

The 2009–2020 LFG emissions were estimated using the both the BAU and the “Policy” waste management scenario outlined in the Waste-2 *Statewide Recycling Initiative Work Plan* see below). It was assumed that any uncontrolled landfills would be converted to landfill gas-to-energy (LFGTE)/flared collection over the policy period as part of the BAU assumptions. Tables 1-2 and 1-3 summarize the methane emissions that would be captured by LFGTE projects and flares for beneficial use according to the 2025 target of 80 percent beneficial use. Table 1-2 presents the results for the BAU scenario for MSW landfill disposal, while Table 1-3 presents the results using the projected emissions resulting from the Policy scenario from the *Statewide Recycling Initiative Work Plan.* The term “beneficial use” applies to LFG that is combusted for the purposes of generating energy (direct heat, in this case) that can be used in place of energy generated from traditional sources (i.e., fossil fuels).

[10] EPA LMOP Benefits Calculator using 43,200 MMscf/year / 365 days/year, or 118.36 MMscf/day (http://www.epa.gov/lmop/res/lfge_benefitscalc.xls)

Table 1-2. Methane Emissions Captured by GTE and Flares for Beneficial Use (Stand-Alone Analysis)

Year	Emissions captured by LFGTE & Flares (million m^3 CH_4)	Beneficial Use Goal (% of LFG Collected)	BAU Beneficial Use (% of LFG Collected)	LFG Applied to Beneficial Use (million m^3 CH_4)	Difference Over BAU (million m^3 CH4)	$MMtCO_2e$ of Difference After Thermal Destruction	GHG Reduction
2009	680	69%	69%	469	-	-	-
2010	687	70%	69%	478	4.72	0.07	0.01
2011	693	70%	69%	488	9.53	0.14	0.02
2012	700	71%	69%	498	14.44	0.21	0.02
2013	707	72%	69%	508	19.45	0.28	0.03
2014	715	72%	69%	518	24.57	0.35	0.04
2015	722	73%	69%	528	29.80	0.43	0.05
2016	730	74%	69%	539	35.15	0.50	0.06
2017	738	75%	69%	550	40.61	0.58	0.07
2018	747	75%	69%	561	46.20	0.66	0.08
2019	755	76%	69%	573	51.92	0.74	0.09
2020	764	77%	69%	585	57.77	0.82	0.10
2021	773	77%	69%	597	63.75	0.91	0.11
2022	782	78%	69%	609	69.88	1.00	0.12
2023	791	79%	69%	622	76.16	1.09	0.13
2024	801	79%	69%	635	82.58	1.18	0.14
2025	811	80%	69%	648	89.16	1.27	0.15
			Total (2009-2020)		**334**	**4.77**	**0.56**
			Total (2009-2025)		**715.69**	**10.22**	**1.20**

Table 1-3. Methane Emissions Captured by GTE and Flares for Beneficial Use (Integrated Analysis)

Year	Emissions captured by LFGTE & Flares (million m^3 CH_4)	Beneficial Use Goal (% of LFG Collected)	BAU Beneficial Use (% of LFG Collected)	LFG Applied to Beneficial Use (million m^3 CH_4)	Difference over BAU (million m^3 CH4)	$MMtCO_2e$ of difference after thermal destruction	GHG Reduction
2009	680	69%	69%	469	0.00	0.00	-
2010	687	70%	69%	478	4.72	0.07	0.01
2011	693	70%	69%	488	9.53	0.14	0.02
2012	699	71%	69%	496	14.41	0.21	0.02
2013	704	72%	69%	505	19.37	0.28	0.03
2014	709	72%	69%	514	24.38	0.35	0.04
2015	714	73%	69%	522	29.45	0.42	0.05
2016	718	74%	69%	530	34.57	0.49	0.06
2017	722	75%	69%	538	39.73	0.57	0.07
2018	726	75%	69%	546	44.93	0.64	0.08
2019	730	76%	69%	554	50.18	0.72	0.08
2020	733	77%	69%	562	55.46	0.79	0.09
2021	737	77%	69%	569	60.78	0.87	0.10
2022	740	78%	69%	577	66.16	0.94	0.11
2023	744	79%	69%	585	71.58	1.02	0.12

Year	Emissions captured by LFGTE & Flares (million m^3 CH_4)	Beneficial Use Goal (% of LFG Collected)	BAU Beneficial Use (% of LFG Collected)	LFG Applied to Beneficial Use (million m^3 CH_4)	Difference over BAU (million m^3 CH4)	$MMtCO_2e$ of difference after thermal destruction	GHG Reduction
2024	747	79%	69%	593	77.06	1.10	0.13
2025	751	80%	69%	601	82.60	1.18	0.14
				Total (2009–2020)	**327**	**4.67**	**0.55**
				Total (2009–2025)	**685**	**9.78**	**1.15**

Assuming full implementation of all other waste sector work plans, the amount of LFG that would be applied to beneficial use through 2020 as a result of this work plan's target is 334 MMm^3 CH_4 (stand-alone). Assuming a heat content of 35,700 British thermal units (Btu)/m^3 CH_4, 348 MMm^3 of CH_4 would have a heat content of 11.9 x 10^6 MMBtu, the equivalent of 11.6 x 10^3 MMscf/yr of natural gas, 86 MMgal heating oil, or 591,900 shorts tons of coal.[11]

However, in terms of GHG emissions, the 334 MMm^3 CH_4 shifted from flaring to thermal projects yields no direct benefit—the CH_4 gas would be destroyed either in a flare or in a thermal project. The only GHG reduction quantified under this work plan is for the offset of CO_2 from avoiding the use of fossil fuels (about 0.12 lb CO_2/scf of natural gas).

Therefore, the estimated GHG reduction of this work plan is 1.15 $MMtCO_2e$ through 2025, with a maximum annual reduction of 0.14 $MMtCO_2e$ in 2025. These savings would be seen in the industry or residential/commercial sectors, depending on what kind of beneficial use project they are applied to. However, the GHG reduction from this work plan is presented in the summary table at the beginning of the plan, with the intersector overlaps addressed in the sector total.

Cost-Effectiveness Analysis

The cost-effectiveness estimates are based on the cost figures provided by EPA's LMOP Project Handbook (see "Data Sources/Assumptions/Methods for Costs" section, above). These estimates ($0.98/MMBtu project cost, $0.42/MMBtu O&M cost) are applied to the values in the "Incremental LFG Applied to Beneficial Use" columns in Tables 1-2 and 1-3 to determine the capital and O&M costs for the stand-alone and integrated analyses of this work plan, respectively. The capital costs are annualized using the Cost Recovery Factor (CRF) method, assuming a 5 percent interest rate and 15-year loan period and multiplied by a factor of two to account for installation cost. As additional energy production capacity is added, the annualized capital cost figure represents the annualized capital cost for additional capacity added in that year, plus the annualized capital cost for capacity added in all previous years.

The social savings yielded from beneficial use of methane combusted in LFG is assumed to be equal to the difference between the avoided levelized costs of natural gas, as reported by the Residential and Commercial Subcommittee, and the assumed value of gas produced at

[11] Heat content of methane from http://www.epa.gov/lmop/res/converter.htm; heat content of other fuels from http://www.eia.doe.gov/kids/energyfacts/science/energy_calculator.html, accessed May 2009.

LFGTE facilities ($3/MMBtu).[12] The estimates are variable from year to year, and are presented in Tables 1-4 and 1-5, along with the cost estimates. The assumed discount rate for the net project cost (savings) is 5 percent.

The estimated levelized cost-effectiveness of this work plan is estimated to be –$5/t$CO_2$e for the stand-alone analysis and –$2/t$CO_2$e for the integrated analysis. Tables 1-4 and 1-5 present the detailed cost analysis results.

Table 1-4. Cost-Effectiveness of Additional LFG Beneficial Use (Stand-Alone)

Year	Incremental LFG Available for Beneficial Use (million m^3 CH4)	Direct Heat Generation (MMBtu)	Levelized Cost Savings of Avoided Natural Gas ($/MMBtu)	Annualized Capital Costs ($MM)	O&M Cost ($MM)	Beneficial Use Revenue ($MM)	Net Work Plan Cost ($MM)	Discounted Work Plan Cost ($MM)
2009	0.00	-	$8.21	$0.00	$0.00	$0.00	$0.00	$0.00
2010	4.72	168,613	$8.17	$0.15	$0.07	$0.87	-$0.65	-$0.56
2011	9.53	340,540	$8.24	$0.45	$0.14	$1.78	-$1.19	-$0.98
2012	14.44	515,946	$8.17	$0.91	$0.22	$2.67	-$1.54	-$1.21
2013	19.45	694,992	$8.14	$1.51	$0.29	$3.57	-$1.77	-$1.32
2014	24.57	877,839	$8.18	$2.27	$0.37	$4.54	-$1.91	-$1.36
2015	29.80	1,064,646	$8.22	$3.18	$0.45	$5.55	-$1.93	-$1.31
2016	35.15	1,255,572	$8.31	$4.24	$0.53	$6.67	-$1.90	-$1.22
2017	40.61	1,450,775	$8.42	$5.46	$0.61	$7.87	-$1.80	-$1.11
2018	46.20	1,650,410	$8.51	$6.83	$0.69	$9.09	-$1.6	-$0.92
2019	51.92	1,854,635	$8.45	$8.35	$0.78	$10.11	-$1.0	-$0.55
2020	57.77	2,063,604	$8.35	$10.03	$0.87	$11.04	-$0.1	-$0.1
2021	63.75	2,277,475	$8.35	$11.86	$0.96	$12.18	$0.6	$0.3
2022	69.88	2,496,402	$8.35	$13.85	$1.05	$13.35	$1.5	$0.7
2023	76.16	2,720,541	$8.35	$16.00	$1.14	$14.55	$2.6	$1.2
2024	82.58	2,950,048	$8.35	$18.30	$1.24	$15.78	$3.8	$1.6
2025	89.16	3,185,080	$8.35	$20.76	$1.34	$17.04	$5.1	$2.1
	Total (2009-2020)	**11,937,571**		**$43.4**	**$5.0**	**$63.8**	**-$15.4**	**-$11**
	Total (2009-2025)	**25,567,117**		**$124.1**	**$10.7**	**$136.7**	**-$1.8**	**-$5**

[12] Personal communication – Mike McLaughlin (SCS Engineers) to Brad Strode (CCS) via e-mail on June 2, 2009.

Table 1-5. Cost-Effectiveness of Additional LFG Beneficial Use (Integrated Analysis)

Year	Incremental LFG Available for Beneficial Use (million m^3 CH4)	Direct Heat Generation (MMBtu)	Levelized Cost Savings of Avoided Natural Gas ($/MMBtu)	Annualized Capital Costs ($MM)	O&M Cost ($MM)	Beneficial Use Revenue ($MM)	Net Work Plan Cost ($MM)	Discounted Work Plan Cost ($MM)
2009	0.00	-	$8.21	$0.00	$0.00	$0.00	$0.00	$0.00
2010	4.72	168,613	$8.17	$0.15	$0.07	$0.87	-$0.65	-$0.56
2011	9.53	340,276	$8.24	$0.45	$0.14	$1.78	-$1.19	-$0.98
2012	14.41	514,758	$8.17	$0.91	$0.22	$2.66	-$1.54	-$1.20
2013	19.37	691,843	$8.14	$1.51	$0.29	$3.55	-$1.75	-$1.31
2014	24.38	871,099	$8.18	$2.27	$0.37	$4.51	-$1.88	-$1.33
2015	29.45	1,052,204	$8.22	$3.18	$0.44	$5.49	-$1.87	-$1.27
2016	34.57	1,234,854	$8.31	$4.24	$0.52	$6.56	-$1.80	-$1.16
2017	39.73	1,419,205	$8.42	$5.45	$0.60	$7.70	-$1.65	-$1.01
2018	44.93	1,605,138	$8.51	$6.82	$0.67	$8.84	-$1.35	-$0.79
2019	50.18	1,792,545	$8.45	$8.33	$0.75	$9.77	-$0.69	-$0.38
2020	55.46	1,981,326	$8.35	$10.00	$0.83	$10.60	$0.24	$0.13
2021	60.78	2,171,393	$8.35	$11.83	$0.91	$11.61	$1.13	$0.57
2022	66.16	2,363,319	$8.35	$13.80	$0.99	$12.64	$2.16	$1.04
2023	71.58	2,557,164	$8.35	$15.93	$1.07	$13.68	$3.33	$1.53
2024	77.06	2,752,987	$8.35	$18.22	$1.16	$14.73	$4.65	$2.03
2025	82.60	2,950,852	$8.35	$20.65	$1.24	$15.78	$6.11	$2.54
	Total (2009-2020)	**11,671,862**		**$43.3**	**$4.9**	**$62.3**	**-$14.1**	**-$10**
	Total (2009-2025)	**24,467,577**		**$123.7**	**$10.3**	**$130.8**	**$3.2**	**-$2**

<u>Implementation Steps:</u>

- Provide tax credits to municipalities for the installation of beneficial use projects.
- Installation of beneficial use projects is dependent on landfill permitting.
- Require all active and recently closed landfills containing greater than 1 million tons of disposed of waste to install gas collection systems.
- Do not apply to closed landfills.
- Prioritize right-of-way access for LFG pipeline projects.
- Work with LFG project developers to identify the nearest economical end uses.
- Prioritize LFG projects presenting economic development benefits or that otherwise enhance the application of renewable energy technologies.
- Encourage LFG electrical and thermal use projects to incorporate waste heat recovery. This could help maximize fossil fuel displacement.
- Encourage projects that utilize all LFG generated at a site and/or projects able to grow with landfill site gas generation.

- Promote the high reliability of LFG projects. Most projects are able to operate continuously over extended periods of time, other than for periodic maintenance.
- Prioritize self-powered thermal LFG projects that include an electric generation component.
- Compared to incentives available for LFG to electricity projects (in the range of $2.50/MMBtu for a typical project), the incentives available for LFG to thermal projects (essentially zero) are notable by their absence.

Potential Overlap:

- Recycling work plan (see integrated analysis, above).
- Waste-to-energy MSW (see integrated analysis, above).
- Industry and/or Residential/Commercial sectors, depending on what fuels the beneficial use projects would replace.

Subcommittee Comments

Overall the member of the subcommittee felt that while the reductions were not that large the work plan would result in GHG reductions and that it appears to be cost effective to carry out.

Waste-2. Statewide Recycling Initiative

Summary: Support the expansion of statewide recycling to increase the amount of materials recycled. Increase the 2000 baseline MSW diversion rate of 28.2 percent by a factor of 0.50 by 2025. The resulting target diversion rate is 42.4 percent. This rate represents the total mass of MSW diverted (recycled or composted) divided by the total MSW generated in Pennsylvania.

Goals: Achieve a 42.4 percent diversion rate in Pennsylvania by 2025.

Implementation Period:

Table 2-1. Implementation Schedule for Goal

YEAR	ACTION	% OF GOAL
2000	Historical	
2012	Legislation and Regulations in Place	20%
2015	Increased Non-regulatory Enhancements	50%
2020	Program Maintained and Improvement	80%
2025	Completion	100%

Other Involved Agencies: DEP, counties and municipalities, recycling companies, end users of recycled materials.

Background Discussion on Recycling in PA: Based on data analyzed by the Northeast Recycling Council's (NERC's) Environmental Benefits Calculator, Pennsylvania saved 2.5 MMtCe or 9 MMtCO_2e as a result of recycling approximately 4.9 MMt of materials in 2005. There is potential to reduce an additional 2.9 MMtCe or 11 MMtCO_2e, assuming the recycling of an additional 4 MMt of Pennsylvania-generated recyclables identified as discarded in landfills and incinerators by the *Statewide Municipal Waste Composition Study* (April 2003).

More than 5.4 MMtCe or 20 MMtCO_2e could be avoided annually if all recyclable materials being disposed of were added to the materials currently recovered from the municipal waste stream through recycling programs in the commonwealth. These materials include newspaper, corrugated cardboard, office paper, magazines, mixed paper, plastic bottles, film plastic, rigid plastic, glass, steel and aluminum cans, steel scrap, and other metals. Additional savings above and beyond this projection could be realized if comprehensive programs were developed for the collection and recycling of wood waste, textiles, and carpet.

Energy conserved from manufacturing products using recycled feedstock rather than virgin raw materials, or non-renewable resources, resulted in the savings of 98 *trillion* Btu of energy in 2005, enough to power over 941,000 Pennsylvania homes for one year or the equivalent of conserving 786 MMgal of gasoline.

Emission and energy credit accrued by the state's recycling efforts could be recognized as a tradable commodity that may help achieve the commonwealth's sustainability goals.

PA DEP could target recycling programs to specifically begin or increase collecting those materials that provide the maximum GHG reductions. To further stimulate recycling opportunities, PA DEP could ultimately ban those materials from disposal or processing. Aluminum, steel, plastics, cardboard, and paper should be initially targeted, as these materials will yield the greatest reductions.

Act 101, the Municipal Waste, Planning Recycling and Waste Act Reduction of 1988, provides the foundation for recycling that has resulted in comprehensive environmental and economic benefits for Pennsylvania. The Act provides for a $2/ton recycling fee on waste disposed of or processed at municipal waste landfills and resource recovery facilities in the commonwealth. The recycling fee generates approximately $47 million annually to a Recycling Fund administered by PA DEP. The Recycling Fund provides support to local governments for implementation of recycling programs. The recycling fee also supports the stimulation of markets for recyclable materials. DEP is focusing Act 101 funds on programs geared toward financial sustainability, including those that are targeting new materials that were previously disposed of. Increasing the amount of materials recycled will provide direct reduction in GHG emissions.

Pennsylvania’s recycling program provides annual economic benefits in excess of $23 billion and nearly 82,000 jobs (National Recycling Council, REI Study, 2001). The program also provides extensive environmental benefits. The 2.5 MMtCe eliminated in 2005 by recycling amounted to a savings of approximately 3 percent of all GHG emissions in the commonwealth. Also, recycling conserved considerable natural resources. By recycling almost 1.2 million tons of steel cans, appliances, and similar materials in 2005, Pennsylvania industries saved almost 1.5 million tons of iron ore, 829,786 tons of coal, and 71,124 tons of limestone. Through recycling newspapers, phone books, office paper, cardboard, and mixed paper, the commonwealth saved the equivalent of 78 million tree seedlings grown for 10 years. These trees would sequester CO_2 from the atmosphere and store it in their wood.

Table 2-2 lists the baseline data that reflect the reduction of carbon equivalent since 2001.

Table 2-2. GHG Reduction Under Historical Recycling

YEAR	GHG REDUCTION
2001	2.1 MMtCe
2002	1.7 MMtCe
2003	2.1 MMtCe
2004	1.9 MMtCe
2005	2.5 MMtCe

Historically, data reported to PA DEP demonstrates an annual modest increase in the tonnage of materials recycled. In 1989, the first full year of Act 101 recycling reporting, approximately 378,000 standard tons of materials were recycled. Since then, the program has grown to nearly 4.9 million tons of materials recycled in 2005 (Table 2-3). These annual increases provide a proven track record of quantifiable environmental and economic benefits.

Table 2-3. Historical Disposal and Recycling Data

Year	Population	Disposal (tons)	Per Capita Disposal/Day (tons)	Recycling (tons)
2000	12,281,054	9,324,468	0.76	3,791,433
2001	12,281,054	9,477,159	0.77	3,941,949
2002	12,281,054	9,613,250	0.78	3,927,048
2003	12,281,054	10,201,821	0.83	4,448,937
2004	12,281,054	10,373,136	0.84	4,747,332
2005	12,440,621	10,181,392	0.82	4,865,923

Pennsylvania's recycling data were analyzed in the NERC Environmental Benefits Calculator. The raw 2005 data inputs used for the analysis are displayed in Attachment 1. Attachment 2 shows GHG reductions estimated by the calculator for 2005. Attachment 3 shows GHG reductions based on the recycling of recyclable materials that were identified as disposed of in the *Statewide Waste Characterization Study* (April 2003). Attachment 4 is the NERC Environmental Benefits Calculator in spreadsheet form, including five worksheets reflecting 2005 PA recycling data, showing a total reduction of 10.3 $MMtCO_2e$. This reduction is based on the 2005 level of recycling in PA, compared to 100 percent disposal of recyclables.

The goal of 18 $MMtCO_2e$ represents 86 percent of the state's total recycling potential of 20 $MMtCO_2e$. This has been determined to be a feasible goal. Baseline reductions have been subtracted to reveal the additional reductions gained by this measure (10.3 $MMtCO_2e$).

Data Sources/Assumptions/Methods for GHG:

Baseline Recycling Composition Data Source: PA DEP. 2005. "Pennsylvania Recovered Material Composition Study." Available on-line at: http://www.dep.state.pa.us/dep/deputate/airwaste/wm/RECYCLE/document/Rec_Mat_Comp.pdf

Baseline Landfill Waste Composition Source: PA DEP. 2003. "Statewide Municipal Waste Composition Study." Section 4. Available on-line at: http://www.dep.state.pa.us/dep/deputate/airwaste/wm/RECYCLE/Waste_Comp/Study.htm.

Data Sources/Assumptions/Methods for Costs:

The overall cost to the commonwealth needed to increase recycling to achieve the increased GHG reductions could be funded partly through the Recycling Fund, provided it is reauthorized by the General Assembly. The commonwealth should realize an overall economic benefit from avoided waste disposal cost, increased numbers of jobs from an increased recycling industry, taxes from new business, and some increased revenues from the sales of the new materials being recycled.

The Center for Climate Strategies (CCS) utilized an evaluation of a material recovery facility (MRF) located in Lycoming County to provide estimates of capital costs, O&M costs, and potential revenues associated with an increase in recycling volumes.[13] The average landfill tip fee was provided in an article from PennFuture, which cited the *Solid Waste Digest* as the primary source.[14] The estimate for additional collection cost due to increased recycling comes from an EPA Web page describing the difference in collection costs between low and high diversion rates,[15] adjusted to represent the number of households in Pennsylvania.[16] Assumptions and methods will be documented in further detail, following the presentation of the waste management scenario projections and GHG emissions reduction quantification.

Waste Management Scenario Projections

[NOTE: THE SECTION BELOW DESCRIBES THE WASTE MANAGEMENT FORECAST BASED ON SCENARIO 3A (SEE ATTACHMENT 5), WHICH WAS SELECTED BY THE SUBCOMMITTEE]

Waste disposal data on the PA DEP Web site display the amount of waste deposited at PA landfills and waste-to-energy/resource recovery facilities (hereafter referred to as WTE).[17] These data also provide information on the origin of waste disposed of, allowing for the identification of imported waste deposited at landfill and WTE facilities. CCS utilized these disposal data for 2000 through 2005, in conjunction with the recycling total from Table 2-3, to develop the waste management business-as-usual (BAU) projection. The amount of MSW exported from PA (600,000 tons) was reported in an article in *Biocycle* magazine.[18]

Table 2-4 displays the waste management baseline that serves as the basis for the waste management scenario projections. The “MSW In-State Generation” total includes all in-state MSW deposited in PA landfills and WTE facilities that originated in PA, MSW exported from PA, and MSW recycled. The “In-State MSW Disposed of in Landfills” is the sum of the “In-State MSW Disposed of in PA Landfills” and “Reported MSW Exported.” The baseline diversion rate was calculated by dividing the tonnage of MSW recycled by the in-state MSW generation.[19] To maintain consistency with other work plans in Pennsylvania, the Industry and Waste Subcommittee utilizes 2000 as the baseline year for waste management in Pennsylvania. According to available disposal and recycling data, the recycling rate in 2000 was 28.2 percent.

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[13] RW Beck. 2004. “Lycoming County Material Recovery Facility Evaluation.” Available through PA DEP at: http://www.dep.state.pa.us/dep/deputate/airwaste/wm/recycle/document/MRF_Lycoming.pdf.

[14] PennFuture. 2007. “Critical PA Environmental Program Issues: Waste Disposal and Other Fees in Pennsylvania.” Primary source cited as, “Solid Waste Digest, Year 17, Report No. 1. 2007.” Available at: http://www.pennfuture.org/UserFiles/Tipping%20Fee%20Fact%20Sheet.pdf.

[15] US EPA. 2009. “Wastes-Resource Conservation-Tools for Local Government Recycling Programs-Collection Costs.” Available at: http://www.epa.gov/osw/conserve/tools/localgov/economics/collection.htm.

[16] U.S. Census Bureau. “State & County QuickFacts—Pennsylvania.” Available at: http://quickfacts.census.gov/qfd/states/42000.html.

[17] PA DEP. “Municipal Waste Disposal Information.” Data available for 1988 through 2008. Available at: http://www.depweb.state.pa.us/landrecwaste/cwp/view.asp?A=1238&Q=464453.

[18] Lrsova, Ljupka *et al.* 2008. “The State of Garbage in America – 16th Nationwide Survey of MSW Management in the U.S.” *Biocycle*. December 2008. Available for a limited time without subscription at www.biocycle.net.

[19] The term “diversion” is used to identify all waste that does not end up at a landfill or incineration facility as a result of source reduction, recycling, or composting. For the purposes of this Work Plan, diversion is equal to the sum of recycling and composting. It is generally assumed that all food and yard waste is diverted to compost facilities, while all other diverted waste materials are recycled.

This baseline recycling rate was applied to actual disposal data for 2006 to provide a starting point for the waste management BAU projection.

Table 2-4. Pennsylvania Baseline Waste Management

Item	Year 2006
MSW In-State Generation (tons)	**15,199,459**
Total MSW Disposed in PA Landfills (tons)	14,805,019
Imported MSW Disposed of in PA Landfills (tons)	6,773,180
In-state MSW Disposed of in PA Landfills (tons)	8,031,839
Reported MSW Exported (tons, assumed landfilled)	601,706
In-State MSW Disposed of in Landfills (tons)	8,633,545
Total MSW Combusted in PA WTE Facilities (tons)	2,752,084
Imported MSW Disposed of in PA WTE Facilities (tons)	479,643
In-state MSW Combusted PA WTE Facilities (tons)	2,272,442
Total In-State MSW Disposal (LF + WTE, tons)	**10,905,987**
MSW Diverted (tons)	**4,293,472**

The waste management baseline scenario for 2006 was utilized to project the BAU and Policy (implementation goal of 42.4 percent recycling rate) scenarios through 2025. The growth in waste generation (disposal + diversion) was assumed to follow the average annual growth in per-capita generation from the 2000–2008 data described above (0.52 percent). The BAU waste management projection was generated by increasing the "In-State MSW Generation" annually by multiplying the projected population by the average annual per-capita generation growth rate of 0.52 percent, and assuming a constant recycling rate of 28.2 percent of in-state generation. Additional recycling in each year is assumed to reduce in-state waste landfilled, so waste disposed of at WTE facilities increases constantly at 0.52 percent.[20] The results of the BAU projection are displayed in Table 2-5.

Table 2-6 displays the implementation of the work plan goal through 2025, including the incremental change in the recycling rate throughout the project period. The "Target Recycling Rate" from Table 2-6 was multiplied by the "MSW In-State Generation" from each year in Table 2-5 to yield the total tons recycled under the Policy scenario, shown in Table 2-7. It was assumed that all incremental recycling will offset "In-state MSW Disposed of in PA Landfills."

[20] The Industry and Waste Subcommittee and members of the public have noted that there is currently no additional planned capacity for WTE in Pennsylvania. For the purposes of this analysis, it is assumed that limitations in capacity will reduce the WTE management of imported waste.

Table 2-5. BAU Pennsylvania Waste Management, 2005–2025

Item	2005	2010	2012	2015	2020	2025
MSW In-State Generation (tons)	**15,630,089**	**14,450,125**	**14,655,662**	**14,969,013**	**15,444,567**	**15,858,076**
Total MSW Disposed of in PA Landfills (tons)	15,385,112	12,568,151	12,934,198	13,503,354	14,508,146	15,587,705
Imported MSW Disposed of in PA Landfills (tons)	7,515,388	5,024,535	5,280,806	5,682,571	6,435,047	7,297,708
In-state MSW Disposed of in PA Landfills (tons)	7,869,725	7,543,616	7,653,392	7,820,783	8,073,100	8,289,998
Reported MSW Exported (tons, assumed landfilled)	600,000	609,782	615,980	625,395	641,407	657,829
In-State MSW Disposed of in Landfills (tons)	8,469,725	8,153,398	8,269,372	8,446,178	8,714,507	8,947,827
Total MSW Combusted in PA WTE Facilities (tons)	2,728,123	2,841,537	2,870,418	2,914,291	2,988,907	3,065,433
Imported MSW Disposed of in PA WTE Facilities (tons)	433,681	626,615	623,991	619,832	621,555	634,699
In-state MSW Combusted in PA WTE Facilities (tons)	2,294,442	2,214,923	2,246,428	2,294,458	2,367,351	2,430,734
Total In-State MSW Disposal (LF + WTE, tons)	**10,764,166**	**10,368,321**	**10,515,799**	**10,740,636**	**11,081,858**	**11,378,561**
MSW Diverted (tons)	**4,865,923**	**4,081,804**	**4,139,863**	**4,228,377**	**4,362,709**	**4,479,515**

Table 2-6. Implementation of Targets, 2010–2025

Goal Implementation	2010	2012	2015	2020	2025
Percent Implementation	7%	20%	50%	80%	100%
Target Recycling Rate	29.2%	31.1%	35.3%	39.5%	42.4%
Incremental Increase in Recycling Rate	0.9%	2.8%	7.1%	11.3%	14.1%

GHG Emissions Reduction Analysis

CCS utilized the NERC Environmental Benefits Calculator (EBC) to estimate the net GHG benefit of incremental MSW diversion, described by Table 2-6. This model presents both a life-cycle GHG benefit and a direct landfill GHG benefit for diversion, as opposed to disposal of waste in landfills.[21] The EBC is informed by the EPA WAste Reduction Model (WARM), but only requires the user to input material-specific tonnage of MSWTE diverted, whereas WARM

[21] The Environmental Benefits Calculator and associated documentation may be found at http://www.nerc.org/documents/environmental_benefits_calculator.html.

requires composition detail for landfill disposal and combustion of each waste material, in addition to the composition of diverted MSW.

Table 2-7. Policy Pennsylvania Waste Management, 2005–2025

Item	2005	2010	2012	2015	2020	2025
MSW In-State Generation (tons)	15,630,089	14,450,125	14,655,662	14,969,013	15,444,567	15,858,076
In-State MSW Disposed of in Landfills (tons)	8,469,725	8,017,338	7,855,385	7,389,084	6,969,423	6,708,069
In-state MSW Combusted in PA WTE Facilities (tons)	2,294,442	2,214,923	2,246,428	2,294,458	2,367,351	2,430,734
MSW Diverted (tons)	4,865,923	4,217,864	4,553,849	5,285,471	6,107,793	6,719,273
Incremental MSW Diverted (tons)	**-**	**136,060**	**413,986**	**1,057,094**	**1,745,084**	**2,239,758**

CCS utilized the recycling composition provided in Attachments 1 and 3 by PA DEP.[22] The material categories for Attachment 1 were regrouped, as necessary, in order to place all diverted waste into one of the categories accepted by the EBC. The composition based on Attachment 1 is considered to be the BAU diversion composition (Table 2-8). Table 2-8 also displays the Policy diversion composition. This column was derived by adding the additional diversion for each material from Attachment 3 to the BAU diversion composition derived from Attachment 1.

Table 2-8. Material-Specific MSW Diversion Composition—BAU and "Policy"

Material Type[23]	BAU Recycling Composition (% of Diversion)	Policy Recycling Composition (% of Diversion)
Aluminum Cans	0.4%	0.8%
Steel Cans	0.4%	1.4%
Glass	1.5%	0.0%
HDPE	0.2%	0.9%
LDPE	0.0%	0.0%
PET	0.2%	1.1%
Corrugated Cardboard	18.2%	18.9%
Magazines/Third-Class Mail	0.6%	3.3%
Newspaper	6.2%	7.9%
Office Paper	1.9%	5.1%
Phonebooks	0.0%	0.0%
Textbooks	0.0%	0.0%
Whole Computers	0.1%	0.0%

[22] Attachment 1 is informed by data from the PA Recovered Materials Composition Report: http://www.dep.state.pa.us/dep/deputate/airwaste/wm/RECYCLE/document/Rec_Mat_Comp.pdf.
[23] For some of the material types accepted by the EBC, there was not enough information from the available data sources to provide a composition estimate. The unrepresented diversion was included in such categories as "Mixed Plastics", "Mixed Metals", or "Mixed Recyclables."

Material Type[23]	BAU Recycling Composition (% of Diversion)	Policy Recycling Composition (% of Diversion)
Food Scraps	1.7%	0.9%
Yard Trimmings	14.9%	7.9%
Grass	0.0%	0.0%
Leaves	0.0%	0.0%
Branches	0.0%	0.0%
Ferrous Scrap Metal	14.8%	11.1%
Aluminum Scrap Metal	0.0%	0.5%
Copper Wire	0.0%	0.0%
Tires	0.0%	0.0%
Construction & Demolition	0.0%	0.0%
Carpet	0.0%	0.0%
Dimensional Lumber	5.4%	2.9%
Medium-density Fiberboard	0.0%	0.0%
Clay Bricks	0.0%	0.0%
Aggregate	0.0%	0.0%
Fly Ash	0.0%	0.0%
Mixed Paper, Broad Definition	6.1%	8.3%
Mixed Metals	12.6%	7.0%
Mixed Plastics	1.3%	11.4%
Mixed Recyclables	13.5%	10.7%
Mixed Organics	0.0%	0.0%
Other Recyclables	0.0%	0.0%

The BAU and Policy recovered materials composition from Table 2-8 for each material type were multiplied by the BAU and Policy waste diversion from Tables 2-5 and 2-7, respectively. This calculation yielded the inputs for the NERC EBC. CCS ran the EBC for the years 2015, 2020, and 2025, inputting the material-specific waste diversion, as well as the total in-state waste landfill disposal and WTE combustion for that year. The EBC was used twice for each year—once for the BAU diversion and once for the Policy diversion. The difference between the two results yielded the net GHG reduction.

As previously stated, the EBC provides the net landfill GHG reduction, as well as the total life-cycle GHG reduction. The landfill benefit takes into account the reduction in carbon sequestered in landfills, as well as the reduction in energy-producing LFG due to reduced waste disposal. Therefore, it is possible that the incremental GHG reduction at landfills from increased waste diversion will be very small, or possibly negative.

Table 2-9 displays a summary of the incremental waste diversion, life-cycle GHG reduction, and direct landfill GHG reduction. In total, this work plan would result in an additional 36 million tons diverted through 2025, with a cumulative life-cycle and direct landfill GHG reduction of 65.1 and 3.11 MMtCO_2e, respectively.

Table 2-9. Incremental MSW Diversion GHG Benefit

Year	Incremental Diversion (tons)	Life-cycle GHG Reduction ($MMtCO_2e$)	Direct Landfill GHG Reduction ($MMtCO_2e$)
2009	-	-	-
2010	136,060	0.47	0.04
2011	274,049	0.94	0.08
2012	413,986	1.42	0.13
2013	625,376	2.15	0.19
2014	839,736	2.89	0.26
2015	1,057,094	3.63	0.32
2016	1,191,378	3.72	0.17
2017	1,327,304	4.14	0.19
2018	1,464,887	4.57	0.21
2019	1,604,142	5.00	0.23
2020	1,745,084	5.44	0.25
2021	1,842,046	5.54	0.24
2022	1,939,987	5.84	0.22
2023	2,038,915	6.13	0.21
2024	2,138,835	6.43	0.20
2025	2,239,758	6.74	0.18
Total	**20,878,638**	**65.1**	**3.11**
	Total (2009-2020)	**34.4**	**2.07**

Cost-Effectiveness Analysis: The evaluation of the reference case MRF facility in Lycoming County stated capital costs of $8.7 million and annual O&M costs of $407,532.[24] This facility processes about 12,000 tons of recyclables per year. Revenue from recycled material at this facility in 2004 was $702,550. These figures were multiplied by a factor of 1.11545 to convert the financials from 2004 to 2007 dollars.[25]

The additional collection cost from the EPA collection cost fact sheet was $2.25 per household. The number of households in PA from the 2000 census was multiplied by the 2000–2008 population growth to estimate the number of households in 2008 (4,843,881).

The landfill tipping fee ($61/ton, 2007$) assumed for this analysis is the average PA gate rate for waste disposal.[26]

The costs associated with the additional recycling targeted by this work plan include annualized capital costs, annual O&M costs, and additional collection costs. The capital costs were determined by dividing the capital cost (in 2007$) of the reference MRF facility by the annual

[24] O&M costs include labor, materials and supplies, general operating expenses, and maintenance and repairs.
[25] Standardized factor provided by Hal Nelson of CCS via e-mail on May 11, 2009. Original source was Table 10.1 at http://www.gpoaccess.gov/usbudget/fy09/pdf/hist.pdf.
[26] From *Solid Waste Digest*, as cited by PennFuture.

tons processed to determine a per-ton capital cost. This factor is multiplied by the additional tonnage recycled in each year and an annualizing factor,[27] then is added to the annualized capital cost from previous years to capture the assumption that the recycling program will ramp up over time. The annual O&M costs were estimated by dividing the reference MRF O&M cost (in 2007$) by the annual tonnage received at that facility, multiplying that factor by the incremental tonnage recycled in each year as a result of the work plan target. Finally, the additional collection costs for each year were determined by multiplying the per-household collection cost by the 2008 number of households, then multiplying that number by the implementation rate (first row of Table 2-6).

The cost savings associated with additional recycling are assumed to include revenue from recycled materials and the avoided solid waste landfill tip fee. The MRF facility revenue was estimated by multiplying half of the 2004 per-ton revenue from the reference MRF facility by the incremental recycling tonnage for each year due to the work plan target.[28] The avoided solid waste landfill tip fee in each year was found by multiplying the 2007 average PA gate rate of $61/ton by the incremental recycling for each year.

The net program cost, when discounted at a 5 percent rate from 2007, is a net savings of -$465 million (net present value [NPV]) through the project period (2009–2025). The cost-effectiveness is –$7/t$CO_2$e over this same period. The cost savings over the standardized planning period (2009-2020) is –$246 million (NPV), with a cost-effectiveness of –$7/t$CO_2$e. See Table 2-10 for a detailed tabulation of results.

Table 2-10. Incremental MSW Diversion Cost-Effectiveness

Year	Incremental Recycling (tons)	Annualized Capital Cost ($MM)	Annual O&M Cost ($MM)	Additional Collection Cost ($MM)	Materials Revenue ($MM)	Avoided Landfill Tip Fee ($MM)	Net Program Cost ($MM)	Discounted Cost ($MM)
2009	-	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0
2010	136,060	$10.6	$5.2	$0.7	$4.4	$8.3	$3.7	$3.2
2011	274,049	$10.8	$10.4	$1.5	$8.9	$16.7	-$3.1	-$2.5
2012	413,986	$10.9	$15.7	$2.2	$13.5	$25.3	-$10.0	-$7.8
2013	625,376	$16.5	$23.7	$3.3	$20.4	$38.1	-$15.1	-$11.3
2014	839,736	$16.7	$31.8	$4.4	$27.4	$51.2	-$25.8	-$18.3
2015	1,057,094	$16.9	$40.0	$5.4	$34.5	$64.5	-$36.6	-$24.8
2016	1,191,378	$10.5	$45.1	$6.1	$38.9	$72.7	-$49.9	-$32.2
2017	1,327,304	$10.6	$50.3	$6.8	$43.3	$81.0	-$56.7	-$34.8
2018	1,464,887	$10.7	$55.5	$7.4	$47.8	$89.4	-$63.6	-$37.2
2019	1,604,142	$10.8	$60.8	$8.1	$52.4	$97.9	-$70.5	-$39.3
2020	1,745,084	$11.0	$66.1	$8.7	$57.0	$106.5	-$77.6	-$41.2

[27] CCS used the Capital Recovery Factor method of animalization, assuming an 5% interest rate and 15 year loan period.

[28] Based on recent experience of recycling markets, CCS chose to assume that the value of recycled material would be half as much as in 2004. This factor was applied in an attempt to provide a conservatively low estimate for the revenue potential of additional recycling.

Year	Incremental Recycling (tons)	Annualized Capital Cost ($MM)	Annual O&M Cost ($MM)	Additional Collection Cost ($MM)	Materials Revenue ($MM)	Avoided Landfill Tip Fee ($MM)	Net Program Cost ($MM)	Discounted Cost ($MM)
2021	1,842,046	$7.6	$69.8	$9.2	$60.1	$112.4	-$86.0	-$43.4
2022	1,939,987	$7.6	$73.5	$9.6	$63.3	$118.3	-$91.0	-$43.8
2023	2,038,915	$7.7	$77.2	$10.0	$66.6	$124.4	-$96.0	-$44.0
2024	2,138,835	$7.8	$81.0	$10.5	$69.8	$130.5	-$101.0	-$44.1
2025	2,239,758	$7.9	$84.8	$10.9	$73.1	$136.6	-$106.2	-$44.1
Total	**20,878,638**	**$175**	**$791**	**$105**	**$682**	**$1,274**	**-$885**	**-$465**
					Total (2009-2020)			**-$246**

Implementation Steps:

1. Ensure that the state government is taking a leadership role and maximizing recycling efforts. These efforts will be initiated with a new comprehensive management directive that will ensure all commonwealth agencies, boards and commissions are implementing recycling and waste reduction programs, as well as purchasing environmentally preferable products.

2. Encourage county governments to report recycling activities within their jurisdiction, as required by Act 101. To facilitate more timely and improved reporting PA DEP will implement or procure a new or modified reporting system to capture much of the recycling data that currently goes unreported.

3. *Municipal Government Recycling Programs*—Assist in working to amend Act 101 to require recycling programs for municipalities with a lesser density than currently stated in the Act, and with smaller populations than the 5,000 in the current Act. PA DEP should consider proposing the new limits. Seek ways to encourage all municipal recycling programs to include all plastic and paper types in a list that should be developed by PA DEP. This would logically include all types of plastic and paper that have a market potential and/or sorting convenience to home owners—e.g., generally co-mingled materials that do not required confusing requirements for acceptable versus unacceptable materials.

4. *Public Recycling Availability*—PA DEP should consider establishing rules on density and availability of recycling containers for all public areas in which waste disposal receptacles are placed. This should be in the form of guidelines for municipal recycling programs and state governmental agencies. Appropriate language can be incorporated into the Act 101 amendments.

5. *Funding through Act 101*—Continue to financially support and reward recycling programs, as is currently available through Act 101 fees and grant programs.

6. Conduct a comprehensive review of all the current legislation to identify areas where legislation creates obstacles or impediments to the management and beneficial use of waste material.

7. Develop a strategy to focus on expanding recycling programs to:
    a. Support and grow recycling industries.
    b. Eliminate barriers that impede the use of waste for energy production.
    c. Support the growth of private-sector recycling programs by leveling the playing field between government-supported and private-sector programs.
    d. Ensure financial support to protect past investments in recycling programs.
    e. Promote new private-sector investments and protect past private-sector investments in LFGTE projects and similar programs.
    f. Ensure adequate funding to facilitate a sophisticated and robust statewide recycling program for all commonwealth citizens.

8. Assist in developing a single legislative package for consideration that folds all previously enacted legislation under one comprehensive package. The resulting package should include assisting in recycling at the source of generation, encouraging market development, and limiting disposal of recyclable materials at the end.

Potential Overlap:

- Increased Capture and Use of Landfill Methane
- Waste-to-Energy MSW

An overlap may exist between the WTE MSW work plan and the Statewide Recycling Initiative work plan. However, for both work plans it is assumed that waste that is either diverted or combusted reduces MSW solely from landfills. The result is no overlap between the Waste-2 and Waste-6 work plans, as the incremental GHG reduction for each would not change, depending on the implementation of the respective work plans.

Subcommittee Comments

This work plan was substantially revised from the version originally supplied by the department. With these changes the subcommittee members felt that meaningful reductions could be accomplished in a cost effective manner, based on the assumptions in the work plan.

Other Considerations and Notes:

Attachment 1: Pa. Materials Recycled, 2005

MATERIAL	DEP Code(s)	Breakout	TONS
FOOD WASTE	FW1		**66,481.70**
GLASS			
GLASS: CLEAR	GL1	15,577.80	
GLASS: MIXED	GL2	21,866.30	
GLASS: GREEN	GL3	6,311.40	
GLASS: BROWN	GL4	6,681.50	
GLASS: PLATE	GL5	5,153.20	
GLASS: OTHER	GL6	1,929.30	
Subtotal Glass			**57,519.50**
BATTERY: LEAD-ACID	B01		**22,169.90**
METALS			
ALUMINUM CANS	AA1	17,590.00	
FERROUS	F01	580,142.10	
STEEL & BIMETALLIC (TIN) CANS	F02	13,935.90	
WHITE GOODS	F03	56,383.30	
MIXED METALS	MM1	174,797.40	
MIXED CANS	MX2	2,547.00	
NON FERROUS	N01	48,413.40	
COPPER	N02	4,524.60	
BRASS	N03	2,349.60	
LEAD	N04	167.5	
STAINLESS STEEL	N05	203,794.40	
NICKEL	N10	48.7	
WIRE/CABLE	W01	1,455.30	
Subtotal Metals			**1,106,149.20**
PAPER			
PAPER: CARDBOARD	C01	713,552.00	
PAPER: BROWN BAGS & SACKS	C02	3,749.60	
PAPER: MAGAZINE	PA1	24,682.80	
PAPER: NEWSPRINT	PA2	244,252.40	
PAPER: MIX	PA3	230,483.50	
PAPER: OFFICE PAPER	PA4	76,303.80	
PAPER: COMPUTER	PA5	3,807.70	
PAPER: PHONE BOOKS	PA6	1,242.50	
Subtotal Papers			**1,298,074.30**
PLASTICS			
DRUM PLASTIC	DR1	791.2	
PLASTIC: PET	PL1	6,754.60	

MATERIAL	DEP Code(s)	Breakout	TONS
PLASTIC: HDPE	PL2	6,955.40	
PLASTIC: PVC (POLYVINYL/CHLORIDE)	PL3	15,206.50	
PLASTIC: LPDE (LOW DENSITY POLYETHYLENE)	PL4	2,598.90	
PLASTIC: PP (POLYPROPLENE)	PL5	3,236.20	
PLASTIC: PS (POLYSTYRENE)	PL6	1850.2	
PLASTIC: MIXED	PL7	16,225.60	
PLASTIC: FILM	PL8	5,747.40	
PLASTIC: OTHER	PL9	4,594.90	
Subtotal Plastics			**63,960.90**
SINGLE STREAM	SS1		**43,645.80**
TEXTILES	M03		**25,182.70**
TIRES	M01		**55,416.50**
WOOD	WW1		**213,284.90**
YARD TRIMMAGE	Y03		**585,681.50**
OTHER RECYCLABLES			
CIRCUIT BOARDS	CB1	61.6	
CONSUMER ELECTRONICS	CRT	2,900.00	
FLUORESCENT TUBES	FL1	261	
HOUSEHOLD HAZARDOUS WASTE	HHW	1,353.90	
MATTRESSES	MT1	116.6	
ANTIFREEZE	O02	1,342.20	
OIL FILTERS	OL3	798.9	
COMMINGLED MATERIALS	XXX	228,699.80	
Subtotal Other Recyclables			**235,534.00**
904 excess			**25,929.00**
Tire excess			**72,770.00**
ISRI excess			**51,795.00**
Lancaster County (RE-Trac)	INCORPORATED		
TOTAL STANDARD			**3,923,594.90**
TOTAL NON-STANDARD			**942,328.10**
GRAND TOTAL			**4,865,923.00**

Attachment 2: Reductions in Greenhouse Gas Emissions as a Result of 2005 Recycling

Materials	Reporting Year 2005	Greenhouse Gas Emissions Associated with Recycling- Metric Tons Carbon Equivalent (MTCE)	Greenhouse Gas Emissions if Recyclables Had Been Disposed (MTCE)	Net Greenhouse Gas Emissions from Recycling as Compared to Disposal (MTCE)
Aluminum Cans	33,619	-124,418	381	-124,799
Steel Cans	44,590	-21,817	-2,494	-19,323
Glass	201,097	-15,239	2,194	-17,433
HDPE	40,115	-15,230	1,923	-17,152
LDPE	2,599	-1,201	125	-1,326
PET	39,736	-16,667	2,161	-18,828
Corrugated Cardboard	714,526	-606,295	46,378	-652,673
Magazines/Third-class Mail	25,935	-21,718	-2,313	-19,405
Newspaper	276,048	-210,163	-63,883	-146,280
Office Paper	76,652	-59,629	32,309	-91,939
Phonebooks	1,721	-1,246	-398	-848
Textbooks	0	0	0	0
Whole Computers	0	0	0	0
Food Scraps	66,482	-3,600	10,599	-14,199
Yard Trimmings	585,682	-31,717	-35,002	3,286
Grass	0	0	0	0
Leaves	0	0	0	0
Branches	213,285	-11,550	-25,957	14,407
Ferrous Scrap Metal	650,458	-318,251	-36,376	-281,875
Aluminum Scrap Metal	31,681	-117,246	359	-117,605
Copper Wire	0	0	0	0
Tires	128,187	-63,783	2,101	-65,884
Construction & Demolition	688,211	Not Available (NA)	NA	NA
Carpet	0	0	0	0
Dimensional Lumber	0	0	0	0
Medium-density Fiberboard	0	0	0	0
Clay Bricks	0	NA	NA	NA
Aggregate	0	0	0	0
Fly Ash	0	0	0	0
Mixed Paper, Broad Definition	244,234	-235,593	12,891	-248,484
Mixed Metals	490,360	-703,102	-17,722	-685,380
Mixed Plastics	47,652	-19,418	2,407	-21,825
Mixed Recyclables	0	0	0	0
Mixed Organics	0	0	0	0
Other Recyclables	263,279	NA	NA	NA
Total as a Result of Recycling	**4,866,149**	**-2,597,884**	**-70,318**	**-2,527,566**

Attachment 3: Potential GHG Reductions if Recyclable Materials Disposed of Were Recycled

Materials	Potential Tons Recyclable (MSW Composition Study, April 2003)	Greenhouse Gas Emissions Associated with Recycling (MTCE)
Aluminum Cans	48,844	-180,763
Steel Cans	102,532	-50,166
Glass	234,629	-17,780
HDPE	68,082	-25,848
LDPE	0	0
PET	87,601	-36,743
Corrugated Cardboard	785,032	-666,121
Magazines/Third-class Mail	251,027	-210,208
Newspaper	389,263	-296,357
Office Paper	341,975	-266,029
Phonebooks	0	0
Textbooks	0	0
Whole Computers	0	0
Food Scraps	0	0
Yard Trimmings	0	0
Grass	0	0
Leaves	0	0
Branches	0	0
Ferrous Scrap Metal	282,131	-138,039
Aluminum Scrap Metal	43,057	-159,347
Copper Wire	0	0
Tires	0	0
Construction & Demolition	0	NA
Carpet	0	0
Dimensional Lumber	0	0
Medium-density Fiberboard	0	0
Clay Bricks	0	NA
Aggregate	0	0
Fly Ash	0	0
Mixed Paper, Broad Definition	433,821	-418,473
Mixed Metals	32,138	-46,081
Mixed Plastics	906,653	-369,457
Mixed Recyclables	0	0
Mixed Organics	0	0
Other Recyclables	0	NA
Total as a Result of Recycling	**4,006,785**	**-2,881,412**

Attachment 4: NERC Environmental Benefits Calculator, 2005 Pa. Recycling Data

2005v1_NERC_Calculator_Pennsyl…

Attachment 5: Waste Management Projection Scenarios

PA DEP provided CCS historical disposal data for 1990–2008. These data show the amount of waste disposed of at each facility in Pennsylvania, as well as the origin of that waste. CCS used these data, in addition to the recycling data provided in Table 2-3. The methods used to develop these scenarios are similar to those used to develop the Waste Management Projection (highlighted above), except for the application of the average annual growth (AAG) in per-capita generation as the growth factor for waste generation.

Scenario 3a was selected by the Industry and Waste Subcommittee during a public teleconference that took place on May 6, 2009. This scenario was used to quantify GHG reduction and cost-effectiveness.

Note for Scenario 1: The AAG in the diversion rate from 2000 through 2005 was used to simulate an increase in the BAU diversion rate. Under this scenario, the BAU diversion rate in 2025 would be 46.6 percent.

Scenario 1 - BAU Growth in Diversion Rate (AAG 2000-2005)					
Scenario 1a - 2000-2008 AAG in per-capita generation	Baseline Diversion Rate	31.1%			
	AAG Diversion Rate (2000-2005)	2.0%			
	AAG Per-Capita Generation (2000-2008)	1.4%			
		2005	2010	2015	2025
	Total MSW Generation (tons)	15,630,089	15,784,007	17,128,905	19,914,458
	BAU In-State MSW Landfilled (tons)	8,469,725	8,137,042	8,336,915	8,355,735
	BAU MSW Diverted (tons)	4,865,923	5,436,486	6,527,214	9,288,834
	Incremental MSW Diversion (tons)	-	192,112	1,249,859	1,206,085
Scenario 1b - 2000-2005 AAG in per-capita generation	Baseline Diversion Rate	31.1%			
	AAG Diversion Rate (2000-2005)	2.0%			
	AAG Per-Capita Generation (2000-2005)	3.1%			
		2005	2010	2015	2025
	Total MSW Generation (tons)	15,630,089	16,292,711	19,140,177	26,077,464
	BAU In-State MSW Landfilled (tons)	8,469,725	8,399,291	9,315,834	10,941,617
	BAU MSW Diverted (tons)	4,865,923	5,611,699	7,293,638	12,163,486
	Incremental MSW Diversion (tons)	-	198,304	1,396,618	1,579,337
Scenario 1c - 2003-	Baseline Diversion Rate	31.1%			
	AAG Diversion Rate (2000-2005)	2.0%			

Scenario 1 - BAU Growth in Diversion Rate (AAG 2000-2005)					
2008 AAG in per-capita generation	AAG Per-Capita Generation (2000-2008)	0.1%			
		2005	2010	2015	2025
	Total MSW Generation (tons)	15,630,089	15,369,086	15,604,049	15,879,252
	BAU In-State MSW Landfilled (tons)	8,469,725	7,923,140	7,594,743	6,662,638
	BAU MSW Diverted (tons)	4,865,923	5,293,575	5,946,146	7,406,666
	Incremental MSW Diversion (tons)	-	187,062	1,138,594	961,700

Scenario 2 - 2005 Baseline Recycling Rate					
Scenario 2a - 2000-2008 AAG in per-capita generation	Baseline Diversion Rate	31.1%			
	AAG Per-Capita Generation (2000-2008)	1.1%			
		2005	2010	2015	2025
	Total MSW Generation (tons)	15,630,089	15,218,941	16,197,327	18,112,373
	BAU In-State MSW Landfilled (tons)	8,469,725	8,242,019	8,771,877	9,808,995
	BAU MSW Diverted (tons)	4,865,923	4,737,925	5,042,514	5,638,702
	Incremental MSW Diversion (tons)	-	218,830	1,746,739	3,906,519
Scenario 2b - 2000-2005 AAG in per-capita generation	Baseline Diversion Rate	31.1%			
	AAG Per-Capita Generation (2000-2008)	3.1%			
		2005	2010	2015	2025
	Total MSW Generation (tons)	15,630,089	15,832,224	18,599,211	25,340,425
	BAU In-State MSW Landfilled (tons)	8,469,725	8,574,150	10,072,648	13,723,442
	BAU MSW Diverted (tons)	4,865,923	4,928,851	5,790,263	7,888,922
	Incremental MSW Diversion (tons)	-	227,649	2,005,760	5,465,482
Scenario 2c - 2003-2008 AAG in per-capita generation	Baseline Diversion Rate	31.1%			
	AAG Per-Capita Generation (2000-2008)	-0.5%			
		2005	2010	2015	2025
	Total MSW Generation (tons)	15,630,089	14,765,643	14,570,723	14,007,246
	BAU In-State MSW Landfilled (tons)	8,469,725	7,996,529	7,890,968	7,585,809
	BAU MSW Diverted (tons)	4,865,923	4,596,806	4,536,124	4,360,703
	Incremental MSW Diversion (tons)	-	212,313	1,571,324	3,021,115

Scenario 3 - 2000 Baseline Recycling Rate

Scenario 3a - 2000-2008 AAG in per-capita generation	Baseline Diversion Rate	28.2%			
	AAG Per-Capita Generation (2000-2008)	0.5%			
		2005	2010	2015	2025
	Total MSW Generation (tons)	15,630,089	14,450,125	14,969,013	15,858,076
	BAU In-State MSW Landfilled (tons)	8,469,725	8,153,398	8,446,178	8,947,827
	BAU MSW Diverted (tons)	4,865,923	4,081,804	4,228,377	4,479,515
	Incremental MSW Diversion (tons)	-	235,561	1,830,146	3,877,691
Scenario 3b - 2000-2005 AAG in per-capita generation	Baseline Diversion Rate	28.2%			
	AAG Per-Capita Generation (2000-2008)	3.1%			
		2005	2010	2015	2025
	Total MSW Generation (tons)	15,630,089	15,195,816	17,851,578	24,321,816
	BAU In-State MSW Landfilled (tons)	8,469,725	8,574,150	10,072,648	13,723,442
	BAU MSW Diverted (tons)	4,865,923	4,292,443	5,042,630	6,870,313
	Incremental MSW Diversion (tons)	-	247,717	2,182,576	5,947,284
Scenario 3c - 2003-2008 AAG in per-capita generation	Baseline Diversion Rate	28.2%			
	AAG Per-Capita Generation (2000-2008)	-1.2%			
		2005	2010	2015	2025
	Total MSW Generation (tons)	15,630,089	13,949,375	13,230,742	11,750,525
	BAU In-State MSW Landfilled (tons)	8,469,725	7,870,853	7,465,369	6,630,165
	BAU MSW Diverted (tons)	4,865,923	3,940,354	3,737,358	3,319,233
	Incremental MSW Diversion (tons)	-	227,398	1,617,621	2,873,293

Waste-4. Improved Efficiency at Wastewater Treatment Facilities

Initiative Summary: Improving efficiency at wastewater treatment facilities through outreach programs based on sustainable infrastructure principles.

Goals: Assist 50 percent more treatment plants per year to improve efficiency (a 50 percent improvement over the current 6–8 treatment plants)

Implementation Period: 3–4 additional treatment plants per year from 2010 through 2020

Other Involved Agencies: DEP, Outreach Assistance Provider Program (OAPP), wastewater system owners and operators.

Implementation Steps:

- DEP—Increase personnel assigned to OAPP wastewater treatment plant outreach by 50 percent.
- Provide grant funding for wastewater plant upgrades.
- Improve ease of permitting for wastewater plant upgrades.

Data sources/Assumptions/Methods for GHG:

Based on past program performance, treatment facilities visited by this program tend to treat around 1–2 million gallons of water per day. Calculations on GHG savings are as follows:

- 2,500 Kilowatt-hours (kWh)/MMgal treated x 1.5 MMgal/day facility = 3,750 kWh/day[29]
- 3,750 kWh x 365 days = 1,368,750 kWh/yr

Savings at these facilities is estimated at 10 percent, so:

- 1,368,750 kWh/yr x 0.10 = 136,875 kWh/yr savings per facility

Converting to CO_2 emissions:

136,875 kWh/yr x 7.18 x 10^{-4} tCO_2/kWh[30]= 98.3 tCO_2/yr per facility

Table 4-1 summarizes the GHG savings possible from implementing a 50 percent increase in treatment plant upgrades. By upgrading an average of 3–4 additional facilities per year, a total of 0.022 $MMtCO_2e$ can be saved.

[29] Electricity usage was determined by surveying twelve wastewater treatment plants in Pennsylvania and plotting electricity usage against the size of facility. This information was provided by Jim Elliott, Gannett Fleming, Inc. to Rachel Anderson, CCS via email, June 2009.
[30] Kilowatt-hour conversion from http://www.epa.gov/grnpower/pubs/calcmeth.htm,accessed May 2009.

Table 4-1. GHG Savings and Costs of Treatment Plant Upgrades

Year	Average Additional Treatment Plants Improved	Savings per Facility (metric tons CO_2e/ year)	Total Savings Above BAU (metric tons CO_2e/year)	Annualized Capital Costs ($)	Cost Savings to Plants ($)	Cost of Additional Personnel	NPV of Net Costs (2007$)	Cost-Effec-tiveness ($/t$CO_2e$)
2010	3.5	98.3	344	1,686	-$175,000	42,500	-$37,416	
2011	3.5	98.3	688	3,372	-$262,500	42,500	-$106,234	
2012	3.5	98.3	1,032	5,058	-$350,000	42,500	-$168,413	
2013	3.5	98.3	1,376	6,744	-$437,500	42,500	-$224,429	
2014	3.5	98.3	1,720	8,430	-$525,000	42,500	-$274,728	
2015	3.5	98.3	2,064	10,116	-$612,500	42,500	-$319,728	
2016	3.5	98.3	2,408	11,802	-$700,000	42,500	-$359,819	
2017	3.5	98.3	2,752	13,488	-$787,500	42,500	-$395,368	
2018	3.5	98.3	3,096	15,174	-$875,000	42,500	-$426,714	
2019	3.5	98.3	3,441	16,860	-$962,500	42,500	-$454,179	
2020	3.5	98.3	3,785	18,546	-$1,050,000	42,500	-$478,060	
		TOTAL	22,707				-$3,245,088	-$143

Data Sources/Assumptions/Methods for Costs:

The cost of implementation of treatment plant upgrades is estimated at $5,000 per plant, and upgrades result in an average cost savings of $25,000 per plant per year.[31] Upgrades were annualized over 15 years at a 5 percent interest rate. The cost to DEP to hire additional personnel necessary to increase outreach efforts is estimated at $35,000–$50,000.[32] The total cost savings over the policy period is $3.2 million discounted to 2007 dollars, as summarized in Table 4-1.

Notes/Other Considerations:

The DEP Office of Water Management proposes several methods to improve efficiency in order to maintain sustainable infrastructure (SI) within wastewater treatment systems. The efficient use of energy is crucial for sustaining infrastructure and national security. Electrical energy rate cap expirations set for 2010 further exacerbate this issue.

Wastewater treatment plants typically are the largest consumer of electricity on most municipal bills, often consuming more than one-third of the energy consumed for all municipal services. In many instances, opportunities exist to reduce energy consumption at these facilities. To assist treatment plants in improving efficiency, DEP provides outreach to these facilities, teaching system operators how to use the system in the most efficient manner for treatment and suggesting ways to reduce the amount of energy required to operate the facility.

[31] Thomas Brown, PA DEP; communicated via email to Rachel Anderson, CCS, May 2009.
[32] Thomas Brown, PA DEP; personal communication to Kim Hoover, DEP, June 2009.

Three basic types of treatment plants are in use today: activated sludge, fixed film, and lagoon systems. Of the many treatment facilities in Pennsylvania, approximately 70 percent are activated sludge facilities. These facilities inject diffused air into an aeration basin to sustain a biological growth in order to treat the wastewater. The aeration basins that these facilities require are the largest consumer of electricity in wastewater treatment systems. Opportunities exist to improve efficiency in many of these facilities throughout the state.

OAPP uses part-time wage payroll instructors who are certified operators or specialists in a given field. These instructors provide on-site technical, managerial, and financial assistance to wastewater system owners and operators. The program responds to system needs identified by DEP regional staff, local government associations, or system personnel. On-site assistance and training are provided through a combination of video, classroom, and Web-based training and one-on-one assistance to address specific system problems. In the coming fiscal year, OAPP plans to accomplish the following:

- Continue on-site technical assistance for facilities requesting assistance with energy efficiency. The average activated sludge wastewater treatment plant consumes 6,000 kWh/MMgal of wastewater treated. At approximately $0.08/kWh, the energy consumption is estimated at $500/MMgal treated. Using energy audits under the auspices of OAPP, DEP proposes to assist 6–8 wastewater systems in reducing energy consumption in FY 2008–2009, with a focus on assisting at least one in each DEP region. On average, these audits will result in an estimated annual energy savings of 10 percent–15 percent in the cost of kWh per treatment plant. It must be kept in mind that due to the relatively low cost of electricity in the past, the preference for wastewater treatment has been aerobic treatment processes. This will no longer be the most cost-effective solution once the expected sharp increases in costs per kWh take place. Therefore, a further focus of this outreach effort will be to encourage and re-educate the owners and operators of wastewater treatment systems on the benefits of more energy-efficient and effective wastewater treatment processes related to anaerobic treatment.
- Continue collaboration with DEP Central and Regional staff in providing training opportunities for operators in conjunction with various associations.
- Integrate the principles of SI in all technical assistance provided by OAPP. This would include providing training with regard to all aspects of SI.
- Distribute the DVD on energy efficiency and other tools for SI.
- In conjunction with the Pennsylvania Water Environment Association, another special Nutrient Reduction Technology conference is scheduled for this fall in the Scranton area on September 10–12, 2009. This year’s conference will include energy efficiency, improvements to water quality, and other SI principles.
- Enhance the operator information center web site "Technical Corner" as it relates to SI, energy efficiency, and other operational issues.

The DEP Wastewater Outreach Program has provided assistance in energy efficiency since 1993. Unfortunately, in the 1990s energy costs were not high enough to cause a significant amount of interest. While the program had several success stories in the past, many people simply were not tuned into the idea of energy efficiency. In one case, the program saved a municipality over

$100,000 annually (in an approximately 6 MMgal/day system). By today's standards, this type of savings would be greatly magnified. With the pending expiration of electrical energy rate caps and the spiraling cost of oil, people are now starting to pay attention and ask questions.

Below are examples of our past accomplishments:

- On-site technical assistance to Ridgeway Borough on energy efficiency and process control utilized the process of denitrification to save energy and chemical costs. This process utilizes the nitrate that is produced in the process of nitrification for facultative organism respiration. This results in improved water quality by reducing total nitrogen released to the receiving stream and saves money. With an investment of $500, Ridgeway was able to document savings of $31,000 annually in energy and chemical costs, in addition to improving the quality of its effluent.
- On-site energy efficiency technical assistance was provided to the City of Warren. In this system older sparge ring diffusers were used for mixing and aeration. By changing the cycles of mixing and aeration, the system could realize a savings of several thousand dollars per month. This project is still underway.
- DEP Central and Regional office staff collaborated to produce a continuing education training program titled "Flush Away High Energy Costs." In conjunction with PA Rural Water, this training session was piloted in the northwestern region and was well received by operators throughout the region. This session provides operators with the tools they need to reduce energy costs within their systems, while maintaining or improving water quality.
- In 1996, an energy efficiency in wastewater treatment systems video was produced jointly by DEP and the Maryland Center for Environmental Training. In the past year, this video was upgraded and digitized to a DVD format so it can be widely distributed.
- A training session was held in the State College area for DEP Central and Regional Office staff on energy efficiency in water/wastewater systems. This session followed a format similar to the "Flush Away High Energy Costs" operator training session. This session will help regional staff to further spread the word about energy efficiency.
- A special conference on total nutrient reduction was held in the Lancaster area last fall. This sold-out event provided operators and managers with tools needed to improve reduction of nutrients and increase efficiency.
- Assistance was provided to program staff involved in a pilot project with Montgomery County Community College to create a certificate program focusing on water and wastewater treatment. Based on the input provided, the pilot program will be modified to include basics of SI with an emphasis on energy efficiency, as well as effective process control.

All treatments plants produce excess solids, often referred to as sludge or biosolids. These excess solids have to be treated before their ultimate disposal. There are two basic types of treatment for these solids: aerobic digestion and anaerobic digestion. Anaerobic treatment tends to be more energy neutral or even produces energy, as the methane produced through this process can be used as a fuel. Unfortunately, this technology is not used in many instances in Pennsylvania, due to past problems with the operation, mostly due to problems in handling the gases produced in the treatment process. Technology in this arena has improved in recent years, making the management of these systems safer and more efficient. PA DEP currently has a pilot project in the works that will use anaerobic treatment and, depending on the outcome of this project, expects that other facilities may consider this option moving forward.

In the past fiscal year, DEP had several projects in this arena. These projects are closely tied into the overall goal of SI. In many cases, treatment systems have operated in a fashion set forth by previous generations, where energy consumption was not a large concern. Taking a moment and asking why we operate in this fashion can lead to significant opportunities for reduced energy costs and improved water quality. By today's standard, any treatment facility that is required to nitrify should also consider denitrification, as it can lead to reduced operating costs, lower sludge production, and improved water quality.

The savings realized by energy-efficient measures could easily be used to fund improved water quality. In fact, in cases where a facility starts using denitrification for the beneficial uptake of nitric acid, there would be a recovery of 60 percent of the cost of nitrification and improved water quality at the same time. Cost savings are certain, and the savings could escalate as energy costs continue to rise.

It is a goal for systems to be self-sustaining in the water/wastewater industry. The single largest cost for a wastewater system is the cost of aeration. Fine bubble aeration could reduce those costs by 50 percent. This money could be incorporated into sustainable infrastructure.

Potential Overlap:

Waste-to-Energy Digesters (for use of biosolids)

Subcommittee Comments

The reductions from this work plan are very small, but highly cost effective and sensible. The subcommittee felt that the effort was worth it even with the small reductions projected.

Waste-5. Waste-to-Energy Digesters

Summary: This initiative encourages an expansion of regional digesters that can offer larger-scale and higher technology treatment.

Goals: Install four 1–4-megawatt (MW) digesters by 2020.

Implementation Period: This work plan targets four additional digesters by 2020, capable of utilizing a mixture of feedstock from organic MSW, organic residual waste, manure, and biosolids. It is assumed that these digesters come on line in 2012, 2014, 2016, and 2018.

Other Involved Agencies: DEP, counties and municipalities, digester owners and operators, businesses, food companies.

Background Discussion on Anaerobic Digestion:

Thermophilic anaerobic digestion is the preferred strategy for future digestion facility planning, rather than the common mesophilic technologies that predominate on U.S. farms and wastewater treatment plants. Technologies common in Europe provide for mixed feedstocks, yield more gas, and are more efficient than manure-only digesters. The effluent (digestate) is closely monitored and can yield precision-agriculture soil amendment with a guaranteed nitrogen-phosphorus-potassium analysis for fertilizer application. Depending on the exact technology/vendor selected for these digesters, about 50 percent of the input is manure, and the remainder is some combination of food residues, crop residues, yard wastes, organic fraction of MSW, or sewage sludge. The European model for centralized digestion relies on processes that digest waste that has a moisture content of less than 25 percent. Utilizing drier feedstock creates a higher biogas yield and allows for a more stable digestion process that requires less mixing and disposal of wastewater.

Based on data provided by DEP on residual waste availability, it appears that York and Adams counties are potential locations for digestion facilities. These data, in addition to the availability of manure and organic MSW in PA, suggest that there would be ample feedstock to support four additional anaerobic digesters, each requiring 25,000 tons of waste feedstock per year. For a digester project to reach its full environmental and economic potential, a constant feedstock supply is required.

In the regional (centralized) model,

- New feedstocks for digesters include food waste and yard waste, as well as conventional manure and sludge.
- WTE digesters produce electrical power, along with high-grade solid and liquid end products.
- The business community can participate as both user and investor.
- Food companies would have an outlet for food waste.
- The concept expands upon local on-farm digesters that produce power for farm use and treated solid and liquid fertilizers.

Two known vendors of anaerobic digesters are Waste-to-Energy Solutions and BioFerm Energy Systems. Waste-to-Energy Solutions is a licensed vendor in PA and sells Niras[33] Danish digesters. BioFerm Energy Systems[34] is a German company that has recently expanded operations to North America.

CCS consulted with a representative of BioFerm Energy Systems and received information from this consultation to provide a reference case for the analysis of this work plan.[35] The BioFerm system utilizes a dry fermentation technology, optimal for feedstocks with less than 25 percent moisture content. The minimum methane content of the resulting biogas is 55 percent, although higher levels have been realized. The elimination of most liquid from the digester input eliminates the need for mixing of the input. Therefore, dry fermentation anaerobic digestion facilities use much less energy (5 percent of electricity and 3 percent of heat generated by the digestion process) than traditional digesters. BioFerm Energy Systems has completed construction on 27 digesters worldwide, with many more in development. A byproduct of all anaerobic digestion is a nutrient-rich digestate that, after processing, may be used as an organic soil amendment. If markets for electricity and direct heat are not available for a given anaerobic digestion facility, it is possible to process the biogas into a liquid vehicle fuel substitute for compressed natural gas. Further information on BioFerm's dry fermentation process is available on its Web site.[36]

Data sources/Assumptions/Methods for GHG: The reference case digestion facility converts 25,000 tons per year in 8 fermentation chambers into 5.4 MMkWh electricity and almost 22 MMBtu of direct heat through the dry fermentation anaerobic digestion process. In addition, 17,543 tons of marketable compost is produced as a result of the process. The methane displacement as a result of the combustion of the digestion biogas is nearly 21 tCO_2e/yr.[37] The assumed GHG reduction from offset grid electricity is based on annual emission factor projections from the Electricity Generation Subcommittee (displayed in Table 5-1). A natural gas emission factor of 0.05369 tCO_2e/MMBtu was used to estimate the GHG reduction from offset direct heat (the emissions factor from Residential/Commercial Subcommittee assumptions).

Data Sources/Assumptions/Methods for Costs: The assumed capital cost for a reference case dry fermentation anaerobic digestion facility is $5.5 million. O&M costs include a front loader ($4,550 per year), compost processing cost ($15 per ton compost), maintenance cost ($4,000 per fermentation chamber per year), and facility operation (1 full-time-equivalent position per year: $50,000). Revenues received by the facility include the value of compost ($30.00/ton)[38] and the value of electricity ($0.05/kWh)[39] and direct heat produced ($3.00/MMBtu).[40]

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[33] http://www.niras.com/Services/Energy.aspx
[34] http://www.bioferm-es.com/us/
[35] Personal Communication – Leah Simmet (BioFerm Energy Systems) to Brad Strode (CCS) via telephone and e-mail on May 18 and May 19, 2009.
[36] http://www.bioferm-es.com/us/wp-content/uploads/2009/03/bioferm-dry-fermentation.pdf
[37] Information regarding energy and compost outputs, as well as methane offset was provided by BioFerm Energy Systems. BioFerm asserts that these values are based on the AVERAGE results of dry fermentation anaerobic digestion systems. Actual yields may differ depending on feedstock mix, facility location, and other factors.
[38] Based on discussion with BioFerm, but not a PA-specific value. CCS suggests refining assumption for compost value.
[39] Consistent with electricity value used in Waste-to-Energy MSW Work Plan, provided by Dave Vollero.
[40] Consistent with heat value used in Landfill Methane Displacement of Fossil Fuels Work Plan, provided by Mike McLaughlin.

GHG Emissions Reduction Analysis: The GHG reduction is estimated by computing the sum of the methane displacement, offset grid electricity, and avoided natural gas combustion for direct heat. The methane displacement is found by multiplying the number of digesters on line by the annual methane displacement value. The electricity generated per year in a single digester is multiplied by the projected grid-based electricity emission factor for each year and the number of digesters on line in each year to yield the GHG reduction from offset electricity generation. The GHG reduction from avoided natural gas combustion for direct heat is found by multiplying the direct heat produced per digester by the natural gas emission factor and the number of facilities on line in each year. The resulting cumulative GHG reduction for 2009–2020 is 0.6 $MMtCO_2e$ (see Table 5-1).

Table 5-1. Anaerobic Digestion GHG Reduction

Year	Number of Facilities	GHG Reduction: Methane Displacement ($MMtCO_2e$)	Projected Grid-Based Electricity Generation (tCO_2e/MWh)	GHG Reduction: Offset Grid Electricity ($MMtCO_2e$)	GHG Reduction: Offset Heat Generation - Assume Nat. Gas ($MMtCO_2e$)	Total GHG Reduction ($MMtCO_2e$)
2009	0	-	0.539	-	-	-
2010	0	-	0.539	-	-	-
2011	0	-	0.539	-	-	-
2012	1	0.02	0.539	0.003	0.001	0.02
2013	1	0.02	0.539	0.003	0.001	0.02
2014	2	0.04	0.538	0.006	0.002	0.05
2015	2	0.04	0.538	0.006	0.002	0.05
2016	3	0.06	0.537	0.009	0.004	0.07
2017	3	0.06	0.536	0.009	0.004	0.07
2018	4	0.08	0.535	0.012	0.005	0.10
2019	4	0.08	0.534	0.012	0.005	0.10
2020	4	0.08	0.533	0.012	0.005	0.10
Total (2009-2020)		**0.50**		**0.07**	**0.03**	**0.60**

Additional GHG reduction potential includes reduced transport of solid waste to landfills and the downstream benefit of applying compost as a soil amendment. These benefits have not been included in this quantification. The transportation benefit would require additional assumptions regarding the relative distance between the waste source and the disposal facilities (digester versus landfill) and the efficiency of trucks used. The downstream soil amendment benefit would require additional research regarding the amount of fossil fuel-based fertilizer offset and the GHG emission profile of the production and use of the traditional fertilizer.

Cost-Effectiveness Analysis: The project costs include capital cost and O&M costs highlighted in the Data Sources for Costs section. The annualized capital cost is found by multiplying the assumed capital cost by the number of facilities on line and an annualization factor.[41] The O&M

[41] CCS used the Capital Recovery Factor method of animalization, assuming an 5% interest rate and 15 year loan period.

costs are found for each of the four O&M cost elements using the following calculations, with the sum of the products being the total annual O&M cost:

- Multiply the cost of the front loader by the number of facilities on line in each year.
- Multiply the compost processing cost by the per-facility quantity of compost produced and the number of facilities on line in each year.
- Multiply the maintenance cost per fermentation chamber by the number of fermentation chambers per facility (8) and the number of facilities on line in each year.
- Multiply the facility operation cost by the number of facilities on line in each year.

The revenues are calculated by taking the sum of the following products:

- Multiply the value of compost by the tons of compost produced and the number of facilities on line in each year.
- Multiply the value of electricity by the amount of electricity generated per facility and the number of facilities on line in each year.
- Multiply the value of direct heat by the amount of direct heat generated per facility and the number of facilities on line in each year.

The cost analysis produces an estimated cost of $0.70 million ($2007, NPV) for the project period 2009–2020. The cost-effectiveness over this time period is equal to $1.2 $/t$CO_2$e. The results of the cost-effectiveness analysis are presented in Table 5-2.

Table 5-2. Anaerobic Digestion Cost-Effectiveness

Year	Number of Facilities	Annualized Capital Cost ($MM)	Annual O&M Cost ($MM)	Annual Revenue ($MM)	Net Project Cost ($MM)	Discounted Project Cost ($MM)
2009	0	$0.00	$0.00	$0.00	$0.00	$0.00
2010	0	$0.00	$0.00	$0.00	$0.00	$0.00
2011	0	$0.00	$0.00	$0.00	$0.00	$0.00
2012	1	$0.53	$0.38	$0.86	$0.05	$0.04
2013	1	$0.53	$0.38	$0.86	$0.05	$0.04
2014	2	$1.06	$0.76	$1.73	$0.09	$0.07
2015	2	$1.06	$0.76	$1.73	$0.09	$0.06
2016	3	$1.59	$1.14	$2.59	$0.14	$0.09
2017	3	$1.59	$1.14	$2.59	$0.14	$0.09
2018	4	$2.12	$1.53	$3.46	$0.19	$0.11
2019	4	$2.12	$1.53	$3.46	$0.19	$0.11
2020	4	$2.12	$1.53	$3.46	$0.19	$0.10
					Total (2009-2020)	**$0.70**

Implementation Steps:

Centralized mixed-feedstock anaerobic digestion would be more viable, given the following incentive mechanisms:

- Allowance of renewable energy credits for carbon offset trading.
- Provision of renewable energy grants and loans from federal, state, and municipal funds.
- Purchasing agreements with utilities for electricity and direct heat provided by digestion facilities.
- Streamlining of the permitting process to allow location within 30 miles of a reliable feedstock source.

Potential Overlap:

- Increased Capture and Use of Landfill Methane
- Improved Efficiency at Wastewater Treatment

Subcommittee Comments

This work plan was not one of the original work plans presented to the subcommittee by the department. It was developed later by department staff at the suggestion of the subcommittee. The reductions projected were somewhat lower than expected, but that may be a function of the number of digesters assumed to be on-line. Again the subcommittee felt that the work plan was cost effective and produced some GHG reductions.

Waste-6. Waste-to-Energy MSW

Summary: This initiative encourages the expansion of existing WTE facilities.

Goals: Increase WTE derived from MSW at existing facilities by 40 percent by 2030.

Re-evaluate the use of alternative fuels in 3 years.

Implementation Period: 20 percent increase by 2020, 40 percent by 2030

Parties Affected/Implementing Parties: DEP, power stations, private and public WTE facilities.

Background Discussion on Waste-to-Energy MSW: In 2006, Pennsylvania saved approximately 2.3 $MMtCO_2e$ as a result of recovering energy from 2.92 million tons of municipal and residual waste.[42] The commonwealth can reduce additional emissions by recovering energy from additional Pennsylvania municipal and residual wastes.[43]

The burning of solid waste reduces GHGs from avoided landfill emissions and the displacement of traditional fossil fuel energy sources, despite the fact that the operation of WTE facilities and the burning of waste also produce GHG emissions.

The recent Oneida-Herkimer Supreme Court Decision should encourage regional solid waste authorities to revisit the role of WTE as a waste management option.

DEP has been doing extensive work in an effort to include more WTE projects and volume in the energy mix. It is shown, using an EPA life-cycle measurement tool, that WTE has environmental and GHG performance superior to landfilling (with recycling and gas usage) over the complete materials management life cycle—including 30 percent up-front recycling, reprocessing, mining, power generation (fossil fuel avoidance), and other factors. Comparing power generation (viewing the combustion cycle only) to coal shows WTE emitting about one-third of the GHGs of a coal plant.[44]

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[42] As presented by Brian Bahor, Covanta Energy at the May 10, 2007 Solid Waste Advisory Committee Meeting; meeting materials can be found at http://www.dep.state.pa.us//dep/subject/advcoun/solidwst/swac2007.htm under the link "Waste as an Alternative Fuel"

[43] http://www.depweb.state.pa.us/landrecwaste/cwp/view.asp?A=1216&Q=488974
link is at "2006 Residual Waste Biennial Report Data" (Excel spreadsheet – 2006_rw.xls).
5.3 million tons is probably combustible portion of the total 19.4 million tons of residual waste ("2006 PA RW" tab of spreadsheet). Additional 4.1 $MMTCO_2$-e is 0.788 times 5.2 million tons residual waste (same multiplier as that used by Covanta).

[44] "Application of the U.S. Decision Support Tool for Materials and Waste Management," by Susan Thorneloe, Keith Weitz, and Jenna Jambeck, 2006. .Thorneloe, from EPA, and Weitz, from RTI, have written numerous works on waste and WTE, going back into the 1990's. These can be found at http://www.wte.org/docs/Thorneloe2006.pdf. This report and others may also be accessed through the IWSA site on greenhouse gases. http://www.wte.org/environment/greenhouse_gas.html.

Consideration of using waste (as refuse-derived fuel) in standard power stations, especially waste coal circulating fluidized beds, is also considered as a good way to make use of existing capital and gain the environmental advantages from WTE. These projects would meet all current environmental standards. That a significant amount of energy is present in the waste currently being landfilled is understood. This is usually thought of as electricity or heat, but research is underway to convert trash to liquid fuel. As such, 20–40 million barrels of liquid fuel (diesel) could be created annually from the waste the state landfills once that technology becomes viable.

Data sources/Assumptions/Methods for GHG: The information used to develop the waste management projections for the *Statewide Recycling Initiative Work Plan* was also used to establish the baseline MSW WTE combustion for the State of Pennsylvania (2,613,109 tons in 2000, including 534,850 tons imported of MSW). The GHG reduction was calculated by adding the incremental WTE combustion to the "Tons Sent to Incinerators" data input for the NERC CEB calculator. This is the same model used to quantify the GHG reduction for the *Statewide Recycling Initiative Work Plan*, and was chosen to quantify this work plan also to maintain consistency.

Data Sources/Assumptions/Methods for Costs: The assumptions for the cost elements of this work plan are $250,000/ton MSW combusted per day for capital cost and $40/ton MSW combusted per day for O&M cost. These numbers convert to $684.93/ton/year for capital cost and $0.11/ton/year for O&M cost. The revenue assumptions include the difference between the WTE and landfill tipping fees ($65/ton for WTE, $61/ton for landfills) and an estimated electricity price of $0.05/kWh.[45]

GHG Emissions Reduction Analysis: As indicated in the Data Sources section, the waste management projection used for the *Statewide Recycling Initiative Work Plan* is also used for the quantification of this work plan. The WTE targets (20 percent in 2020, 40 percent in 2030) are multiplied by the 2000 baseline WTE combustion to project the future WTE combustion under this work plan. This work plan assumes the targets will be met by expansion of existing WTE facilities. The BAU scenario WTE combustion projections are subtracted from the target WTE combustion totals to yield the incremental WTE combustion. The NERC model was used to estimate the GHG reductions of this work plan. The model was run twice each for the years 2015, 2020, and 2025. One run estimates the BAU GHG reduction, while the second estimates the GHG reduction from the WTE combustion target. The difference between the two results is the incremental GHG reduction. As the MSW management projection only goes through 2025, GHG emissions are estimated through 2025. The incremental GHG reduction through the entire target period (2009–2025) is 2.80 $MMtCO_2e$. The incremental GHG reduction for the subcommittee's analysis period (2009–2020) is 1.42 $MMtCO_2e$. Table 6-1 displays these results.

[45] All information provided by Dave Vollero to Brad Strode via e-mail on June 2, 2009, with the exception of the landfill tipping fee, which was cited by the PennFuture article mentioned in the Statewide Recycling Initiative Work Plan.

Table 6-1. Incremental GHG Reduction from WTE-MSW Combustion

Year	BAU WTE Combustion (tons)	Policy WTE Combustion (tons)	Incremental WTE Combustion (tons)	GHG Reduction (WP ESF) (MMtCO2e)
2009	2,193,983	2,193,983	-	-
2010	2,214,923	2,279,596	64,674	0.02
2011	2,230,624	2,365,210	134,586	0.04
2012	2,246,428	2,450,823	204,396	0.06
2013	2,262,334	2,536,437	274,103	0.09
2014	2,278,344	2,622,050	343,706	0.11
2015	2,294,458	2,707,664	413,206	0.13
2016	2,308,862	2,793,277	484,416	0.15
2017	2,323,352	2,878,891	555,539	0.17
2018	2,337,930	2,964,504	626,574	0.19
2019	2,352,597	3,050,118	697,521	0.22
2020	2,367,351	3,135,731	768,380	0.24
2021	2,379,895	3,187,993	808,099	0.25
2022	2,392,504	3,240,256	847,751	0.26
2023	2,405,180	3,292,518	887,337	0.28
2024	2,417,924	3,344,780	926,856	0.29
2025	2,430,734	3,397,042	966,308	0.30
2026	2,443,056	3,449,304	1,006,249	-
2027	2,455,440	3,501,566	1,046,127	-
2028	2,467,886	3,553,829	1,085,942	-
2029	2,480,396	3,606,091	1,125,695	-
2030	2,492,969	3,658,353	1,165,384	-
			Total (2009-2020)	**1.42**
			Total (2009-2025)	**2.80**

Additional GHG reduction potential may include the reduced transport of solid waste to landfills. This benefit has not been included in this quantification. It would require additional assumptions regarding the relative distance between the waste source and the disposal facilities (WTE facility versus landfill) and the efficiency of trucks used.

Cost-Effectiveness Analysis: The costs associated with the additional WTE MSW combustion targeted by this work plan include annualized capital costs and annual O&M costs. The capital costs are determined by multiplying the capital cost for WTE combustion by the annual tons combusted and an annualizing factor.[46] Then, the annualized capital costs for each year are added to the annualized capital costs from previous years to capture the assumption that WTE MSW combustion will ramp up over time. After 2025, the capital costs for 2010 expire.

[46] CCS used the Capital Recovery Factor method of animalization, assuming an 5% interest rate and 15- year loan period.

Therefore, in 2025, the annualized capital cost for the year 15 years prior are subtracted from the 2025 cost. This process is repeated for 2025 through 2030). The annual O&M costs are estimated by multiplying the per-ton O&M cost by the annual tonnage combusted in each year as a result of the work plan target.

The annual cost savings related to offset landfill tipping fees are calculated by multiplying the difference between the landfill and WTE tip fees by the incremental WTE combustion for each year. The revenue generated from generated electricity is calculated by multiplying the assumed price of electricity by the incremental WTE combustion for that year. The result is a cost savings of $40 million (NPV, 2007$) through 2020. The cost-effectiveness over the period 2009–2020 is –$28/t$CO_2$e. The results are displayed in Table 6-2.

Table 6-2. Cost-effectiveness of Incremental WTE MSW Combustion

Year	Incremental WTE Combustion (tons)	Annualized Capital Cost ($MM)	O&M Cost ($MM)	Additional Tip Fee ($MM) ($MM)	Revenue from Produced Electricity ($MM)	Net Project Cost ($MM)	Discounted Cost ($MM)
2009	-	$0.0	$0.00	$0.00	$0.00	$0.0	$0.0
2010	64,674	$4.3	$0.01	$0.26	$1.94	$2.6	$2.2
2011	134,586	$4.6	$0.01	$0.54	$4.04	$1.1	$0.9
2012	204,396	$4.6	$0.02	$0.82	$6.13	-$0.7	-$0.5
2013	274,103	$4.6	$0.03	$1.10	$8.22	-$2.5	-$1.9
2014	343,706	$4.6	$0.04	$1.37	$10.31	-$4.3	-$3.1
2015	413,206	$4.6	$0.05	$1.65	$12.40	-$6.1	-$4.1
2016	484,416	$4.7	$0.05	$1.94	$14.53	-$7.8	-$5.1
2017	555,539	$4.7	$0.06	$2.22	$16.67	-$9.7	-$5.9
2018	626,574	$4.7	$0.07	$2.51	$18.80	-$11.5	-$6.7
2019	697,521	$4.7	$0.08	$2.79	$20.93	-$13.4	-$7.4
2020	768,380	$4.7	$0.08	$3.07	$23.05	-$15.2	-$8.1
2021	808,099	$2.6	$0.09	$3.23	$24.24	-$18.3	-$9.2
2022	847,751	$2.6	$0.09	$3.39	$25.43	-$19.3	-$9.3
2023	887,337	$2.6	$0.10	$3.55	$26.62	-$20.4	-$9.3
2024	926,856	$2.6	$0.10	$3.71	$27.81	-$21.4	-$9.3
2025	966,308	$2.6	$0.11	$3.87	$28.99	-$22.4	-$9.3
2026	1,006,249	$2.6	$0.11	$4.02	$30.2	-$23.4	-$9.3
2027	1,046,127	$2.6	$0.11	$4.18	$31.4	-$24.5	-$9.2
2028	1,085,942	$2.6	$0.12	$4.34	$32.6	-$25.5	-$9.1
2029	1,125,695	$2.6	$0.12	$4.50	$33.8	-$26.5	-$9.1
	Total (2009-2020)	**$51**	**$0.5**	**$18.3**	**$137.0**	**-$67.5**	**-$40**
	Total (2009-2025)	**$64**	**$1.0**	**$36.0**	**$270.1**	**-$169.3**	**-$86**
	Total (2009-2030)	**$77**	**$1.6**	**$57.7**	**$433.0**	**-$296.8**	**-$132**

Implementation Steps:

Incentives for WTE MSW projects include:

- Make it easier to flow waste to privately owned facilities.
- Include WTE in state renewable energy standards.

From 2009 to 2011, WTE facilities will be supported by funds already committed to the solid waste program via the Recycling Fund. These funds will not divert dollars from the expanded recycling initiative because they come from a dedicated funding stream that is separate from recycling funding. In 2015, it is assumed that significant market potential will have been created for WTE facilities that will cause counties and private industry to invest in construction to increase WTE capacity. This market potential is a result of potential profitability from the sale of electricity generated, funds earned through collection of tipping fees, and savings from avoided landfill construction costs.

Long-term actions include regulatory changes to further reduce obstacles to the use of waste as an energy source.

Potential Overlap:

- Increased Capture and Use of Landfill Methane
- Statewide Recycling Initiative—Reduced Transportation of Waste
- Solid Waste Initiative
- Fuels for Schools Work Plan

An overlap may exist between the WTE MSW work plan and the Statewide Recycling Initiative work plan. However, for both work plans, it is assumed that waste that is either diverted or combusted reduces MSW solely from landfills. Thus, there would not be an overlap between Waste-2 and Waste-6, as the incremental GHG reduction for each would not change depending on the implementation of the respective work plans.

Subcommittee Comments

Another work plan with less than huge reductions but still cost effective. Some subcommittee members expressed concerns regarding feasibility given expected public opposition to such facilities. Nonetheless the subcommittee felt the concept was worth pursuing.

APPENDIX J
Agriculture Sector Work Plans

Summary of Work Plan Recommendations

Work Plan No.	Work Plan Name		Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $)	Annual Results (2020) Cost-Effectiveness ($\$/tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $)	Cumulative Results (2009-2020) Cost-Effectiveness ($\$/tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)
1	Foodshed Development Strategy		Not Quantified[1]						21 / 0 / 0
2	Next-Generation Biofuels		Costs and GHG savings from biofuels are considered in Transportation-2 and Residential-11 Work Plans						21 / 0 / 0
3	Management-Intensive Grazing		0.62	-$59	-$95	5.50	-$369	-$67	21 / 0 / 0
4	Manure Digester Implementation Support	Dairy	0.26	-$0.3	-$1	1.46	$2	$1	21 / 0 / 0
		Swine	0.04	$0.1	$4	0.23	$1	$4	21 / 0 / 0
5	Regenerative Farming Practices		0.059	$2.1	$36	0.30	$17	$56	21 / 0 / 0
	Soil Sequestration from Continuous No-Till Agronomic Systems		0.44	-$5	-$11	2.7	-$31	-$12	21 / 0 / 0
Sector Total After Adjusting for Overlaps			1.42	-$62	-$44	10.2	-$380	-$37	
Reductions From Recent State and Federal Actions			0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Sector Total Plus Recent Actions			1.42	-$62	-$44	10.2	-$380	-$37	

[1] The CCAC recommends that this be a research and analysis work plan.

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above work plans is for reference purposes only; it does not reflect prioritization among these important work plans.

Table 1. Potential Annual Biomass Resource Supply in PA

Biomass Resource	Annual Biomass Supply (thousand dry tons)	Delivered Cost[1] ($2007/dry ton)	Notes
Crop Residues	810	$74[2]	Biomass supply based on 2005 NREL Report.[3]
Potential Energy Crops (Switchgrass)	672	$85[4]	2005 NREL Report.
Potential Energy Crops (Dry Poplar)	556	$85[5]	2005 NREL Report.
Low-Use Wood	6000	$58[6]	http://www.dcnr.state.pa.us/PA_Biomass_guidance_final.pdf Based on estimate from Penn State's Dr. Charles Ray, 480 mm tons LUW x 2½ % growth = 12 million tons/yr * 50% for green/dry conversion = 6 mm dry tons/yr. 6 million tons of Low-Use Wood could be harvested in Pennsylvania annually. The Pennsylvania Department of Conservation and Natural Resources felt that this was overly optimistic, but did not provide a lower estimate.
Paper	1,488	$0	From Waste Subcommittee[7]
Wood Waste	643	$0	From Waste Subcommittee
Food Waste	1,298	$0	From Waste Subcommittee
Yard Waste	465	$0	From Waste Subcommittee
Mixed Organics	178	$0	From Waste Subcommittee
Total Annual Biomass Supply	12,110		

[1] Delivered cost expressed in units of $/dry ton.
[2] "Estimating a Value for Corn Stover" Ag Decision maker File A1-70, December 2007, http://www.extension.iastate.edu/agdm/crops/html/a1-70.html. The max a livestock owner would pay for corn stover as feed. Additional Transportation costs of $14.75 were assumed, taken from Iowa State University, University Extension, publication "Estimated Costs for Production, Storage and Transportation of Switchgrass"
[3] A. Milbrandt. *A Geographic Perspective on the Current Biomass Resource Availability in the United States.* Technical Report NREL/TP-560-39181. Golden, CO: U.S. Department of Energy, National Renewable Energy Laboratory, December 2005. Available at: www.nrel.gov/docs/fy06osti/39181.pdf.
[4] "Estimating the Economic Impact of Substituting Switchgrass for Coal for Electric Generation in Iowa." Center for Global and Regional Environmental Research. University of Iowa. 2005. http://www.iowaswitchgrass.com/__docs/pdf/8-6-0%20Final%20Report.pdf
[5] Ibid. Same cost for Dry Poplar assumed as for switchgrass.
[6] Based on information from John Karkash. Cited Woody biomass value at 29$/green ton. Converted to dry tons, results in a cost of $58/ton.
[7] Waste subcommittee provides estimates of MSW feedstocks. These estimates may change as recycling forecasts are modified. $0 cost for MSW feedstocks is used because no more specific estimate could be found. Typically (particularly in the short term), removing MSW from the waste stream will result in a cost-savings, because you avoid tipping/landfilling fees. It is possible that as demand for biomass resources grows, the value of MSW feedstocks will become positive.

Agriculture-1. Foodshed Development Strategy

Initiative Summary:

This initiative would start with an economic, demographic, and land-use analysis of all of Pennsylvania to determine a limited number of "foodsheds," where the utilization of locally produced and processed foods would be maximized and the use of fossil fuels in the procurement and delivery of the food would be minimized. To quantify greenhouse gas (GHG) reductions due to the use of local food, more data are needed on what food is being imported from where into the various regions of Pennsylvania. Packaged and processed foods are especially difficult to define, as they may use ingredients or elements from different states or countries.

After analysis of food origination is complete, the next implementation steps would include:

- Granting authority to specialized "food policy teams" in each foodshed to work in conjunction with county governments to develop and implement "foodshed strategic plans" within a specified time.
- Providing funds from the state and other sources in the form of grants to farmers, market venues, and municipalities wishing to participate. In addition, each team could maintain its own development function to raise funds through local foundations, businesses, and individuals to supplement state funds.
- Establishing of backyard gardens (e.g., victory gardens), urban farming initiatives, farmers' markets, community-supported agriculture (CSA) projects, cooperatives and on-farm or community-based processing facilities (e.g., meatpacking, creameries, packaging and storage of fruits and vegetables, etc.), and plans for consolidating transportation and distribution.

Other Involved Agencies: Pennsylvania Departments of Environmental Protection (DEP), Agriculture (PDA), Conservation and Natural Resources (DCNR), Health (PDH), Community and Economic Development (DCED); Pennsylvania State Association of Township Supervisors (PSATS), county commissioners, school districts, colleges and universities, municipalities.

Goals:

- Foodshed analysis,
- Formation of foodshed policy teams,
- Development of strategic plans,
- Fund development,
- Granting and implementation,
- Creation of market-based, local investment opportunities

Data Sources/Assumptions/Methods for GHG: See relevant attachments.

Data Sources/Assumptions/Methods for Costs: Initial costs would be for foodshed analysis and strategic planning.

Potential Overlap: Not applicable.

Other:

Here are links to the relevant Foodshed literature:

http://www.ruralpa.org/farm_school_report08.pdf

http://www.ruralpa.org/Farm_School_Guide08.pdf

http://www.farmandfoodproject.org/documents/uploads/The%20Case%20for%20Local%20&%20Regional%20Food%20Marketing.pdf

http://www.leopold.iastate.edu/research/marketing_files/NEIowa_042108.pdf

http://www.leopold.iastate.edu/pubs/staff/health/health.htm

http://www.leopold.iastate.edu/research/marketing_files/consumer_PNMWG5-05.pdf

http://www.leopold.iastate.edu/research/marketing_files/WorldBook.pdf

http://attra.ncat.org/attra-pub/PDF/foodmiles.pdf

http://www.leopold.iastate.edu/news/newsreleases/2007/organic_041807.htm

http://www.leopold.iastate.edu/pubs/staff/ppp/index.htm

http://www.leopold.iastate.edu/research/marketing_files/GoodFoodIowa_0408.pdf

Subcommittee Comments

This initiative would start with an economic, demographic and land-use analysis of the whole of Pennsylvania to determine a limited number of "foodsheds" where the utilization of locally produced and processed foods would be maximized and the use of fossil fuels in the procurement and delivery of the food would be minimized. In order to quantify GHG reductions due to the use of local food, more data is needed on what food is being imported from where into the various regions of Pennsylvania. Packaged and processed foods are especially hard to define as they may use ingredients or elements from different states or even countries.

After analysis of food origination is complete, the next implementation steps would including:

Granting authority to specialized "food policy teams" in each foodshed to work in conjunction with county governments to develop and implement "foodshed strategic plans" within a specified time; Providing funds from the state and other sources in the form of grants to farmers, market venues, and municipalities wishing to participate. In addition, each team could maintain its own development function to raise funds through local foundations, businesses and individuals to supplement state funds.

Establishing of backyard gardens (i.e. victory gardens), urban farming initiatives, farmers' markets, Community Supported Agriculture (CSA) projects, cooperatives and on-farm or community-based processing facilities (e.g. meatpacking, creameries, packaging and storage of fruits and vegetables, etc…) and plans for consolidating transportation and distribution.

The subcommittee believes there is merit to this work plan and further consideration is appropriate. There is a potential opportunity to combine this with Forestry – 2 as a research and analysis project for further investigation.

Agriculture-2. Next-Generation Biofuels

Summary: This work plan quantified the amount of biofuel necessary to meet Pennsylvania's share of the federal RFS. It also considers the technical potential of biofuel production based on available feedstocks.

Other Involved Agencies: DEP, U.S. Environmental Protection Agency (EPA) Chesapeake Bay Program Office, feedstock producers, biofuel producers.

Goals: Provide sufficient biofuels to fulfill Pennsylvania's share of the federal Renewable Fuels Standard (RFS). This means that 545 million gallons (MMgal) of biofuel will need to be produced in Pennsylvania in 2020.

Implementation Period: Increase production such that by 2020 Pennsylvania is producing 545 MMgal of biofuel.

Implementation Steps:

Commonwealth policy should encourage:

- The production of feedstocks for biofuel, including winter crops.
- Biofuel producers to utilize these crops as a feedstock.
- The establishment of coordinated systems for biofuel production, including corn-based and cellulosic ethanol and biodiesel fuels, with economic incentives to agricultural producers to ensure the sufficient commitment of production of corn, soybean, and plant materials for biofuel use.

Data Sources/Assumptions/Methods for GHG:

Biofuel Required

The GHG reductions for this option are dependent on developing in-state production capacity that achieves GHG reductions beyond petroleum fuels. This option quantifies the GHG reductions and costs of producing sufficient renewable liquid biofuels to meet Pennsylvania's share (3.63 percent) of the federal RFS. The three biofuels being considered in this analysis are cellulosic ethanol, soy/grease biodiesel, and algae biodiesel.

Corn ethanol was not considered because it provides lower GHG reductions compared to other biofuels. Pennsylvania produced 23 MMgal of soy/grease biodiesel in 2008, and this production is projected to increase through 2013.[8] For 2014–2020, all growth in biodiesel production is assumed to take the form of algae biodiesel, which is less land intensive and provides greater GHG reductions than first-generation biofuels.

Table 2-1 outlines the amounts of each type of fuel that will be needed to fulfill Pennsylvania's share of the RFS. This is the amount of biofuel that is assumed to be produced in the analysis, and will be given to the Transportation and Land Use (TLU) and Residential, Commercial, and Industrial (RCI) (for heating-oil biodiesel use) Technical Work Groups (TWGs) as available in-state biofuel.

To illustrate the costs and GHG reductions of different levels of production, this analysis will also consider the costs of producing one-half Pennsylvania's share of the RFS and also maximum technical potential available if all available biomass resources were going toward cellulosic biofuel production. To get this third estimate, it must be assumed that there are no other demands upon biomass resources in the state in 2020 (which is very unlikely), and that a huge effort has been made to expand biofuel production capacity. Biodiesel production is held constant in the technical potential example, because availability of biodiesel resources (particularly algae biodiesel) is very difficult to quantify. Tables 2-2 and 2-3 show these additional examples.

Table 2-1. Quantity of Biofuel Required (100 percent RFS)

Year	Million Gallons of Cellulosic Ethanol	Million Gallons of Grease/Soy Biodiesel	Million Gallons of Algae Biodiesel
2010	4	31	0
2011	9	40	0
2012	18	54	0
2013	36	64	0
2014	64	64	9
2015	109	64	27
2016	154	64	45
2017	200	64	64
2018	254	64	82
2019	309	64	100
2020	381	64	100

[8] Based on personal communication with Mike Rader by Jackson Schreiber. 5/6/09.

Table 2-2. Quantity of Biofuel Required (50 percent RFS)

Year	Million Gallons of Cellulosic Ethanol	Million Gallons of Grease/Soy Biodiesel	Million Gallons of Algae Biodiesel
2010	2	31	0
2011	5	31	0
2012	9	31	0
2013	18	32	0
2014	32	32	5
2015	54	32	14
2016	77	32	23
2017	100	32	32
2018	127	32	41
2019	154	32	50
2020	191	32	50

Table 2-3. Quantity of Biofuel Required (Technical Potential)

Year	Million Gallons of Cellulosic Ethanol	Million Gallons of Grease/Soy Biodiesel	Million Gallons of Algae Biodiesel
2010	0	31	0
2011	85	40	0
2012	218	54	0
2013	327	64	0
2014	436	64	9
2015	545	64	27
2016	654	64	45
2017	763	64	64
2018	872	64	82
2019	981	64	100
2020	1,211	64	100

Annual cellulose production is multiplied by the estimated ethanol yield per ton of biomass, based on the projection that ethanol yield will increase from 70 gallons/ton biomass to 90 gal/ton biomass by 2012 and to 100 gal/ton biomass by 2020.[9] Table 2-4 shows the number of 70-MMgal/year cellulosic plants that will need to go on line in Pennsylvania to provide the biofuel needed to meet Pennsylvania's share of the RFS. Table 2-5 shows the number of plants needed for 50 percent of the RFS, and Table 2-6 shows the number of plants needed if all technically available biomass is going toward cellulosic ethanol production in 2020. All plants are not expressed in whole numbers, and in such a case should be assumed to be operating at less than full capacity during the given year.

[9] J. Ashworth, US Department of Energy, National Renewable Energy Laboratory, personal communication, S. Roe, CCS, April 2007.

Table 2-4. Projected Biofuel Production (100 percent RFS)

Year	EtOH yield from cellulosic feedstock (gal/ton biomass)*	Cellulosic Ethanol Production Plants Required	Cellulosic Ethanol Required to meet goal (million gallons)	Biomass Required (million dry tons)
2010	70	0.1	4	0.1
2011	70	0.1	9	0.1
2012	90	0.3	18	0.2
2013	90	0.5	36	0.4
2014	90	0.9	64	0.7
2015	90	1.6	109	1.2
2016	90	2.2	154	1.7
2017	90	2.9	200	2.2
2018	90	3.7	254	2.8
2019	90	4.5	309	3.4
2020	100	5.5	381	3.8

*Source: J. Ashworth, NREL, personal communication, 4/06/07.

Note: Cellulosic plants required are not whole numbers. The analysis assumes that these plants will be going on line mid-year or operating at less than full capacity.

Table 2-5. Projected Biofuel Production (50 percent RFS)

Year	EtOH yield from cellulosic feedstock (gal/ton biomass)*	Cellulosic Ethanol Production Plants Required	Cellulosic Ethanol Required to meet goal (million gallons)	Biomass Required (million dry tons)
2010	70	0.0	2	0.0
2011	70	0.1	5	0.1
2012	90	0.1	9	0.1
2013	90	0.3	18	0.2
2014	90	0.5	32	0.4
2015	90	0.8	54	0.6
2016	90	1.1	77	0.9
2017	90	1.4	100	1.1
2018	90	1.8	127	1.4
2019	90	2.2	154	1.7
2020	100	2.8	191	1.9

* Source: J. Ashworth, NREL, personal communication, 4/06/07.

Note: Cellulosic plants required are not whole numbers. The analysis assumes that these plants will be going on line mid-year or operating at less than full capacity.

Table 2-6. Projected Biofuel Production (Technical Potential)

Year	EtOH yield from cellulosic feedstock (gal/ton biomass)*	Cellulosic Ethanol Production Plants Required	Cellulosic Ethanol Required to meet goal (million gallons)	Biomass Required (million dry tons)
2010	70	0.0	0	0.0
2011	70	1.2	85	1.2
2012	90	3.1	218	2.4
2013	90	4.7	327	3.6
2014	90	6.3	436	4.8
2015	90	7.9	545	6.1
2016	90	9.4	654	7.3
2017	90	11.0	763	8.5
2018	90	12.6	872	9.7
2019	90	14.2	981	10.9
2020	100	17.5	1,211	12.1

* Source: J. Ashworth, NREL, personal communication, 4/06/07.

Note: Cellulosic plants required are not whole numbers. The analysis assumes that these plants will be going on line mid-year or operating at less than full capacity.

The GHG savings of biofuel production and consumption are accounted for in the TLU analysis (T-2). This analysis instead focuses on the total costs of biofuel production, the amount of biofuels required, and the wholesale $/gal for each biofuel produced.

Biofuel Costs

Cellulosic Ethanol Costs

The cellulosic ethanol costs of this option are estimated based on the capital and operating costs of cellulosic ethanol production plants. A study by the National Renewable Energy Laboratory (NREL) was used to estimate the operation and maintenance (O&M) costs of a 70-MMgal/yr cellulosic ethanol plant.[10] The capital costs of a cellulosic plant came from an average of the capital cost estimates for six biofuels plants across the country. Using this method, the average capital cost of a new cellulosic ethanol plant is $549 million. A new plant will need to be built for every 70 MMgal of annual ethanol production needed. It was assumed that the capital costs will be paid according to a cost recovery factor over the 20-year lifetime of the plant. The cost of biomass feedstocks made up a significant portion (~60 percent) of variable costs. Therefore, we replaced the NREL estimate of feedstock costs ($30/ton) with more current estimates of the cost

[10] National Renewable Energy Laboratory, *Lignocellulosic Biomass to Ethanol Process Design and Economics Utilizing Co-Current Dilute Acid Prehydrolysis and Enzymatic Hydrolysis for Corn Stover*, NREL/ TP-510-32438 (Golden, CO, June 2002), www.nrel.gov/docs/fy02osti/32438.pdf , accessed June 2008.

of delivered biomass: $74/ton for agricultural feedstocks[11] and $58/ton for woody feedstocks.[12] Energy crops were estimated to cost $85/ton.[13]

Municipal solid waste (MSW) costs are very difficult to estimate. Most MSW landfills charge a tipping fee. Therefore, there is a cost savings when waste is delivered to a cellulosic facility, rather than a landfill. However, in the interest of providing a more conservative estimate, a $0/ton estimate was used for MSW costs.

Other annual costs cover unavoidable expenses of running an ethanol plant, such as employee wages, insurance, maintenance, etc. The plant proposed by the NREL study produces some excess electricity, although the costs and GHG reductions of generating this electricity are not considered in this analysis.

Which feedstocks will be used in cellulosic ethanol is difficult to determine. It was assumed that a mix of all feedstocks would be used, based on a percentage of each with respect to overall availability (which can be seen on page 2 of this analysis).

There is no assumed revenue for selling the ethanol in this option. The cost savings (avoided gasoline) are considered in T-2. The costs of cellulosic ethanol production for Pennsylvania's share of the RFS are shown in Table 2-7. Half this production is shown in Table 2-8. The total cost of cellulosic ethanol production when all technically available biomass is going toward ethanol production is shown in Table 2-9.

Table 2-7. Cost Summary for Cellulosic Ethanol Plants (100 percent RFS)

Year	Cost of Feedstock (2007 $MM)	Annualized Capital Costs ($ MM)	Other Annual Costs ($ MM)	Total Costs ($ MM)	Discounted Total Costs ($MM)
2010	$2	$2	$2	$6	$5
2011	$5	$6	$4	$15	$13
2012	$9	$12	$8	$28	$22
2013	$17	$23	$16	$57	$42
2014	$30	$40	$29	$99	$70
2015	$51	$69	$49	$170	$115
2016	$73	$98	$70	$241	$155
2017	$94	$127	$91	$311	$191
2018	$120	$161	$115	$396	$232
2019	$145	$196	$140	$481	$268
2020	$161	$242	$173	$576	$306
Total				$2,380	$1,419

gal = gallon; $MM = million dollars.

[11] "Estimating a Value for Corn Stover" Ag Decision maker File A1-70, December 2007, http://www.extension.iastate.edu/agdm/crops/html/a1-70.html. The max a livestock owner would pay for corn stover as feed. Additional Transportation costs of $14.75 were assumed, taken from Iowa State University, University Extension, publication "Estimated Costs for Production, Storage and Transportation of Switchgrass"

[12] Based on information from John Karkash. Cited Woody biomass value at 29$/green ton. Converted to dry tons, results in a cost of $58/ton.

[13] "Estimating the Economic Impact of Substituting Switchgrass for Coal for Electric Generation in Iowa." Center for Global and Regional Environmental Research. University of Iowa. 2005. http://www.iowaswitchgrass.com/__docs/pdf/8-6-0%20Final%20Report.pdf

Table 2-8. Cost summary for cellulosic ethanol plants (50 percent RFS)

Year	Cost of Feedstock (2007 $MM)	Annualized Capital Costs ($ MM)	Other Annual Costs ($ MM)	Total Costs ($ MM)	Discounted Total Costs ($MM)
2010	$1	$1	$1	$3	$3
2011	$3	$3	$2	$8	$6
2012	$4	$6	$4	$14	$11
2013	$9	$12	$8	$28	$21
2014	$15	$20	$14	$50	$35
2015	$26	$35	$25	$85	$57
2016	$36	$49	$35	$120	$78
2017	$47	$63	$45	$156	$96
2018	$60	$81	$58	$198	$116
2019	$73	$98	$70	$241	$134
2020	$81	$121	$86	$288	$153
Total				$1,190	$709

gal = gallon; $MM = million dollars.

Table 2-9. Cost summary for cellulosic ethanol plants (Technical Potential)

Year	Cost of Feedstock (2007 $MM)	Annualized Capital Costs ($ MM)	Other Annual Costs ($ MM)	Total Costs ($ MM)	Discounted Total Costs ($MM)
2010	$0	$0	$0	$0	$0
2011	$51	$54	$38	$143	$118
2012	$102	$138	$99	$340	$266
2013	$154	$207	$148	$509	$380
2014	$205	$277	$198	$679	$483
2015	$256	$346	$247	$849	$574
2016	$307	$415	$296	$1,019	$657
2017	$359	$484	$346	$1,188	$730
2018	$410	$553	$395	$1,358	$794
2019	$461	$622	$444	$1,528	$851
2020	$512	$768	$549	$1,829	$970
Total				$9,442	$5,822

gal = gallon; $MM = million dollars.

Soy/Waste Grease Biodiesel Costs

Biodiesel from soy and waste grease was the only biofuel produced in Pennsylvania in 2008. This production is expected to increase until 2013, at which point production of these first-generation biofuels will remain constant, and algae biodiesel production will begin increasing. The costs of biodiesel production from waste grease and soy come from the U.S. Energy Information Administration (EIA), which predicted the wholesale price of both fuels through 2012[14] (EIA, 2004). These estimates are then held constant through 2020.

[14] US EIA. Radich, Anthony. "Biodiesel Performance, Costs, and Use". 2004. http://www.eia.doe.gov/oiaf/analysispaper/biodiesel/

The costs of this option are also dependent on the ratio of waste grease and soy in the biodiesel. Because waste grease is more cost-effective, these supplies will be used first. However, it is unlikely that grease supplies can be expanded significantly from their current levels. It is assumed that waste grease supplies remain relatively constant (capable of producing 17 MMgal/yr), and all additional biodiesel production must come from soy oil. It is possible that other feedstocks will be used for biodiesel production, such as semolina, but soy is used as an example of feedstock costs in this analysis. This is used to estimate the overall production costs of biodiesel in Pennsylvania through 2020.

The TLU analysis requires that we provide costs for each biofuel. These costs are based on the production costs, although there are other costs that must be accounted for in order to estimate the cost at the pump. It can be difficult to estimate the difference in fuel costs between wholesale (cost to the producer) and retail (cost to the consumer). The EIA *Annual Energy Outlook 2008* (AEO 2008) does not estimate wholesale costs of biodiesel, but does estimate wholesale costs of corn ethanol. When these costs are compared to the retail cost estimates, the markup is 45-65 cents/gal.[15] This figure is used as a stand-in for the cost difference between wholesale and retail biodiesel. The costs of producing Pennsylvania's share of the federal RFS are shown in Table 2-10. Table 2-11 shows half of that amount. The maximum technical feasibility of biodiesel feedstocks is not easy to calculate in this analysis; therefore, the technically feasible amount is assumed to match that of Table 2-10 for biodiesel production.

[15] US EIA. Annual Energy Outlook 2008. http://www.eia.doe.gov/oiaf/archive/aeo08/index.html

Table 2-10. Soy/Waste Grease Production Costs (100 percent RFS)

Year	Gen 1 Biodiesel Displacement Goal (Million Gals)	Wholesale Waste Grease Cost ($/gal)	Wholesale Soy Biodiesel Cost ($/Gal)	Wholesale Cost Gen 1 Biodiesel ($/Gal)	Retail Cost, Gen 1 Biodiesel ($/Gal)	Production Costs of Gen 1 Biodiesel ($MM)
2010	31	$1.88	$3.41	$2.55	$3.00	$93
2011	40	$1.93	$3.48	$2.81	$3.35	$134
2012	54	$1.98	$3.57	$3.06	$3.67	$200
2013	64	$1.98	$3.57	$3.13	$3.73	$237
2014	64	$1.98	$3.57	$3.13	$3.67	$233
2015	64	$1.98	$3.57	$3.13	$3.50	$223
2016	64	$1.98	$3.57	$3.13	$3.76	$239
2017	64	$1.98	$3.57	$3.13	$3.83	$244
2018	64	$1.98	$3.57	$3.12	$3.79	$241
2019	64	$1.98	$3.57	$3.12	$3.77	$239
2020	64	$1.98	$3.57	$3.12	$3.75	$239
Total						$2,321

Table 2-11. Soy/Waste Grease Production Costs (50 percent RFS)

Year	Gen 1 Biodiesel Displacement Goal (Million Gals)	Wholesale Waste Grease Cost ($/gal)	Wholesale Soy Biodiesel Cost ($/Gal)	Wholesale Cost Gen 1 Biodiesel ($/Gal)	Retail Cost, Gen 1 Biodiesel ($/Gal)	Production Costs of Gen 1 Biodiesel ($MM)
2010	31	$1.88	$3.41	$2.55	$3.00	$93
2011	31	$1.93	$3.48	$2.61	$3.16	$97
2012	31	$1.98	$3.57	$2.67	$3.28	$101
2013	32	$1.98	$3.57	$2.70	$3.29	$105
2014	32	$1.98	$3.57	$2.69	$3.23	$103
2015	32	$1.98	$3.57	$2.69	$3.06	$97
2016	32	$1.98	$3.57	$2.68	$3.31	$105
2017	32	$1.98	$3.57	$2.68	$3.39	$108
2018	32	$1.98	$3.57	$2.67	$3.34	$106
2019	32	$1.98	$3.57	$2.67	$3.32	$105
2020	32	$1.98	$3.57	$2.67	$3.30	$105
Total						$1,125

Algae Biodiesel Costs

Keystone Biofuels is working on pre-commercial biodiesel production in Pennsylvania, and commercial algae biodiesel production is assumed to begin by 2014. Algae biodiesel costs are estimated based on a study on the costs and GHG reductions of algae biodiesel production in Australia. This study had numerous estimates of the costs to produce algae biodiesel, and the highest cost cited was used to make a conservative estimate of algae biodiesel prices.[16] It is

[16] Campbell, Peter, Beer, Tom and Batten, David. "Greenhouse Gas Sequestration by Algae – Energy and Greenhouse Gas Life Cycle Studies". 2008. Transport Biofuels Stream, CSIRO Energy Transformed Flagship PB1, Aspendale, Vic. 3195, Australia http://www.csiro.au/org/EnergyTransformedFlagship.html

highly likely that as production increases, economies of scale will reduce the overall price, but this is not taken into account in this analysis. The wholesale costs are again scaled up based on the difference between wholesale and retail ethanol costs, from AEO 2008. The costs for Pennsylvania's share of the RFS for algae and total biodiesel are shown in Table 2-12, and 50 percent of that amount is shown in Table 2-13.

Table 2-12. Algae Biodiesel Production Costs (100 percent RFS)

Year	Algae Biodiesel Displacement Goal (Million Gals)	Wholesale Algae Biodiesel Cost ($/gal)	Retail Cost of Algae Biodiesel ($/gal)	Production Costs, Algae Biodiesel ($ MM)	Production Costs, All Biodiesel ($ MM)	Discounted Production Costs, All Biodiesel ($MM)
2010	0	$0.00	$0.00	$0	$93	$80
2011	0	$0.00	$0.00	$0	$134	$110
2012	0	$0.00	$0.00	$0	$200	$157
2013	0	$0.00	$0.00	$0	$237	$177
2014	9	$3.75	$4.29	$39	$272	$193
2015	27	$3.75	$4.12	$112	$335	$227
2016	45	$3.75	$4.38	$199	$438	$282
2017	64	$3.75	$4.46	$283	$527	$324
2018	82	$3.75	$4.42	$361	$602	$352
2019	100	$3.75	$4.40	$439	$679	$378
2020	100	$3.75	$4.38	$438	$677	$359
Total					$4,193	$2,638

Table 2-13. Algae Biodiesel Production Costs (50 percent RFS)

Year	Algae Biodiesel Displacement Goal (Million Gals)	Wholesale Algae Biodiesel Cost ($/gal)	Retail Cost of Algae Biodiesel ($/gal)	Production Costs, Algae Biodiese ($ MM)	Production Costs, All Biodiesel ($ MM)	Discounted Production Costs, All Biodiesel ($MM)
2010	0	$0.00	$0.00	$0	$93	$80
2011	0	$0.00	$0.00	$0	$97	$80
2012	0	$0.00	$0.00	$0	$101	$79
2013	0	$0.00	$0.00	$0	$105	$78
2014	5	$3.75	$4.29	$19	$122	$87
2015	14	$3.75	$4.12	$56	$153	$104
2016	23	$3.75	$4.38	$99	$205	$132
2017	32	$3.75	$4.46	$142	$249	$153
2018	41	$3.75	$4.42	$181	$287	$168
2019	50	$3.75	$4.40	$220	$325	$181
2020	50	$3.75	$4.38	$219	$324	$172
Total					$2,061	$1,313

Total biofuel costs are shown in Table 2-14 for 100 percent of PA's share of the RFS, Table 2-15 for 50 percent of PA's share, and Table 2-16 for the technical potential. The costs shown in these tables are discounted back to 2007 dollars, using a 5 percent discount rate.

Table 2-14. Total Biofuel Costs (100 Percent RFS)

Year	Discounted Cellulosic Costs ($MM)	Discounted Production Costs, All Biodiesel ($MM)	Discounted Biofuel Costs ($MM)
2010	$5	$80	$85
2011	$13	$110	$123
2012	$22	$157	$179
2013	$42	$177	$219
2014	$70	$193	$264
2015	$115	$227	$342
2016	$155	$282	$437
2017	$191	$324	$515
2018	$232	$352	$584
2019	$268	$378	$646
2020	$306	$359	$664
Total			$4,057

$MM = millions of dollars.

Table 2-15. Total Biofuel Costs (50 percent RFS)

Year	Discounted Cellulosic Costs ($MM)	Discounted Production Costs, All Biodiesel ($MM)	Discounted Biofuel Costs ($MM)
2010	$3	$80	$83
2011	$6	$80	$87
2012	$11	$79	$90
2013	$21	$78	$99
2014	$35	$87	$122
2015	$57	$104	$161
2016	$78	$132	$209
2017	$96	$153	$249
2018	$116	$168	$283
2019	$134	$181	$315
2020	$153	$172	$325
Total			$2,023

$MM = millions of dollars.

Table 2-16. Total Biofuel Costs (Technical Potential)

Year	Discounted Cellulosic Costs ($MM)	Discounted Production Costs, All Biodiesel ($MM)	Discounted Biofuel Costs ($MM)
2010	$0	$80	$80
2011	$118	$110	$228
2012	$266	$157	$423
2013	$380	$177	$557
2014	$483	$193	$676
2015	$574	$227	$801
2016	$657	$282	$939
2017	$730	$324	$1,053
2018	$794	$352	$1,146
2019	$851	$378	$1,229
2020	$970	$359	$1,329
Total			$8,461

$MM = millions of dollars.

The costs of delivered biomass are be used for the cost-effectiveness analysis in TLU-2. Table 2-17 shows the estimated cost at the pump from this analysis for cellulosic ethanol, soy/grease biodiesel, and algae biodiesel. These costs assume that 100 percent of PA's share of the RFS pathway is taken, which corresponds to the goal in TLU-2.

Table 2-17. Estimated Costs of Biofuels at the Pump

Year	Retail Cellulosic Cost/Gal	Retail Cost, Gen-1 Biodiesel	Retail Cost of Algae Biodiesel ($/gal)
2010	$2.14	$3.00	$0.00
2011	$2.24	$3.35	$0.00
2012	$2.16	$3.67	$0.00
2013	$2.15	$3.73	$0.00
2014	$2.09	$3.67	$4.29
2015	$1.93	$3.50	$4.12
2016	$2.18	$3.76	$4.38
2017	$2.26	$3.83	$4.46
2018	$2.22	$3.79	$4.42
2019	$2.20	$3.77	$4.40
2020	$2.14	$3.75	$4.38

Key Assumptions: Annual cellulosic plant costs are $40 MM/yr for a 69-MMgal/yr plant. They include labor, general overhead, maintenance, taxes, insurance, and other operational costs, but not feedstock costs. Capital costs are $548 million per plant and assume an interest rate of 5 percent and a project life of 20 years.

Key Uncertainties

Cellulosic ethanol and biodiesel-from-algae technology and production capacity have not yet been proven on a commercial scale. This raises concerns about the viability for volumes of cellulosic and biodiesel fuel.

Additional Benefits and Costs

Other benefits or costs of increased biofuel use that are not quantified here include:

- The impact (positive or negative) on other air pollutants of concern.
- The sustainability of production.
- Flexibility to adjust based on the emergence of other technologies that might result in greater or more cost-effective GHG reductions.
- The impact on food prices.
- The impact on fuel tax revenue.
- The impact on the cost of delivering goods (i.e., fuel prices).
- Other environmental impacts, such as water quality and quantity, and conservation of land. Winter crops provide significant water quality benefits by removing excess nitrogen from the soil. From analyses of Pennsylvania cropping systems for the purpose of water quality improvements, there is significant acreage in the state that is available to produce winter crops that is not already used for this purpose.
- Secondary land-use impacts.
- Security benefits from domestic fuel production.

References:

Potential contacts for information include:
Mark Dubin
Agricultural Technical Coordinator
Chesapeake Bay Program Office
410-267-9833 TEL

Dr. Tom Richard, Director
Penn State Institutes of Energy and the Environment
(814) 865-3722

Potential Overlap: This work plan has overlap with the work plans Residential-11 Conservation and Fuel Switching for Heating Oil, where biodiesel will be used as an additive in home heating oil, and with Transportation-2 Biofuel Development and In-State Production Incentive. This Agriculture-2 Next Generation Biofuels work plan quantifies the cost for producing the biofuel. All GHG savings of using the biofuels will be accounted for in the Residential-11 and Transportation-2 work plans.

Other Considerations:

For both GHG and water quality reasons, a transition to a regional biofuels industry based on cellulosic and other next-generation feedstocks is desirable. However, this transition will not be instantaneous, and anything that can be done in the interim to facilitate that transition will be advantageous.

Much has been made of the "chicken-and-egg" problem facing new biofuel production endeavors. Feedstock producers are reluctant to invest in new crops and cropping systems without a sure market, and biofuel producers are reluctant to rely on a feedstock without a clear supply. To minimize this dilemma when cellulosic ethanol technologies ultimately become commercially feasible, action must be taken now to create a growing supply of cellulosic material that also meets current needs.

Winter crops, such as barley, can serve this purpose. The grain can be used as a feedstock for first-generation ethanol technology as a substitute for corn. The straw can support existing biomass combustion efforts and can be used as a cellulosic feedstock when that technology becomes available. In the meantime, the current technologies drive increased plantings of the winter crops, resulting in a relatively predictable supply of cellulosic material down the road.

Subcommittee Comments

Costs and GHG savings from biofuels are considered in Transportation-2 and Residential-11 work plans.

There is a considerable amount of work currently occurring directly related to this topic through the Chesapeake Bay Biofuels Initiative - http://www.chesbay.state.va.us/biofuels.html

Although the costs and GHG savings have been quantified in other sectors of CCAC, it appears there are important opportunities to inform policy as it relates to the CBBI and that many potential policy recommendations will directly impact stakeholders within the agriculture community. Therefore, there will be a strong need to monitor developments and assure that recommendations within sectors are considered and congruent as they relate to this work plan.

The subcommittee believes there is merit to this work plan and further consideration is appropriate.

Agriculture-3. Management-Intensive Grazing

Initiative Summary: This initiative would create incentives and provide support for farmers wishing to transition their livestock operations from grain-intensive practices (which usually requiring the importing of grain/nutrients into the region) to continuous MiG, which by contrast takes advantage of more local resources and increases sequestered carbon in pasturelands.

In addition to the implementation of MiG on farms, the initiative would help in marketing Pennsylvania-grown, pasture-based products to Pennsylvanians. A strategy of "Eating the View" would emphasize the need for consumers to choose products that help to maintain the bucolic pasturelands for which Pennsylvania is famous, while also improving their own nutrition and the health of the planet by sequestering more carbon through intensive grass production.

Other Involved Agencies: PDA, Natural Resources Conservation Service (NRCS), DEP, DCED, DCNR.

Goals: Double the number of acres under management-intensive grazing (MiG) by 2020.

Implementation Period: The implementation of this option will proceed with a linear increase in additional MiG acres between 2010 and 2020.

Implementation Steps: Provide incentives for farmers/grazers/ranchers to transition to MiG.

Estimated GHG Reductions and Net Costs or Cost Savings

GHG Reductions from MiG

The goal is to double the number of acres with MiG in Pennsylvania by 2020. The number of MiG farms in Pennsylvania as of 2007 was 10,871.[17] This was divided by the total number of dairy and cattle farms in the state in 2007 (42,749) to calculate the percentage of farms already utilizing MiG practices (25.4 percent). When this number is multiplied by the total pastureland acreage in Pennsylvania (1,279,590 acres), we can estimate the number of acres with MiG practices, just over 325,000. This is used as our baseline, and under the policy, this number will double to over 650,000 acres of MiG pastureland by 2020.

The GHG savings of MiG come primarily from two areas: soil carbon sequestration and reduced methane emissions. Land that is intensely grazed or that is being used to produce crops (such as corn) to be fed to cattle typically has minimal soil carbon sequestration. MiG allows greater carbon sequestration than traditional grazing methods, probably due to increased carbon inputs either from greater above-ground inputs (greater productivity or manure inputs), increased root turnover, or a combination of the two.[18] For the purpose of this quantification, no GHG savings were attributed to increased root volume. GHG savings are estimated to be 14.3 metric tons of carbon dioxide equivalent (tCO_2e)/acre (3.9 metric tons of carbon/acre) under MiG.[19] These savings are assumed to occur all in one year, although they actually build up for about 10 years. The GHG savings of MiG are shown in Table 3-1.

[17] USDA. Census of Agriculture, 2007. Volume 1, Chapter 2: County Level Data (Pennsylvania). http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Pennsylvania/index.asp

[18] Conant, Richard and Paustian, Keith. "The Effects of Grazing Management on Soil Carbon (Carbon Sequestration)". National Renewable Energy Laboratory. 2002. http://www.nrel.colostate.edu/projects/agecosys/people/files/rtc/pres/2000/lv00/glci00.pdf

[19] Ibid.

Table 3.1 Carbon Sequestration from Management-Intensive Grazing

Year	Implementation Path	Total Additional Acres of Beef/Dairy Cattle	Additional Sequestration ($MMtCO_2e$)
2010	0%	0	0
2011	10%	32,540	0.47
2012	20%	65,080	0.47
2013	30%	97,619	0.47
2014	40%	130,159	0.47
2015	50%	162,699	0.47
2016	60%	195,239	0.47
2017	70%	227,778	0.47
2018	80%	260,318	0.47
2019	90%	292,858	0.47
2020	100%	325,398	0.47
Total			**4.65**

There are also GHG savings that result from reduced methane emissions. Cattle digest grass through a natural process called enteric fermentation. Enteric fermentation results in methane emissions, which can vary depending on the amount and type of feed given to the cattle. MiG practices reduce the overall amount of feed and generally result in a diet that is easier to digest than the diet given to cattle in confined feeding operations.[20] While methane emission reductions can vary based on other factors, an average reduction of 22 percent was found when MiG practices were implemented.[21] These are applied to all animals in this analysis, as shown in Table 3-2.

[20] DeRamus, H.A. Clement, T.C., Giampola, D.D., and Dickinson, Peter. "Methane Emissions of Beef Cattle on Forages: Efficiency of Grazing Management Systems". Journal of Environmental Quality. 2003. http://jeq.scijournals.org/cgi/reprint/32/1/269.pdf

[21] DeRamus, H.A. Clement, T.C., Giampola, D.D., and Dickinson, Peter. "Methane Emissions of Beef Cattle on Forages: Efficiency of Grazing Management Systems". Journal of Environmental Quality. 2003. http://jeq.scijournals.org/cgi/reprint/32/1/269.pdf

Table 3-2. Reduced Methane Emissions and Total GHG Reductions from Ag-3

Year	Additional Beef/Dairy Cattle in MiG	Enteric Fermentation Emissions ($MMtCO_2e$)	Emissions Reduction ($MMtCO_2e$)	Total Emissions Reduction ($MMtCO_2e$)
2010	0	2.77	0.000	0.00
2011	40,920	2.76	0.015	0.48
2012	81,841	2.75	0.031	0.50
2013	122,761	2.75	0.046	0.51
2014	163,681	2.73	0.062	0.53
2015	204,602	2.72	0.077	0.54
2016	245,522	2.71	0.093	0.56
2017	286,442	2.69	0.108	0.57
2018	327,363	2.68	0.124	0.59
2019	368,283	2.67	0.139	0.60
2020	409,203	2.66	0.154	0.62
Total			**0.85**	**5.5**

Costs of Management-Intensive Grazing

MiG often results in decreased production from the dairy herd, because animals have less feed available. However, costs are often significantly lower, which typically counterbalances this loss in revenue.[22] The switch from centralized feeding to managed grazing can be made relatively inexpensively. According to Kriegel and McNair, "transitioning from a traditional dairy farm to a managed grazing operation requires very little additional investment."[23] The primary cost of implementing MiG practices is fencing, which is estimated to be between $30 and $70 dollars per acre. The higher cost is used to account for the cost of constructing livestock lanes.[24] This is discounted forward to reflect 2007 dollars, and applied to the first year MiG practices are implemented, as shown in Table 3-3.

There are also associated costs and cost savings that come from maintaining MiG practices. Costs come primarily in the form of reduced yield (beef sold or milk produced), and costs savings come from reduced inputs, such as corn to be fed to the cattle. A survey of profitability of different farm types over seven years found that net farm income for dairy operators was higher for managed grazing ($524/head) than for traditional confinement ($245/head) or large-scale confinement practices ($131/head).[25] These costs are also shown in Table 3-3. Final costs are discounted back to 2007 dollars using a 5 percent discount rate. Additional information on the cost-effectiveness of MIG practices in Pennsylvania, if available, would improve this analysis and reduce the underlying uncertainty.

[22] Kriegel, Tom and McNair, Ruth. "Pastures of Plenty: Financial Performance of Wisconsin Grazing Dairy Farms". University of Wisconsin-Madison. 2005. http://www.cias.wisc.edu/wp-content/uploads/2008/07/pastplenty607.pdf
[23] Ibid.
[24] Undersander et al, "Pastures for Profit, A guide to rotational grazing". University of Wisconsin Extension Service. 2002. http://learningstore.uwex.edu/pdf/A3529.pdf
[25] Kriegel, Tom and McNair, Ruth. "Pastures of Plenty: Financial Performance of Wisconsin Grazing Dairy Farms". University of Wisconsin-Madison. 2005. http://www.cias.wisc.edu/wp-content/uploads/2008/07/pastplenty607.pdf

Table 3-3. Costs and Cost Savings of Management Intensive Grazing Practices

Year	Additional Acres of Beef/Dairy Cattle	Additional Cost of Fencing ($MM)	Cost Savings from MiG Practices Compared with Traditional Confinement ($MM)	Net Costs ($MM)	Discounted Net Costs ($MM)
2010	0	$0.0	$0	$0	$0
2011	32,540	$2.9	$11	-$9	-$7
2012	65,080	$2.9	$23	-$20	-$16
2013	97,619	$2.9	$34	-$31	-$23
2014	130,159	$2.9	$46	-$43	-$30
2015	162,699	$2.9	$57	-$54	-$37
2016	195,239	$2.9	$69	-$66	-$42
2017	227,778	$2.9	$80	-$77	-$47
2018	260,318	$2.9	$91	-$88	-$52
2019	292,858	$2.9	$103	-$100	-$56
2020	325,398	$2.9	$114	-$111	-$59
Total				**-$599**	**-$369**

Key Assumptions:

It is assumed that underutilized land is available in PA to allow for expanded MiG.

Note: No costs for leasing pastureland have been included in this quantification. It is assumed that farmers/ranchers would have the acreage they need to graze their cattle. The inclusion of leasing costs or opportunity costs for pastureland will make this option more expensive and less cost-effective.

Key Uncertainties

MiG is typically more land-intensive than centralized feeding operations. GHG impacts from land-use change are very difficult to fully account for. This is particularly difficult in the case of cattle, where land that goes toward grazing may not be usable for alternative agricultural production. In such a case, it is likely that the GHG impacts from expanded land requirements are negligible. However, if additional land going toward MiG is coming from valuable cropland or forestland (for example), then the GHG impacts of that change could be significant.

In addition, some subcommittee members expressed concern that MiG practices often result in increased nitrous oxide (N_2O) emissions. Given that N_2O emissions have a global warming potential of more than 300 times that of CO_2, an increase in these emissions could erode or even negate the GHG savings of this policy option. However, there was no information available regarding the true impact of MiG practices on N_2O emissions, so these impacts were not quantified. In addition, the plants being grazed can dramatically alter N_2O emissions, particularly if they are nitrogen-fixing crops, such as certain legumes.

The cost savings of MiG practices are from a Wisconsin study of dairy cattle. If this is not applicable to beef cattle or to Pennsylvania farms, the cost estimates may not be accurate.

Additional Benefits and Costs

Market demand is already high for milk and beef products, so there should be very little overall cost impact on farmers or communities.

MiG could have some corollary benefits in terms of revenue, such as tourism or aesthetic improvement.

Grazing without supplemental feed can result in more profitable dairy farms, in spite of decreased milk production. However, this may require additional land going toward agriculture to meet overall demand for milk.

It is possible that additional GHG savings can be achieved by growing nitrogen-fixing plants, such as legumes, in a managed area. This would serve to naturally reduce N_2O emissions from cattle manure. These emission reductions were not included because it is difficult to assess the overall effectiveness of this GHG reduction strategy, and no information could be found to detail the impacts of this practice.

Some studies have found nutritional benefits of grass-fed beef, compared to corn-fed beef. It is possible that expanding MiG practices will improve the nutritional value of Pennsylvania milk and beef.

References:

Conant, Richard and Paustian, Keith. “The Effects of Grazing Management on Soil Carbon (Carbon Sequestration)”. National Renewable Energy Laboratory. 2002. http://www.nrel.colostate.edu/projects/agecosys/people/files/rtc/pres/2000/lv00/glci00.pdf

DeRamus, H.A. Clement, T.C., Giampola, D.D., and Dickinson, Peter. “Methane Emissions of Beef Cattle on Forages: Efficiency of Grazing Management Systems”. Journal of Environmental Quality. 2003. http://jeq.scijournals.org/cgi/reprint/32/1/269.pdf

Kriegel, Tom and McNair, Ruth. “Pastures of Plenty: Financial Performance of Wisconsin Grazing Dairy Farms”. University of Wisconsin-Madison. 2005. http://www.cias.wisc.edu/wp-content/uploads/2008/07/pastplenty607.pdf

Undersander et al, “Pastures for Profit, A guide to rotational grazing”. University of Wisconsin Extension Service. 2002. http://learningstore.uwex.edu/pdf/A3529.pdf

USDA. Census of Agriculture, 2007. Volume 1, Chapter 2: County Level Data (Pennsylvania). http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Pennsylvania/index.asp

Potential Overlap: Potential overlap with other work plans that require land—such as for biofuel feedstock production or forestry preservation options.

Feasibility Issues:

The transition from confined feeding to MiG is often most cost-effective on small-scale farms. Given the sunk costs involved in centralized feeding operations (particularly large ones), it may be difficult to make this transition without significant loss of capital.

Subcommittee Comments

This initiative would create incentives and provide support for farmers wishing to transition their livestock operations from grain-intensive practices (i.e. usually requiring the importing of grain/nutrients into the region) to continuous, management intensive grazing (MiG), which by contrast takes advantage of more local resources and increases sequestered carbon in pasturelands.

Agriculture-4. Manure Digester Implementation Support

Initiative Summary: Pennsylvania will continue to support and encourage installation of manure digesters and other energy-saving and -production implements on farms. DEP's Energy Harvest Grant continues to support such improvements, in addition to the PA Grows program, which helps farmers put together finance packages for such projects. Pennsylvania will also take advantage of $2.4 billion of the federal stimulus package that is allocated for carbon capture and sequestration. and the $165 million PA Alternative Energy Investment Act, which reserves some of its funds for alternative energy production.

Anaerobic digestion is a biological treatment process that reduces manure odor, produces biogas which can be converted to heat or electrical energy. and improves the storage and handling characteristics of manure.

Currently, there are 31 manure digesters in Pennsylvania. At least 14 of them have been funded through the Energy Harvest Grant program. Also, 16,600 dairy cows are on farms with digesters out of over 561,000 dairy cows in Pennsylvania.[26]

Other Involved Agencies: PDA, NRCS, DEP, DCED, DCNR.

Goals: 50 percent of animals in large or medium-sized farms (>100 head for cattle and >1,000 head for swine) will have advanced manure management technologies installed to reduce GHG emissions by 2020.

Implementation Period: Implementation will increase steadily between 2010 and 2020.

Implementation Steps: Continuation of grants and funding assistance through the PA Grows Program and Energy Harvest Grant.

[26] Penn State University, College of Agricultural Sciences, "Anaerobic Digestion on the Farm" pamphlet. 2006.

Data Sources/Assumptions/Methods for GHG:

Dairy Cow Management GHG Reductions

This type of technology could be applied to beef cattle, although their methane emissions in Pennsylvania are far lower than emissions from dairy cattle. Swine manure emissions are considered later in this analysis.

Methane emissions data from the Pennsylvania Ag Module (in millions of metric tons of carbon dioxide equivalents [$MMtCO_2e$]) were used as the starting point to estimate the GHG reductions of utilizing the volumes of methane where this technology could be applied. The first portion of GHG reduction is obtained by reducing methane emissions through the capture of methane emissions from manure management. An assumed collection efficiency of 75 percent[27] is applied to methane emissions from manure managed under baseline conditions, which is then multiplied by the assumed mitigation approach target. The implementation scenario considers an increasing use of this technology and ramps up toward 50 percent utilization of centralized feeding operations by 2020.

The second portion of the GHG reduction is obtained by offsetting fossil fuels. For the purposes of this analysis, it is assumed that the methane is used to create electricity, which will displace fossil-based electricity generation (methane could also be used for other energy purposes). The electricity-offset component was estimated by averaging the electricity generated through new anaerobic digesters (ADs) installed in the state. The CO_2e associated with this amount of electricity in each year is estimated by converting the kilowatt-hours (kWh) to megawatt-hours (MWh), and then multiplying this value by the New York-specific emission factor for electricity production from the inventory and forecast (0.86 tCO_2e/MWh).[28] Reduced GHG emissions in milk production through managed outdoor grazing was also discovered by Rotz et al.,[29] who found a GHG reduction of 80 percent per unit of milk, compared to high-density confinement feedlots. This study has not yet been published; thus, these results are not shown in the GHG analysis.

Manure digesters operate most efficiently at 130 degrees Fahrenheit, which is the approximate temperature at which most digesters are maintained. Since it never approaches this temperature in Pennsylvania, it is very likely that more methane will be created and captured in the digester than was previously released before digester installation. The increase in methane produced (and captured) was estimated by comparing the amount of methane captured in an AD, as found in the AA Dairy and Knoblehurst farms, with the amount of methane created in a typical dairy farm (as found in the U.S. Environmental Protection Agency's [EPA's] State Greenhouse Gas Inventory Tool module). This found that slightly more than 80 percent of methane was captured in ADs than would have been created under normal environmental conditions. This figure is applied to calculate the amount of methane captured and used to generate electricity in all ADs.

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[27] The collection efficiency is an assumed value based on engineering judgment, Personal Communication, Dr. Curt Gooch @ Cornell, November 20, 2008. 100% collection efficiency is not possible due to biogas emissions that occur post-digestion and possible inefficiencies in methane capture.

[28] Based on communication with Electricity Supply subcommittee. Figure used for average electricity emissions/MWh. Figures from Energy Supply Work Plan, Electricity Assumptions tab.

[29] Rotz, Alan et al. "Grazing can reduce the environmental impact of dairy production systems." 2009. Paper still in review.

The policy objective begins at 3 percent, because that is the estimate of the percentage of dairy cattle in the state that currently have an anaerobic digestion system and is the assumed baseline.[30] Table 4-1 shows the GHG reductions possible by installing ADs in Pennsylvania dairy farms.

Table 4-1. GHG Reductions from Methane Utilization

Year	Dairy Methane Emissions ($MMtCO_2e$)	Policy Utilization objective	Forecast Dairy Herd ('000 head)	GHG Savings (Electricity) ($MMtCO_2e$)	Methane Emission Reductions ($MMtCO_2e$)	Total Emission Reductions ($MMtCO_2e$)
2010	0.30	3%	556	0.00	0.00	0.00
2011	0.30	5%	552	0.02	0.01	0.03
2012	0.30	8%	548	0.05	0.01	0.06
2013	0.30	10%	544	0.07	0.02	0.08
2014	0.29	13%	537	0.09	0.02	0.11
2015	0.29	15%	529	0.11	0.03	0.14
2016	0.29	18%	522	0.13	0.03	0.16
2017	0.29	20%	514	0.15	0.04	0.19
2018	0.29	23%	507	0.17	0.04	0.21
2019	0.28	25%	499	0.19	0.05	0.23
2020	0.28	27%	492	0.20	0.05	0.26
Total				**1.17**	**0.29**	**1.46**

Utilization Costs

The costs for the small-scale (<100 head) dairy manure utilization were estimated using the average of the analyses provided by Cornell University.[31] The studies used in this analysis were AD4, and 7. From these, capital costs/head for an anaerobic digestion system were estimated. The capital costs/head for medium-scale (100–500 head) and large-scale (>500 head) systems come from a study of Pennsylvania farms.[32] Capital costs/head are shown in Table 4-2, and generally decrease as farm size increases. Capital costs were discounted either forward or backward, so that they were all averaged together in 2007 dollars. The 5 percent discount rate was used for both dollars that had to be discounted forward (like digesters built in 2007), or dollars that had to be discounted backward (digesters built after 2007). The average costs are shown in Table 4-2 in 2007 dollars. New York costs were used for smaller farms because AD information in Pennsylvania on farms this size was not as detailed in terms of capital costs and size.

To apply these capital cost estimates, there is also a need for the breakdown of dairy sizes in Pennsylvania. Survey data for Pennsylvania were used to extrapolate the current and future breakdown between small (0–100 head), medium (101–500 head), and large (>500 head) dairy farms. The breakdown is estimated to change over time, reflecting gradually increasing numbers

[30] Penn State University, College of Agricultural Sciences, “Anaerobic Digestion on the Farm” pamphlet. 2006.
[31] http://www.manuremanagement.cornell.edu/HTMLs/dies.htm
[32] Leuer, Elise. Hyde, Jeffery and Richard, Tom. "Pennsylvania Dairy Farms: Implications of Scale Economies and Environmental Programs" Agricultural and Resource Economics Review 37/2 (October 2008). Estimate of medium size farms used figure for smallest farms in study, whereas estimate of large size farms used average of capital costs/head for 500 and 1000 head AD systems.

of large farms, as shown in Table 4-3. This estimate attempts to reflect the historical trend toward larger dairy farms.[33] It interpolates dairy animal populations between 2013 and 2023.

Table 4-2. Capital Costs/Head for Different Size Farms

Dairy Size	Average Capital Cost ($2007/Head)
Small Farms (<100)	$2,707
Mid-Sized Farms (101-500)	$1,608
Large Farms (>500)	$1,340

Table 4-3. Estimated Breakdown of Dairy Farm Size (head)

Year	Percentage in Large Farms (>500)	Percentage in Medium Farms (100-500)	Percentage in Small Farms (<=100)
2010	5%	40%	55%
2011	5%	41%	54%
2012	5%	42%	53%
2013	6%	43%	52%
2014	6%	43%	51%
2015	6%	44%	50%
2016	6%	45%	49%
2017	6%	45%	48%
2018	7%	46%	47%
2019	7%	47%	46%
2020	7%	48%	45%

The total capital costs by farm size are shown in Table 4-4. The costs are annualized on a 15-year payback period assuming a 5 percent interest rate. Given that the goal of this option is to address 50 percent of confined animal feeding operations (CAFOs), no small dairy farms are considered to have ADs installed.

[33] Jeffrey R. Stokes. "Entry, Exit, and Structural Change in Pennsylvania's Dairy Sector." Agricultural and Resource Economics Review 35/2 (October 2006) 357–373. http://ageconsearch.umn.edu/bitstream/10218/1/35020357.pdf

Table 4-4. Capital Costs by Farm Size

Year	Policy Utilization Objective	Percentage Total Cows in Program From Large Farms	Capital Cost, Large Farms (MM$)	Percentage Total Cows in Program From Medium Farms	Capital Cost, Medium Farms (MM$)	Percentage Total Cows in Program From Small Farms	Annualized Capital Cost (MM$)
2010	3%	3%	0.0	0%	0.0	0%	0.0
2011	5%	5%	16.7	0%	1.6	0%	1.8
2012	8%	5%	1.5	2%	19.8	0%	3.8
2013	10%	6%	1.5	5%	19.6	0%	5.8
2014	13%	6%	1.4	7%	19.4	0%	7.8
2015	15%	6%	1.4	9%	19.1	0%	9.8
2016	18%	6%	1.4	11%	18.8	0%	11.8
2017	20%	6%	1.4	14%	18.5	0%	13.7
2018	23%	7%	1.5	16%	18.2	0%	15.6
2019	25%	7%	1.5	18%	17.8	0%	17.4
2020	27%	7%	1.5	20%	17.5	0%	19.3
Totals							**107**

Because costs are higher for medium- and small-scale farms, it was assumed that changes would be made last to this area in the implementation of this technology in the implementation scenario. Therefore, in the implementation scenario, the installation of ADs begins on large farms in 2010. Only when all existing large farms have the technology installed does installation begin on medium-sized farms (where the technology is less cost-effective), which occurs in significant numbers in 2012 (see Table 4-4).

Annual O&M costs come from an average of annual costs/head ($31/head) that comes from a Cornell study of ADs.[34] It is possible that O&M costs should also vary by farm size, although this cannot be determined until more information is available on the costs of medium- and small-scale AD systems.

Electricity generated is calculated based on the average annual electricity generated/head on farms with ADs already installed. This resulted in a figure of approximately 1.10 MWh/head/year, which is then multiplied by the number of dairy cattle with a new AD system in place to determine total electricity generated. The value of electricity produced comes from the Electricity Supply Subcommittee, based on the value of electricity generated in the commercial sector.[35] The costs and revenues of this option are also summarized in Table 4-5. The net costs are discounted back to 2007 dollars, using a 5 percent discount rate.

[34] Wright, Peter et al. "Preliminary Comparisons of Five Anaerobic Digestion Systems on Dairy Farms in New York State". Cornell University. Written for presentation at the ASAE/CDAE Annual International Meeting, 2004.
[35] Based on communication with Electricity Supply subcommittee. Figures from Energy Supply Work Plan, Electricity Assumptions tab.

Table 4-5. Net Costs of Anaerobic Digesters for Dairy Cows

Year	Annualized Capital Cost (MM$)	Electricity Generated (MWh)	Electricity Cost ($/kWh)	Cost Savings, Electricity (MM$)	Annual O&M Costs of Anaerobic Digesters (MM$)	Net Costs of Program (MM$)	Discounted Net Costs of Program (MM$)
2010	0.0	0	$0.077	0.0	0.0	0.0	0.0
2011	1.8	26,620	$0.084	2.2	0.4	-0.1	-0.1
2012	3.8	52,868	$0.084	4.4	0.8	0.2	0.1
2013	5.8	78,741	$0.083	6.5	1.2	0.5	0.4
2014	7.8	103,542	$0.084	8.7	1.6	0.8	0.6
2015	9.8	127,620	$0.085	10.8	2.0	1.0	0.7
2016	11.8	150,976	$0.088	13.3	2.3	0.8	0.5
2017	13.7	173,608	$0.091	15.8	2.7	0.5	0.3
2018	15.6	195,516	$0.095	18.6	3.0	0.0	0.0
2019	17.4	216,702	$0.096	20.7	3.3	0.1	0.0
2020	19.3	237,165	$0.099	23.4	3.7	-0.5	-0.3
Total						**3**	**2**

Cost-effectiveness is calculated by dividing total, discounted costs (over the entire period) by the cumulative GHG savings of the project to get a $/metric ton (t) figure. For example, in the case of the implementation scenario, the net cost is $2 million (found at the bottom of Table 4-5), and the GHG savings are 1.46 MMt (located at the bottom of Table 4-1). This means that the cost-effectiveness of the implementation scenario is $2/t.

Swine Manure Management GHG Reductions

Information from the Pennsylvania Ag Industries indicated that there is only one swine AD in the state, located in Danville, PA. ADs are often less popular with swine farmers because they require significant daily maintenance and large farm size to be profitable.[36] This analysis considers ADs as an alternative that could yield greater GHG reductions.

The GHG reductions of this policy were estimated for Pennsylvania pig farms, which yield approximately 37 percent of total manure methane emissions. The emissions from pig farms were taken from the Pennsylvania Ag Module. According to a recent waste management study, improved aerobic waste treatment systems in swine farms previously using anaerobic lagoons for manure management were able to reduce GHG emissions by 97 percent.[37] Treatment methods included specialized flocculation (clumping) and aeration with nitrifying bacteria pellets to convert the volatile solids into stable carbon compounds. A manure management survey by the U.S. Department of Agriculture (USDA) found that 58 percent of large-scale (>1,000 head) pig

[36] Based on Personal Communication between Jackson Schreiber and Jennifer Reed-Harry at Penn Ag Industries, June 9, 2009.

[37] Vanotti, M.B., A.A. Szogi, and C.A. Vives. "Greenhouse Gas Emission Reduction and Environmental Quality Improvement From Implementation of Aerobic Waste Treatment Systems in Swine Farms." *Waste Management* 2008;28(4):759-766. Available at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VFR-4R8KT18-3&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=db75fa272fe41653220c60dc09cb4733.

farms used anaerobic lagoons. The availability Pennsylvania-specific information on the breakdown of manure management technologies and farm size would improve this analysis.

CAFO farms are assumed to have more than 1,000 head pigs. Most of these farms have anaerobic lagoons that be replaced with ADs. Based on discussion with the Pennsylvania National Agricultural Statistics Service (NASS), it is assumed that swine population figures will remain constant between 2010 and 2020.[38] While it is likely that the advanced methods described in the Vanotti et al. study could be applied to other manure management systems, such as deep-pit systems, they were not considered in the analysis. It was assumed that the costs and GHG reductions of installing these new aerobic manure management techniques to systems other than anaerobic lagoon facilities would be different from those cited in Vanotti's studies. Thus, the analysis done for AG-4 is likely a conservative estimate of the emission reductions possible through manure management, because the policy considers only the potential GHG reductions from improved management of anaerobic lagoons. Table 4-6 shows the implementation path used for this policy and the GHG reductions expected.

Table 4-6. GHG Emissions Reductions from Improved Manure Management

Year	Implementation Path	Manure Management Emissions From Swine ($MMtCO_2e$)	Emissions Reduction From Policy ($MMtCO_2e$)
2010	8%	0.29	0.01
2011	13%	0.29	0.01
2012	17%	0.29	0.01
2013	21%	0.29	0.01
2014	25%	0.29	0.02
2015	29%	0.29	0.02
2016	33%	0.29	0.02
2017	38%	0.29	0.03
2018	42%	0.29	0.03
2019	46%	0.29	0.03
2020	50%	0.29	0.04
Total			**0.23**

BAU = business as usual; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

[38] Personal Communication with Mark Linstedt by Jackson Schreiber, PA Office of NASS. 5/21/09.

Swine Manure Management Costs

The costs of this policy were estimated based on a study by Vanotti and Szogi,[39] which found that these new methods of manure management resulted in a cost of $1.02/head. Costs of installing this policy are reduced because they include improved health (and therefore sale price) of pigs as a result of this cleaner manure management system. The estimated pig populations come from the Pennsylvania Ag Module, and the cost estimates come from multiplying the pig population under the improved manure management program by the estimated cost/head figure. Table 4-7 presents more information on the costs of the program.

Table 4-7. Costs of Improved Manure Management

Year	Swine In Pennsylvania ('000 head)	Swine Considered in Policy ('000 head)	Net Costs ($MM)	Discounted Net Costs ($MM)
2010	1,170	43	$0.0	$0.0
2011	1,170	64	$0.1	$0.1
2012	1,170	86	$0.1	$0.1
2013	1,170	107	$0.1	$0.1
2014	1,170	129	$0.1	$0.1
2015	1,170	150	$0.2	$0.1
2016	1,170	172	$0.2	$0.1
2017	1,170	193	$0.2	$0.1
2018	1,170	215	$0.2	$0.1
2019	1,170	236	$0.2	$0.1
2020	1,170	257	$0.3	$0.1
Total			**$2**	**$1**

Key Assumptions:

The estimate of current manure management practices in swine farms comes from a federal study, which is assumed to reflect farming practices in Pennsylvania. If this is not correct, the costs and GHG savings from swine manure management could be significantly different.

Information on dairy anaerobic digesters is from New York information. If digesters sold in Pennsylvania are significantly different, that would not be reflected in this analysis.

Key Uncertainties

Some swine farms in Pennsylvania may already have waste management systems in place that may not yet be old enough to require replacement. If these units are to be replaced, then the sunk costs of the previous digester will be a loss, thus increasing the overall cost of the option.

[39] Vanotti, M.B., A.A. Szogi, and C.A. Vives. "Greenhouse Gas Emission Reduction and Environmental Quality Improvement From Implementation of Aerobic Waste Treatment Systems in Swine Farms." *Waste Management* 2008;28(4):759-766. Available at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VFR-4R8KT18-3&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=db75fa272fe41653220c60dc09cb4733.

Because no information was available on the level of manure management currently in place in Pennsylvania, it was assumed that installation of additional digesters is practical in all locations.

The Vanotti et al. studies[40] assume that the improved manure handling and storage practices occur on large facilities (>6,000 head). All of the farms in Pennsylvania for which this technology is considered have at least 1,000 head, but it is possible that without the economies of scale that come with these larger farm sizes, some costs will be higher.

Additional Benefits and Costs

Improved manure management often has additional benefits in terms of avoided odors and local air pollutants.

It is possible that Pennsylvania farmers could sell the carbon credits from their digesters for an additional revenue stream, although this is not factored into the overall cost-effectiveness. If installations of ADs on dairy and other livestock farms becomes more common, farm operators would be able to pool their carbon credits for marketing purposes. Pooling is often necessary to aggregate a large enough volume for efficient marketing. At present, the manure of at least 2,000 lactating cows would be required for a dairy operator to be a viable lone operator on the Chicago Climate Exchange. Therefore, most dairy farms would need to register through an aggregator to sell credits.

Potential Overlap: Not applicable. The potential for overlap between this work plan and the work plan for Waste-5 Waste-to-Energy Digesters was evaluated and it was determined that there is sufficient manure feedstock for both work plans so no overlap was calculated.

Subcommittee Comments

Pennsylvania will continue to support and encourage installation of manure digesters and other energy-saving and production implements on farms. The DEP's Energy Harvest Grant continues to support such improvements in addition to the PA Grows program, which helps farmers put together finance packages for such projects. Pennsylvania will also take advantage of $2.4 billion of the federal stimulus package that is allocated for carbon capture and sequestration and the $165 million PA Alternative Energy Investment Act, which reserves some of its funds for alternative energy production.

Anaerobic digestion is a biological treatment process that reduces manure odor, produces biogas which can be converted to heat or electrical energy and improves the storage and handling characteristics of manure.

Currently, there are 31 manure digesters in Pennsylvania. At least 14 of them have been funded through the Energy Harvest Grant program. Currently, 16,600 dairy cows are on farms with digesters out of over 561,000 dairy cows in Pennsylvania.[41]

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[40] Vanotti, M.B., A.A. Szogi, and C.A. Vives. "Greenhouse Gas Emission Reduction and Environmental Quality Improvement From Implementation of Aerobic Waste Treatment Systems in Swine Farms." *Waste Management* 2008;28(4):759-766. Available at: http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6VFR-4R8KT18-3&_user=10&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000050221&_version=1&_urlVersion=0&_userid=10&md5=db75fa272fe41653220c60dc09cb4733.

[41] Penn State University, College of Agricultural Sciences, "Anaerobic Digestion on the Farm" pamphlet. 2006.

It is important to note that there are existing carbon offset protocols that acknowledge this activity. Specifically, the Climate Action Reserve (CAR), as well as the Chicago Climate Exchange (CCX) has a protocol accepting projects that engage in “Ag Methane Reductions”. It will be important to evaluate these project protocols and encourage pilot projects within Pennsylvania to more fully understand these opportunities. Furthermore, it has a direct relationship with the costs associated with this option; as such potential revenues for entering into such projects will impact the cost effectiveness.

Agriculture-5. Regenerative Farming Practices Initiative/ Soil Sequestration From Continuous No-Till Agronomic Systems

Other Involved Agencies: DEP, PDA, PA NRCS, Penn State College of Agriculture, farmers.

Goals:

No-Till: Increase no-till acres to 1.8 million acres by 2025.

Regenerative Farming Practices: Increase the net carbon sequestration capacity of Pennsylvania agriculture in by (1) increasing the acres of farmland managed with regenerative cropping practices that improve the rate of biological sequestration of atmospheric carbon as soil organic matter; and (2) decreasing practices, and the use of products, that release carbon into the atmosphere.

Implementation Period:

No-Till: 5 percent per year increase from 2010 to 2025.

Regenerative Farming Practices: Increase the number of acres managed with regenerative farming practices by 10 percent/year from 2010 to 2020.

Quantification of Goals:

No-Till:

Data Sources/Assumptions/Methods for GHG:

Total harvested cropland in Pennsylvania was estimated at about 1.2 million acres[42] in 2007. For the purposes of this analysis, it is assumed that conservation practices include conservation till (no-till and strip-till), and other conservation farming practices that provide enhanced ground cover, or other crop management practices that achieve similar soil carbon benefits. Common definitions of conservation tillage are systems that leave 50 percent or more of the soil covered

[42] USDA/NASS, 2007 Pennsylvania Ag Census, Table 1. Historical Highlights: 2007 and Earlier Census Years, Accessed June 2009

with residue. In this work plan, the definition of the Conservation Technology Information Center was used.[43]

Based on the policy design parameters, the schedule for acres to be put into conservation tillage cultivation is displayed in Table 5-1 and assumes a linear ramp-up.

It is assumed that carbon is sequestered at a rate of 0.6 tCO_2/acre/year (404 kilograms of carbon per hectare per year [kg C/ha/year]) and that that this rate of accumulation occurs for 20 years, which extends beyond the policy period. It is estimated that 0.8 million acres of Pennsylvania cropland are using no-till practices.[44] Therefore, to reach the goal of 1.8 million total acres, 1.0 million additional acres are needed.

Additional GHG savings from reduced fossil fuel consumption are estimated by multiplying the fossil diesel emission factor and diesel fuel reduction per-acre estimate. The reduction in fossil diesel fuel use from the adoption of conservation tillage methods is 4.04 gallons (gal)/acre (see Table 5-3).[45] The life-cycle fossil diesel GHG emission factor of 12.31 tCO_2e/1,000 gal was used.[46] Results are shown in Table 5-1, along with total estimated GHG reductions from both carbon sequestration and fossil fuel reductions.

Data Sources/Assumptions/Methods for Costs:

The costs of no-till are based on cost estimates from the Minnesota Agriculture Best Management Practices (AgBMP) Program.[47] This program provides farmers a low-interest loan as an incentive to initiate or improve their current tillage practices. The equipment funded is generally specialized tillage or planting implements that leave crop residues covering at least 15 percent–30 percent of the ground after planting. The average total cost for this equipment is $23,000, though the average loan for tillage equipment is $16,000. The average-size farm using an AgBMP loan to purchase conservation tillage equipment is 984 acres. The average loan size was determined based on the average size of a farm in Pennsylvania (124 acres),[48] and the

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[43] The definitions of tillage practices from the Conservation Technology Information Center are used under this policy. However, only no-till/strip-till and ridge-till are considered "conservation tillage" practices. No-till means leaving the residue from last year's crop undisturbed until planting. Strip-till means no more than one-third of the row width is disturbed with a coulter, residue manager, or specialized shank that creates a strip. If shanks are used, nutrients may be injected at the same time. Ridge-till means that 4–6-inch-high ridges are formed at cultivation. Planters using specialized attachments scrape off the top 2 inches of the ridge before placing the seed in the ground.

[44] Assumes that current conservation tillage percentage is that same as the 1998 percentage, based on 1998 data from Conservation Technology Information Center (includes No-Till and Ridge-Till tillage practices). http://www.crmsurvey.org/

[45] Average reduction from PSU Extension presentation, provided by the PA No Till Alliance.

[46] Life-cycle emissions factor for fossil diesel from J. Hill et al. "Environmental, Economic, and Energetic Costs and Benefits of Biodiesel and Ethanol Biofuels." *Proceedings of the National Academy of Sciences* July 25, 2006;103(30):11206–11210. From the assessment used to evaluate U.S. soybean-based biodiesel life-cycle impacts. See: http://www.pnas.org/cgi/content/full/103/30/11099.

[47] Minnesota Department of Agriculture, Agricultural Best Management Practices Loan Program State Revolving Fund Status Report, February 28, 2006.

[48] USDA, National Agricultural Statistical Service. Ag Census 2007, Table 1. Historical Highlights: 2007 and Earlier Census Years.

amount of a loan per acre as estimated in the Minnesota AgBMP Program ($16.26/acre).[49] This put the average loan size at $2,016 to finance no-till/conservation tillage practices. This loan payment was applied to each new acre entering the program to determine an approximate cost of encouraging the use of soil management practices. The cost savings for this program come from reduced diesel fuel costs, with diesel estimated using U.S. Department of Energy fuel price forecasts.[50] The 2020 cost-effectiveness for this work plan of –$1,132/t$CO_2$e was derived by dividing the cumulative discounted costs shown in Table 5-2 by the cumulative GHG reductions shown in Table 5-1.

Table 5-1. GHG Reductions from No-till Practices

Year	Acres Under Conservation Tillage (%)	New Land Under Conservation Tillage (acres)	Carbon Sequestered (MMtCO_2e)	Diesel Saved (1,000 gal)	GHGs Reduced From Diesel Avoided (tCO_2e)	Total GHG Reduction per Annum (MMtCO_2e)
2010	41%	62,257	0.04	252	0.003	0.040
2011	44%	124,514	0.07	503	0.006	0.081
2012	47%	186,771	0.11	755	0.009	0.12
2013	50%	249,029	0.15	1,006	0.012	0.16
2014	53%	311,286	0.19	1,258	0.015	0.20
2015	55%	373,543	0.22	1,509	0.019	0.24
2016	58%	435,800	0.26	1,761	0.022	0.28
2017	61%	498,057	0.30	2,012	0.025	0.32
2018	64%	560,314	0.34	2,264	0.028	0.36
2019	67%	622,571	0.37	2,515	0.031	0.40
2020	70%	684,828	0.41	2,767	0.034	0.44
2021	73%	747,086	0.45	3,018	0.037	0.49
2022	76%	809,343	0.49	3,270	0.040	0.53
2023	79%	871,600	0.52	3,521	0.043	0.57
2024	82%	933,857	0.56	3,773	0.046	0.61
2025	85%	996,114	0.60	4,024	0.050	0.65
					Total	**5.5**

GHG = greenhouse gas; MMtCO_2e = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent; gal = gallon.

[49] Minnesota Department of Agriculture, Agricultural Best Management Practices Loan Program State Revolving Fund Status Report, February 28, 2006.

[50] AEO 2009 diesel costs, which range from $2.93 in 2010 to $3.79 in 2020.

Table 5-2. Costs of No-till Program

Year	Cost of Loans	Cost Savings of Program	Discounted Costs of Program (5%, 2007$)
2010	$1,012,311	-$736,950	$237,867
2011	$1,012,311	-$1,579,538	-$466,659
2012	$1,012,311	-$2,550,401	-$1,205,133
2013	$1,012,311	-$3,531,324	-$1,879,726
2014	$1,012,311	-$4,590,218	-$2,542,752
2015	$1,012,311	-$5,644,082	-$3,134,965
2016	$1,012,311	-$6,602,368	-$3,603,401
2017	$1,012,311	-$7,545,564	-$4,010,851
2018	$1,012,311	-$8,534,033	-$4,397,795
2019	$1,012,311	-$9,507,411	-$4,730,389
2020	$1,012,311	-$10,485,819	-$5,024,003
2021	$1,012,311	-$11,469,257	-$5,281,468
2022	$1,012,311	-$12,555,818	-$5,552,624
2023	$1,012,311	-$13,486,438	-$5,714,541
2024	$1,012,311	-$14,638,394	-$5,945,015
2025	$1,012,311	-$15,815,502	-$6,151,032
		Total	**-$59,640,355**

Table 5-3 summarizes the estimated fuel savings from adopting no-till.[51]

Table 5-3. Fuel Savings from No-till

Crop	Acreage	Total Fuel Consumption (gals)		Fuel Consumption (gals/ac)		Fuel Saved (gals/ac)
		CT	NT	CT	NT	
Soybeans	100	595.8	162.6	5.96	1.63	4.33
Corn	400	2,231.9	499.1	5.58	1.25	4.33
Oats/Alfalfa	50	238.3	65.0	4.77	1.30	3.47
					Average	**4.04**

CT = conventional till; NT = no-till.

Additional Costs/Benefits:

- Reduction in nitrogen runoff.
- Reduction in erosion of soil by wind and water.
- Better water and nutrient holding capacity, which can lead to reduced synthetic fertilizer use, better water quality, better performance during droughts, and generally "healthier" soil.
- Increased water infiltration.
- Crop profitability is higher in a continuous no-till system.
- No-till provides the most cost-effective solution for reducing erosion and sediment loss.

[51] Average reduction from PSU Extension presentation, provided by the PA No Till Alliance.

Implementation Steps:

- Participate in carbon credit trading.
- Reaching the 80 percent goal will be primarily market-driven, but will be greatly assisted by continuing to offer Resource Enhancement and Protection Program (REAP) tax credits for no-till planting equipment, cost-share incentives for first-time no-tillers, and technical assistance to first-time and inexperienced no-tillers.
- Work with PA NASS to revise its survey processes to capture additional information regarding no-till practices, including a methodology to define and capture data on continuous no-till acres and cover crops.
- Create a PA No-Till and Ag Carbon Sequestration work team.
- Coordinate a state Continuous No-Till action plan between the PA No-Till Alliance, the Pennsylvania State University, USDA NRCS, the State Conservation Commission, County Conservation Districts, farm organizations, and conservation/environmental groups.
- Develop and implement an educational campaign to encourage more farmers to switch to no-till farming**.** Encourage farmers, through education and economic incentives, to implement rotational grazing practices and precision agricultural practices that efficiently use farm inputs in agricultural production.
- Utilize the First Industries Fund (FIF) and REAP tax credits to help farmers purchase no-till equipment. FIF is administered by DCED through PDA and the PA Grows Program. REAP is administered through the State Conservation Commission.
- Provide financial incentives through the State Conservation Commission or Growing Greener II to help farmers transition into a continuous no-till system.
- Promote and encourage nutrient trading as a method to cover initial crop losses due to the switch to a no-till system.
- Fund research projects investigating no-till and continuous no-till systems. One particular project, which is in immediate need, is to fund research about new ways to manage manure, given that no-till does not allow for the incorporation of manure into the soil. Incorporation is currently one of the preferred manure management methods, as it is the best way to reduce odors from manure application. (This research is taking place at Penn State and other universities.)
- Implement a Core 4 approach to conservation in Pennsylvania. Core 4 is a common-sense approach to improving farm profitability while addressing environmental concerns. The approach is easily adaptable to virtually any farming situation and can be fine tuned to meet the farmer's unique needs. The net result is better soil, cleaner water, and greater on-farm profits. No-till is a key component of Core 4.
- Secure a National No-Till Conference for the Pennsylvania Farm Show Complex.
- Highlight no-till and agricultural carbon sequestration opportunities for farmers at the Pennsylvania Farm Show and other agricultural events.
- Advance a privately administered carbon credit trading program in Pennsylvania that generates marketable credits through implementation of environmental practices in agricultural production, providing for reasonable ease in the selling and buying of marketable carbon credits, with vigorous protocols and verification.

Regenerative Farming Practices:

Data Sources/Assumptions/Methods for GHG:

For the purpose of this analysis, it is assumed that the number of acres managed with regenerative farming practices will increase by 10 percent per year from 2010 to 2020. The baseline number of acres is estimated with the total number of organic acres harvested.[52] Table 5-4 summarizes the schedule for the implementation of planting cover crops on new acreage. It is assumed that in the early years of transitioning to cover crops, carbon is sequestered at a rate of 1.104 tCO_2e/acre-year (744 kg C/ha-year).[53] Adoption of cover crop use would result in a total of 0.3 $MMtCO_2e$ being sequestered during the policy period.

Table 5-4. GHG Reductions and Costs from Adoption of Regenerative Farming Practices

Year	Annual New Acres Using Regenerative Farming Practices Added	Cumulative Low-Yield Acres	Cumulative Normal-Yield Acres	Cumulative tCO_2e Sequestered	Annual Costs Low-Yield Acres	Annual Costs Normal-Yield Acres	Discounted Costs (5%, 2007$)
2009	0	0	0	-	-	-	$0
2010	2,885	2,885	0	3,185	456,442	-	$394,292
2011	3,173	6,058	0	6,688	958,528	-	$788,583
2012	3,490	9,548	0	10,541	1,510,823	-	$1,183,769
2013	3,839	13,387	0	14,780	2,118,347	-	$1,580,743
2014	4,223	14,726	2,885	19,442	2,330,182	-$16,042	$1,644,616
2015	4,646	16,199	6,058	24,571	,563,200	-$33,689	$1,712,072
2016	5,110	17,819	9,548	30,213	2,819,520	-$53,101	$1,783,259
2017	5,621	19,601	13,387	36,419	3,101,472	-$74,453	$1,858,327
2018	6,183	21,561	17,611	43,245	3,411,619	-$97,941	$1,937,439
2019	6,802	23,717	22,256	50,755	3,752,781	-$123,778	$2,020,765
2020	7,482	26,088	27,367	59,015	4,128,059	-$152,198	$2,108,484
		TOTAL		**298,854**			**$16,618,058**

Data Sources/Assumptions/Methods for Costs:

The cost per acre for farmers to transition from conventional to regenerative farming practices is estimated at a savings of $5.56/acre.[54] This includes cover crop seed, fuel costs, labor, and equipment (including depreciation). This also accounts for savings from not using fertilizer, manure/compost, and chemicals/biologicals. During the first 4 years of transition to cover crops,

[52] USDA/NASS, 2007 Pennsylvania Ag Census, Table 48. Organic Agriculture: 2007, Accessed June 2009.

[53] The legume-based organic system in the Rodale Institute Farming Systems Trial (FST) has sequestered 744 (+/- 262) kg C/ha/yr during the first 13-year transition period of using cover crops, and has measured an average of 574 kg C/ha/year over a period of 22 years; Rodale Institute, Greg Bowman and Alison Grantham, communicated via email and subcommittee conference call to Rachel Anderson, CCS, June 2009

[54] http://www.rodaleinstitute.org/cropcalculator, assuming the main crop is corn, non-organic cover crop seed is $45 per 100 acres (70% of organic cover crop seed cost); accessed June 2009; costs deflated from $2009 to $2007 by dividing by 1.105009.

there is a 20 percent yield decrease. The yield rebounds after 3–5 years. The yield decrease was estimated to cost $163.80/acre.[55] It is assumed that new acres using cover crops are not converted to organic production. The total cost for the policy period is $16.6 million, with a cost-effectiveness of $56/tCO_2e$.

<u>Possible New Measure(s):</u>

1. Build consensus on the viability of setting net carbon target levels.
2. Set positive-negative ratings for practices.
3. Establish the threshold figure (net carbon impact) needed to trigger payment.
4. Consider the public benefit to add a premium incentive for farmers who pay for annual inspections documenting compliance with whole-farm system plans (such as USDA's National Organic Program) whose selected practices rate high for high sequestration.
5. Determine an incentive for long-term positive practices, as well as year-to-year improvements.

The Regenerative Farming Practices Initiative (RFPI) will encourage and guide farmers to convert to cropping practices that generate a net increase in the amount of carbon sequestered through a crop cycle. Husbandry, mechanical, and biological practices will be rated on their estimated positive or negative GHG contribution, expressed as carbon equivalent (kg Ce/ha) to allow assessment of a range of climate change impacts.

This initiative has the potential to tip the carbon balance, helping Pennsylvania agriculture to become a net carbon sink through agronomically recommended practices, such as crop rotation, cover crops, composting, and limited- or no-till planting. Research-based ratings for farm practices show whether, and to what extent, the practice emits or sequesters carbon (Lal, 2004). This initiative allows policymakers to determine the target level of carbon impact they wish to reward, and how well they want to reward it.

By crediting farmers for “carbon-positive” (sequestering) practices, the policy increases the potential for significant biological soil improvement that can, over time, both sequester carbon and reduce soil erosion, which is considered to be another major source of agriculturally released CO_2. The rating system developed through this program will show the GHG impact of some common practices, giving farmers a new tool to help develop their fertility, crop establishment, and pest management activities in ways that have more beneficial impacts on the environment.

Carbon-positive (sequestering) practices, measured in units of carbon per area, include cover crops, use of manure or compost and integrated nutrient management practices, complex crop rotations, and integrated livestock operations where livestock waste nutrients are recycled back to the fields that produce their feed (pasture or crops). These practices sequester 50–250 kg/ha of carbon.

[55] See previous footnote. Yield drops from 143 to 114.4/acre with a selling price of $6 resulting in a net decrease of $171.60 income per acre; this with deflated from $2009 to $2007 by dividing by 1.105009.

Carbon-negative (emitting) practices, measured in carbon-equivalency (Ce) units per area, include energy-intensive harvesting (corn silage set at 19.6 kg Ce/ha), tillage (especially primary tillage, with emissions of 11–15 kg Ce/ha), all mechanical operations (1–6 kg Ce/ha), and application of pesticides and nitrogen fertility (1.3–6.3 kg Ce/ha).

The figures show that carbon-positive farming practices have a relatively robust positive impact on carbon sequestration, especially when compared to the carbon output of the commonly used carbon-negative practices (the difference is roughly an order of magnitude).

By basing farmers first-year RFPI payment on their practices (both positive and negative) in the prior year, farmers with better existing practices will be rewarded. In succeeding years, an "improvement incentive" for incremental improvement could further reward farmers who add regenerative practices or reduce carbon-degrading practices.

Note: GHG yearly impact figures are expressed in kg/ha, above, while the Pennsylvania application, below, is in pounds per acre (lb/ac). The relative impacts of practices are similar; actual conversions are 1 kg/ha = 0.893 lb/ac or 1 lb/ac = 1.121 kg/ha.

Potential Overlap: Not applicable. The potential for overlap between this work plan and the work plan for Waste-to-Energy Digesters was evaluated and it was determined that there is sufficient manure feedstock for both work plans so no overlap was calculated.

Notes/Other Considerations:

Full potential: If Pennsylvania crop and pasture acreage (2008 = 3.9 million acres) used highly regenerative cropping systems (using cover crops, complex crop rotations, and compost as a soil amendment) sequestering 2,000 lb C/ac, the total carbon trapped (13.2 MMt/CO_2e) would offset all the projected 2010 GHG for industrial-sector processes in PA (also 13 MMtCO_2e) (PEC Roadmap). If the cropland management changes are calculated at only half that carbon sequestration rate (1,000 lb C/ac), the change would still make the agriculture sector for Pennsylvania carbon-neutral for its 2010 projection of 6 MMtCO_2e.

By pioneering agricultural sequestration, Pennsylvania would be in a strong position to partner with states with much more agricultural land relative to their total GHG emissions, helping to mitigate more of Pennsylvania's estimated 2010 net GHG load of 320 MMtCO_2e.

Some additional benefits of this work plan include:

- Working with farmland preservation efforts, this initiative could increase public benefit and preserved farm profitability by improving the farms' soil-carbon levels and their resiliency.
- Working with farmers seeking to re-integrate livestock onto their farms, perennial sod crops used as pasture could become part of their rotation.
- Increasing soil carbon greatly improves a soil's ability to absorb and hold water, dramatically increasing yield potential during drought and decreasing flood potential.

Subcommittee Comments

Regenerative Farming Practices: Increase the net carbon sequestration capacity of Pennsylvania agriculture in two ways: 1) by increasing the acres of farmland managed with regenerative cropping practices that improve the rate of biological sequestration of atmospheric carbon as soil organic matter; 2) by decreasing practices, and the use of products, which release carbon into the atmosphere.

Comments from Public Participation on Subcommittee and Expert Opinion from Soil Scientists:

1. [Here is] a review paper published a couple of years ago (West and Post, 2002) and the introduction to a series of papers published in Soil and Tillage Research on the topic (Franzluebbers and Follet, 2005) as well as a paper highlighting carbon emission reductions with no-till (West and Marland, 2002). Both reviews concluded that carbon sequestration does take place with the adoption of no-tillage. I participated in discussions of the Technical Advisory Committee for the Chicago Climate Exchange that determined sequestration estimates for no-till and grassland. These values were not just plucked out of the air, but based on solid research. The recent controversy has been about the effect of sampling depth. There are some studies that show that carbon was merely distributed differently, but definitely not all studies. The issue of nitrous oxide emissions is still very uncertain, and difficult to measure accurately because of the very small emissions and huge variability. The issue of sampling each individual farm was discussed in the past but was basically rejected because it would be cost prohibitive to do such a thing. When one goes that route it basically eliminates agriculture from participating in carbon trading. Instead it was decided to go a similar route as soil erosion control, which we don't measure, but estimate using research-based models of impact of different practices.

2. The attached paper (Six et al. 2004) is also important – the effect of no-till on N2O emissions can more than balance any positive effect of no-till on soil C sequestration. We are very far from having a consensus on directional change in N2O emissions following conversion to no-till. In my view the former consensus that no-till consistently sequesters C is dissolving for reasons in the attached paper. There seems to be evidence building that no-till alters the depth distribution more than the total quantity of C in soil. But this may not be the case in PA – worth sampling this to figure it out. Verification (sampling on farms) sounds good but would be very difficult to implement.

It is important to note that there are existing carbon offset protocols that acknowledge this activity. Specifically, the Chicago Climate Exchange (CCX) has a protocol accepting projects that engage in "Ag Soil Carbon". It will be important to evaluate these project protocols and encourage pilot projects within Pennsylvania to more fully understand these opportunities. Furthermore, it has a direct relationship with the costs associated with this option, as such potential revenues for entering into such projects will impact the cost effectiveness.

As in other work plans, evaluation of this measure is complicated by the fact that it combines two separate practices which have different cost and emissions reduction values. Independent assessment of these practices would have allowed for a more meaningful consideration of their respective strengths and weaknesses. No-till, in particular, probably would have shown better as a stand-alone.

References:

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Post, W. and K. Kwon. 2000. Soil carbon sequestration and land-use change: processes and potential. *Global Change Biology* 6: 317-327

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The table below is from Robertson et al. 2000 (citation above), and summarizes potential GHG emissions reductions based on agronomic practices:

Table 2. Relative GWPs for different management systems based on soil carbon sequestration, agronomic inputs, and trace gas fluxes. Units are CO_2 equivalents (g m^{-2} $year^{-1}$) based on IPCC conversion factors (*20–22*). Negative values indicate a global warming mitigation potential. All systems are replicated as described in Table 1 and (*10*).

Ecosystem management	CO_2				N_2O	CH_4	Net GWP
	Soil C	N fertilizer	Lime	Fuel			
Annual crops (corn-soybean-wheat rotation)							
Conventional tillage	0	27	23	16	52	−4	114
No till	−110	27	34	12	56	−5	14
Low input with legume cover	−40	9	19	20	60	−5	63
Organic with legume cover	−29	0	0	19	56	−5	41
Perennial crops							
Alfalfa	−161	0	80	8	59	−6	−20
Poplar	−117	5	0	2	10	−5	−105
Successional communities							
Early successional	−220	0	0	0	15	−6	−211
Midsuccessional (HT)*	−32	0	0	0	16	−15	−31
Midsuccessional (NT)*	0	0	0	0	18	−17	1
Late successional forest	0	0	0	0	21	−25	−4

*HT, historically tilled; NT, never tilled.

APPENDIX K
Forestry Work Plans

Summary of Work Plan Recommendations

Work Plan No.	Work Plan Name		Annual Results (2020)			Cumulative Results (2009-2020)			CCAC Voting Results (Yes / No / Abstained)
			GHG Reductions ($MMtCO_2e$)	Costs (Million $2007)	Cost-Effectiveness ($\$/tCO_2e$)	GHG Reductions ($MMtCO_2e$)	Costs (NPV, Million $2007)	Cost-Effectiveness ($\$/tCO_2e$)	
Forest Growth and Protection/Avoided Conversion									
1*	Forest Protection Initiative -- Easement		0.178	$0	$0	12.22	$67.5	$5.53	21 / 0 / 0
3*	Forestland Protection and Avoided Conversion -- Acquisition								21 / 0 / 0
Option	Total acreage protected	Develop-ment threat							
A	80,000	100%	0.178	$0	$0	14.60	$236.4	$16.19	
A	80,000	50%	0.178	$0	$0	8.23	$236.4	$28.71	
A	80,000	20%	0.178	$0	$0	4.41	$236.4	$53.58	
A	80,000	10%	0.178	$0	$0	3.14	$236.4	$75.33	
A	240,000	100%	3.72	$37.1	$9.99	41.68	$590.9	$14.18	
A*	240,000	50%	2.13	$37.1	$17.47	22.57	$590.9	$26.18	
A	240,000	20%	1.17	$37.1	$31.74	11.11	$590.9	$53.20	
A	240,000	10%	0.85	$37.1	$43.62	7.28	$590.9	$81.12	
A	400,000	100%	7.26	$72.2	$10.23	68.76	$945.3	$13.75	
A	400,000	50%	4.07	$72.2	$18.23	36.91	$945.3	$25.61	
A	400,000	20%	2.16	$72.2	$34.35	17.80	$945.3	$53.11	
A	400,000	10%	1.52	$72.2	$48.70	11.43	$945.3	$82.71	
B	64,745	100%	1.7	$18.50	$10.69	10.98	$226.6	$13.22	
B	129,556	100%	3.5	$36.99	$10.69	21.97	$453.4	$13.22	
B	259,046	100%	6.9	$73.99	$10.69	43.94	$906.7	$13.22	
B	129,556	20%	0.9	$36.99	$40.11	5.47	$453.4	$53.14	
B	129,556	10%	0.6	$36.99	$61.16	3.40	$453.4	$85.35	
Increased Utilization of Durable Wood Products									
2	Woodnet		*Qualitative option*						14 / 6 / 1
6*	Durable Wood Products								21 / 0 / 0
	1.12 Bbf/year (2006 PA harvest)*		0.73	NQ	NQ	8.77	NQ	NQ	
	1.5 Bbf/year		0.98	NQ	NQ	11.74	NQ	NQ	
	80 Mbf/year (2006 State Forest harvest)		0.04	NQ	NQ	0.46	NQ	NQ	
Reforestation, Afforestation, Regeneration									
4	Reforestation, Afforestation, Regeneration		3.98	$41.9	$10.52	25.89	$568.7	$21.97	21 / 0 / 0
5	Improved Forest Management								21 / 0 / 0
Scenario	Shift to uneven-aged management								

Work Plan No.	Work Plan Name	Annual Results (2020) GHG Reductions ($MMtCO_2e$)	Annual Results (2020) Costs (Million $2007)	Annual Results (2020) Cost-Effectiveness ($\$/tCO_2e$)	Cumulative Results (2009-2020) GHG Reductions ($MMtCO_2e$)	Cumulative Results (2009-2020) Costs (NPV, Million $2007)	Cumulative Results (2009-2020) Cost-Effectiveness ($\$/tCO_2e$)	CCAC Voting Results (Yes / No / Abstained)
2	Shift 20% of even-aged management to uneven-aged	0.26	NQ	NQ	0.82	NQ	NQ	
3	Shift 50% of even-aged management to uneven-aged	0.65	NQ	NQ	2.04	NQ	NQ	
4	Shift 75% of even-aged management to uneven-aged	0.97	NQ	NQ	3.07	NQ	NQ	
Scenario	Restock understocked forestland**							
1	Restock 100% of poorly stocked forest	(5.1)	$66.8	$13.08	(75.1)	$1,063	$14.15	
2	Restock 100% of poorly stocked forest and 50% of moderately stocked forest	(26.3)	$264.4	$10.04	(359.1)	$4,209	$11.72	
3	Restock 100% of poorly stocked forest and 100% of moderately stocked forest	(47.6)	$462.1	$9.71	(643.1)	$7,355	$11.44	
Urban Forestry								
7*	Urban Forestry							21 / 0 / 0
	Increment existing urban forest by 10%	1.20	-$560	-$468.15	7.78	-$4,399	-$565.74	
	Increment existing urban forest by 25%*	2.99	-$1,400	-$468.15	19.44	-$10,997	-$565.74	
	Increment existing urban forest by 50%	5.98	-$2,800	-$468.15	38.88	-$21,994	-$565.74	
Wood-based Energy								
8*	Wood to Electricity	0.26	$0.18	$0.67	1.71	$2.8	$3.14	21 / 0 / 0
9*	Biomass Thermal Energy Initiatives							21 / 0 / 0
	Combined heat and power*	0.47	-$21.1	-$45.30	3.03	-$151.5	-$50.03	
	Fuels for Schools*	0.61	-$33.9	-$55.23	3.99	-$258.8	-$64.78	
Sector Total After Adjusting for Overlaps*		11.3	-$1,376	-$121	98	-$10,177	-$104	
Reductions From Recent State and Federal Actions		0.0	$0.0	$0.0	0.0	$0.0	$0.0	
Sector Total Plus Recent Actions		11.3	-$1,376	-$121	98	-$10,177	-$104	

GHG = greenhouse gas; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent; $\$/tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; NPV = net present value; Mbf = thousand board feet; Bbf = billion board feet; NQ = Not Quantified.

Negative values in the Cost and the Cost-Effectiveness columns represent net cost savings.

The numbering used to denote the above draft work plans is for reference purposes only; it does not reflect prioritization among these important draft work plans.

* An asterisk identifies the work plan number and name (option) included in the "Sector Total After Adjusting for Overlaps."

** For the F-5 scenario (i.e., restocking of undestocked forestlands), the analysis estimates an emissions increase relative to baseline conditions associated with site preparation and planting, and these increases are recorded in parenthesis.

Forestry-1. Forest Protection Initiative—Easement

Initiative Summary: Increase the carbon sequestration benefits of Pennsylvania's (PA's) forestland by preserving the existing forest base and conserving additional forestland.

Goal: Protect 20,000 acres of forestland each year from 2009 to 2012.

Implementation Period: 2009–2020

Other Involved Agencies: DCNR, Bureau of Forestry

Possible New Measure(s): The goal of the PA Forest Growth & Protection Initiative is to augment the carbon-sequestering benefits of PA's forests by preserving the existing forest base and conserving additional forestland. This will be accomplished in two ways:

- Assisting local partners in acquiring open space, such as parks, greenways, river and stream corridors, trails, and natural areas; and
- Acquiring voluntary conservation easements with private landowners.

Data Sources/ Assumptions/ Methods:

Data Sources:

- J.E. Smith et al. 2006. *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the United States*, GTR NE-343. USFS Northern Research Station. (Also published as part of the U.S. Department of Energy (DOE) Voluntary GHG Reporting Program.)
- Data provided by the USFS for the PA Forestry Inventory and Forecast (I&F); program costs provided by DCNR.
- Austin, K. 2007. "The Intersection of Land Use History and Exurban Development: Implications for Carbon Storage in the Northeast." Undergraduate Thesis, Brown University.

Carbon savings from this option were estimated from two sources: (1) the amount of carbon that would be lost as a result of forest conversion to developed uses (i.e., "avoided emissions"); and (2) the amount of annual carbon sequestration potential that is maintained by protecting the forest area.

This scenario assumes that 50 percent of preserved forests are Oak-Hickory and 50 percent are Maple-Beech-Birch. These forest types were chosen because they are predominant in PA, each making up about 44 percent of total forest cover in PA (Forestry Inventory and Analysis [FIA]). The carbon sequestration rates for those types of forests were applied in deriving estimated sequestration totals.

(1) Avoided Emissions

Carbon savings from avoided emissions were calculated using estimates of total standing forest carbon stocks in PA, provided by the USFS as part of the Forestry I&F for PA (Table F-1).

Table F-1. Carbon Pools in Predominant PA Forests

Forest Carbon Pool	Oak-Hickory	Maple-Beech-Birch
	tC/acre	**tC/acre**
Live tree	35.8	36.7
Standing dead tree	1.6	2.6
Understory	0.7	0.7
Down dead wood	2.4	2.6
Forest floor	3.3	10.8
Soils	21.5	28.1
Total	65.3	81.5

tC = metric tons of carbon.

Loss of forests to development results in a large one-time surge of carbon emissions. In this case, it was assumed that 100 percent of the vegetation carbon stocks would be lost in the event of forest conversion to developed uses, with no appreciable carbon sequestration in soils or biomass following development. The soil carbon loss assumption is based on a study that shows about a 35 percent loss of soil carbon when woodlots are converted to developed uses (Austin, 2007). A comparison of data from the American Housing Survey[1] with land-use conversion data from the Natural Resources Inventory (NRI) suggests that, on average, two-thirds of the land area in a given residential lot is cleared during land conversion. Thus, it was assumed that, during forest conversion to developed use, 100 percent of the forest vegetation carbon and 35 percent of the soil carbon would be lost on 67 percent of the converted acreage.

To estimate avoided emissions, the total number of acres protected in a year was multiplied by the estimate of one-time carbon loss from biomass and soils due to development. In Maple-Beech-Birch forests, the estimated carbon loss was 56.2 tC/acre; in Oak-Hickory forests, it was 49.2 tC/acre. In both forest types, this estimate of carbon loss due to development is calculated as the sum of 100 percent of average standing vegetation carbon stocks (live + dead) and 35 percent of average soil carbon stocks (forest floor + mineral soil). This overall avoided carbon emissions estimate was then converted to $MMtCO_2e$ (Table F-3).

(2) Annual Sequestration Potential in Protected Forests

The calculations below use default carbon sequestration values for Oak-Hickory and Maple-Beech-Birch forest types in the northeastern United States (U.S. Forest Service [USFS] General Technical Report (GTR)-343, Tables A2 and A3) (Table F-2). Average annual carbon sequestration for these forest types was calculated over 125 years by subtracting carbon stocks in 125-year-old stands from carbon stocks in new stands and dividing by 125. Soil carbon density

[1] U.S. Census, http://www.census.gov/hhes/www/housing/ahs/ahs.html.

was assumed constant, and is not included in the calculation because default values for soil carbon density are constant over time in USFS GTR-343.

The total carbon savings associated with this option are summarized in Table F-3.

Table F-2. Forest Carbon Sequestration Rates in Protected Acreage

Forest Types	tC/ac (0 yr)	tC/ac (125 yr)	tC/ac/yr (average)
Oak-Hickory	23.0	110.7	0.7
Map-Bee-Birch	25.0	88.6	0.5

tC/ac/yr = metric tons of carbon per acre per year.

Table F-3. Carbon Avoided and Sequestered as a Result of Implementing Forestry-1

Year	Cumulative Acreage Preserved	Avoided one-time C emissions (MMtCO2e/ yr)	C storage in Cumulative Protected Acreage ($MMtCO_2e$/ yr)	Total C Savings (MMtCO2e/ yr)
2009	20,000	2.590	0.044	2.634
2010	40,000	2.590	0.089	2.678
2011	60,000	2.590	0.133	2.723
2012	80,000	2.590	0.178	2.767
2013	80,000	0.000	0.178	0.178
2014	80,000	0.000	0.178	0.178
2015	80,000	0.000	0.178	0.178
2016	80,000	0.000	0.178	0.178
2017	80,000	0.000	0.178	0.178
2018	80,000	0.000	0.178	0.178
2019	80,000	0.000	0.178	0.178
2020	80,000	0.000	0.178	0.178
Total	**80,000**	**10.358**	**1.864**	**12.222**

C = carbon; $MMtCO_2e$ - million metric tons of carbon dioxide equivalent.

Total Reductions: 12.222 million metric tons of carbon dioxide equivalent ($MMtCO_2e$)

Cost to Regulated Entities:

The cost of protecting forestland under Forestry-1 is calculated as the cost of easement purchase for private land. While in some regions of PA easement costs will be higher than in other regions, the estimated statewide easement cost is $1,000/ acre. Note that the easement cost calculated here could be used as a proxy for the "project implementation agreement" prescribed as part of the Climate Action Reserve forestry protocols. The cost-effectiveness of this option increases with time, as the acreage is preserved in the first four years of the program (Table F-4). The levelized cost-effectiveness of the program over the full implementation period is $5.53 per metric ton of carbon dioxide equivalent (tCO_2e).

Table F-4. Economic Costs of Protecting Forestland

Year	Acres Protected This Year	Total Cost	Discounted Costs ($2007)	Annual Cost-Effectiveness
2009	20,000	$20,000,000	$18,140,590	$6.89
2010	20,000	$20,000,000	$17,276,752	$6.45
2011	20,000	$20,000,000	$16,454,049	$6.04
2012	20,000	$20,000,000	$15,670,523	$5.66
2013	0	$0	$0	$0.00
2014	0	$0	$0	$0.00
2015	0	$0	$0	$0.00
2016	0	$0	$0	$0.00
2017	0	$0	$0	$0.00
2018	0	$0	$0	$0.00
2019	0	$0	$0	$0.00
2020	0	$0	$0	$0.00
Total	**80,000**	**$80,000,000**	**$67,541,914**	**$5.53 (average)**

Implementation Steps: Develop a set of criteria for evaluating proposed projects involving the protection of existing forestland to identify potentially significant carbon sequestration opportunities at low marginal costs and with associated environmental co-benefits. Consider using criteria, such as forest type/age and related carbon values—current and projected, landscape context (e.g., size, contiguity, connectivity), threat of conversion, economic analysis (e.g., opportunity, conversion and maintenance costs, potential credit eligibility), stocking levels/regeneration rates, ecological values, etc. To the greatest extent possible, use data that are currently available (e.g., FIA, Natural Resources Conservation Service [NRCS], etc.).

There is some potential applicability of the planned PA electronic map program (PAMAP), which will use periodic (~ every 3 years) remote sensing to detect land-use/land-cover change and could also be used to estimate changes in net biomass (or ecosystem) productivity.

Through LIght Detection And Ranging (LIDAR)/high-resolution land-cover data, identify and characterize baseline information on priority carbon sinks—high-value natural sequestration areas, including the largest remaining intact blocks of ecologically and economically functional interior forest. (See also Related Policies/Programs in Place.)

Consider enabling actions to reduce leakage. Investigate ways to estimate and understand leakage issues, including improvements in data capabilities to track land-use change. Focus efforts of multiple programs/agencies to reach out to landowners in these priority areas in order to share information on funding/technical assistance/management options that create alternatives to parcelization/fragmentation. Increase state (e.g., Community Conservation Partnership Program [C2P2]) funding for acquisition of priority forestland and for working forest conservation easements to protect forestland from conversion. Consider re-tooling the state's Forest Legacy program to reward landowners for retaining carbon value. Create a state tax credit for conservation of forestland by businesses and individuals. Review the Clean and Green program to identify opportunities for improving benefits to forest landowners. Explore opportunities for converting Conservation Reserve Enhancement Program (CREP) contracts and other forested riparian buffer projects to permanent riparian easements. Encourage and assist counties and municipalities that are interested in creating funding for local forest conservation projects.

Develop a model conservation easement that would incorporate carbon sequestration and trading and that would seamlessly work with emerging state and federal laws and regulations. Incorporate the land trust community's capacity and experience in monitoring and enforcing easements into emerging carbon monitoring programs to avoid reinventing the wheel.

Create financial incentives for landowners and land trusts to accomplish the objectives described above.

Beyond the objectives described above, determine how to interweave emerging PA and federal policy and carbon management mechanisms so that PA stakeholders can act expeditiously. DEP, the Pennsylvania Department of Transportation (PennDOT), and DCNR might consider establishing a joint "Carbon Service" to assist nonprofits, businesses, and consumers in the same way that agriculture agencies assist farmers. Or perhaps the cooperative extension services, chambers of commerce, and other existing entities might assume this responsibility.

DCNR and the Pennsylvania Land Trust Association might consider creating a program to enlist private forest landowners in a PA carbon-trading co-op or similar entity.

Depending on the eventual makeup of the federal climate regulatory system, PA should consider complementary programs to enhance it and speed up its implementation. For example, if programs to avoid deforestation are insufficient at the federal level, PA should enhance that aspect to incentivize landowners to participate, much in the way that many PA counties add their own funds to the state agricultural preservation program.

Currently, the standard practice for development in wooded areas is to completely clear the land. Incentives, education, and regulations should be put in place at the state and local levels to alter this practice and require replacement sufficient to actually make a difference. This will necessitate expanding the current tree-planting infrastructure, which includes growers of native trees, recruitment of volunteers, and husbandry training for landowners in suburban and urban areas.

PA will need some adaptive structure(s) to monitor changes, disseminate information, and assist ecosystem managers as natural communities change as a result of a changing climate.

Potential Overlap: None.

Subcommittee Comments

The goal of the PA Forest Growth & Protection Initiative is to augment the carbon sequestering benefits of PA's forests by preserving the existing forest base and conserving additional forest land. This will be accomplished in three ways:

- Assisting local partners in acquiring open space such as parks, greenways, river and stream corridors, trails, and natural areas
- Acquiring voluntary conservation easements with private landowners

It is important to note that there are existing carbon offset protocols that acknowledge this activity. Specifically, the Climate Action Reserve (CAR) has a protocol accepting projects that relate to "Avoided Conversion". It will be important to evaluate these project protocols and encourage pilot projects within Pennsylvania to more fully understand these opportunities. Furthermore, it has a direct relationship with the costs associated with this option, as such potential revenues for entering into such projects will impact the cost effectiveness.

This work plan should be re-quantified to include avoided emissions. Failing to do so likely undervalues the GHG reduction potential. Generally, the consideration of forest-related practices is complicated by the relatively short time horizon for this process. Forest measures have the potential to achieve substantial GHG reductions, but much of these gains are likely to be realized on a longer-term basis--beyond 2020. This work plan only evaluates implementation through 2012. If we assume continued investment and activity over the full study period (a reasonable expectation), potential reduction values would be higher.

Forestry-2. Woodnet

Initiative Summary: Acknowledge, increase, and value the carbon sequestration benefits of durable wood products by encouraging expanded utilization of locally and sustainably produced wood products.

Goals:

- Expand the state's current green building efforts beyond the current LEED (Leadership in Energy and Environmental Design) standards to include a mandate for greater utilization of local wood products;
- Utilize local wood as a substitute material for government procurement; and
- Provide access to state financial assistance to logger and wood product companies for equipment resulting in improved efficiencies and reduced carbon emissions.

Implementation Period: 2009–2020

Other Involved Agencies: Pennsylvania Department of Agriculture, Hardwood Development Council, Department of Environmental Protection (DEP), Department of Community and Economic Development (DCED), General Services

Strategy Name: "Woodnet," or similar title aimed at the promotion of locally and sustainably produced and purchased wood products, along with the inclusion of structural wood within certified green building efforts as a lower-carbon alternative to steel and concrete.

Possible New Measure(s): The goal of the initiative is to promote the utilization of locally and sustainably produced wood products to extend the forest carbon storage cycle and reduce the emissions from the utilization of alternative products.

Data Sources/ Assumptions/ Methods:

Measures include lumber production and timber output in the state, utilization of locally and sustainably produced wood in state-financed buildings, and utilization of wood substitutes for high-carbon emission products by the commonwealth.

Durable products made from wood prolong the length of time forest carbon is stored and not emitted to the atmosphere. Wood products disposed of in landfills may store carbon for long periods under conditions that minimize decomposition and when methane gas is captured from landfills (carbon originally stored in wood products becomes methane during decomposition). Maintaining a sustainable harvest rate and converting it into a durable wood products pool increases carbon sequestration from forests. This can be achieved through improvements in production efficiency, product substitution, expanded product lifetimes, and other practices.

While expanded wood utilization is the long-term goal, an equally critical goal is to sustain the historic level of local wood products production and utilization. In 2008, eastern U.S. hardwood lumber production declined for the third straight year, with production declining about 20 percent from 2007. For the region, hardwood lumber production is at its lowest level since 1981. Additionally, 2009 production is estimated to decrease by as much as an additional 20 percent, and a fundamental change in the state's forest products economy is a distinct possibility.

While short-term impacts of any decreased wood products production on carbon sequestration will be minimal, long-term impacts are negative. More forested biomass will remain in the woods, eventually releasing its captured carbon back into the atmosphere. The net efficiency of Pennsylvania's forests to be carbon sinks will be reduced.

Decreased markets for wood products will financially impact public and private forestland owners. For private owners, lack of markets could result in an increase of acres being converted to other uses.

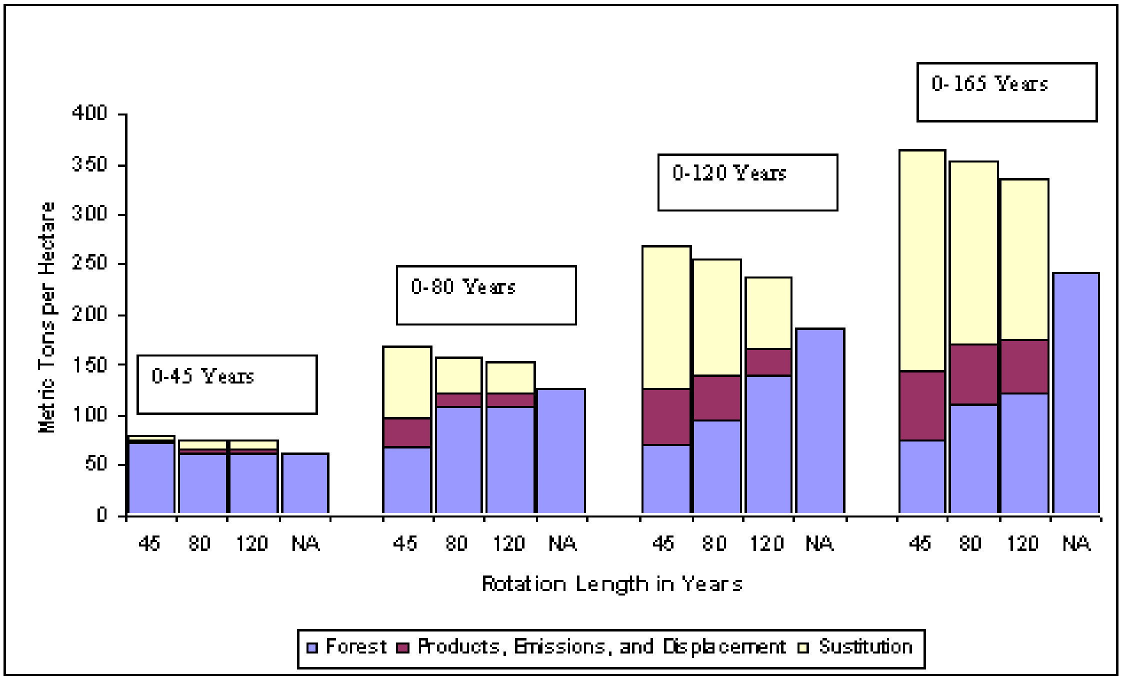
The current level of harvest is also lower than 1990 or other baseline years, which could result in a negative net impact on GHG reduction goals, should wood product production levels not improve.

There are secondary impacts as well. A vibrant forest products industry is essential to the success of any biomass-based energy initiatives, as mill and forestry residuals are an important source of biomass energy stock. The demand for traditional wood products also supports the local logger community and makes it economically viable (considering the fixed and regulatory costs) to harvest forest biomass for energy initiatives.

Current state green building policies encourage utilization of LEED standards that currently do not take into account the net carbon impact of its product standards. Furthermore, the current LEED scoring system may put local Pennsylvania wood producers at a disadvantage versus non-wood and foreign suppliers. The system currently recognizes only one "branded" sustainable forestry program, while limiting the credit garnered for the use of wood compared to other materials. (For example, LEED gives more credit for the use of bamboo product—grown on converted rainforest and produced and transported from half a world away—than it does to locally produced wood products sustainably managed from a Pennsylvania forest.).

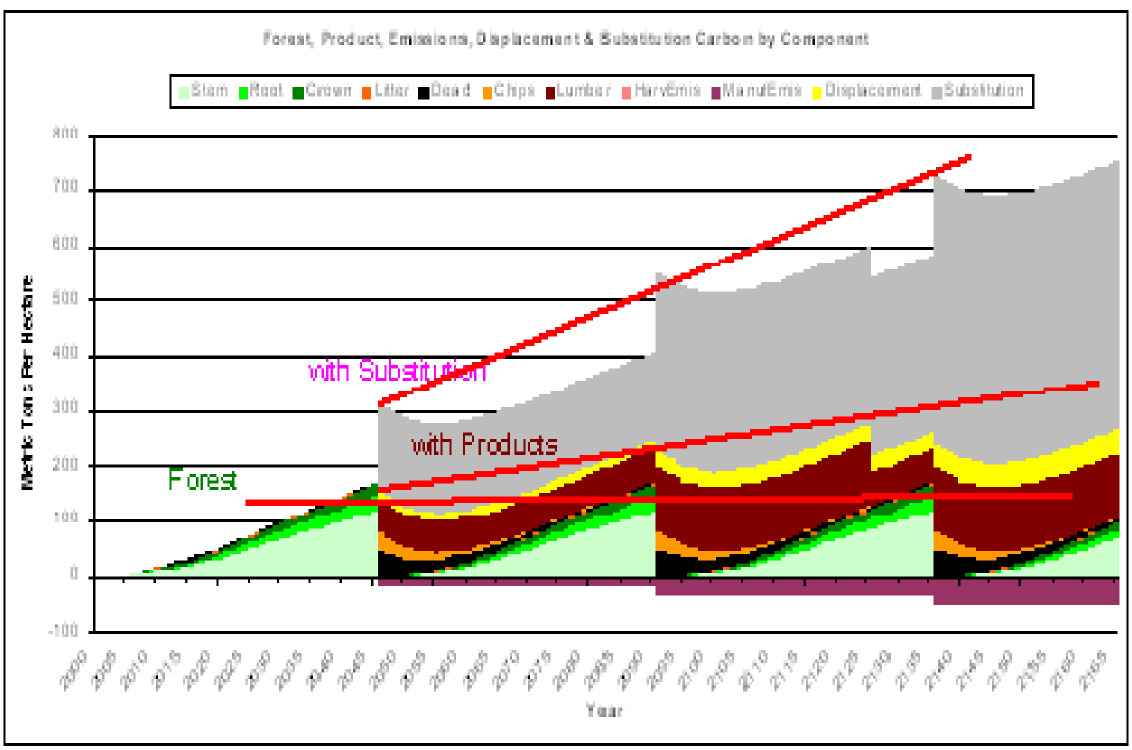
CORRIM: The Consortium for Research on Renewable Industrial Materials (CORRIM) provides relevant information on the GHG savings through construction materials, such as wood, steel, and concrete and their associated embodied energy. Figures F-1 and F-2 provide examples of the kinds of GHG reductions accomplished by substituting wood-based materials in place of materials with more embodied energy.

Figure F-1. Average Annual Carbon in Forest, Product and Concrete Substitution Pools for Different Rotations



Source: http://www.corrim.org/factsheets/fs_03/index.asp.

Figure F-2. Carbon in the Forest and Product Pools with Concrete Substitution for the 45-Year Rotation



Source: Additional information can be found at: http://www.corrim.org/factsheets/fs_03/index.asp.

Potential GHG Reduction: Varies and is yet to be calculated. DCNR Carbon Management (CMAG) members (See Forestry-6) suggests that efforts to support demand that would maintain state timber harvests at a level of 1.1 billion board feet annually would result in GHG reductions of .73 $MMtCO_2e$. Efforts to support demand that would increase timber harvests to 1.5 billion board feet (Bbf) annually (still a sustainable amount) would result in GHG reductions from 0.81 to 1.0 $MMtCO_2e$.

Cost to Regulated Entities: This effort would modify current commonwealth procurement and financing policies, which would require minimal up-front costs. The cost of the commonwealth's additional utilization of wood products is unknown.

Implementation Steps: This effort would modify current commonwealth procurement and financing policies.

Potential Overlap: Forestry-6 (Durable Wood Products)

Subcommittee Comments

The subcommittee believes there is merit to this work plan and further consideration is appropriate.

Forestry-3. Forestland Protection and Avoided Conversion—Acquisition

Initiative Summary:

The policy recommendations in the Landscape Preservation sector seek to examine the carbon benefits from various land conservation scenarios. Conservation might be accomplished in two ways: (1) direct DCNR purchase of forestland that might otherwise be converted (see Forestry-1 for a similar approach to quantifying the impacts of this strategy), and (2) incentives that seek to reduce the rate of conversion of privately owned land. The GHG benefit is twofold: avoided carbon emissions that might otherwise have taken place on converted acreage, and carbon storage on cumulative protected acreage. Note that Forestry-3 assumes direct fee-simple land acquisition as the implementation mechanism, while Forestry-1 assumes easement purchase for forest protection.

Possible New Measure(s):

Goals:

Option A:

Protect private forestland through direct acquisition or through various DCNR programs for open-space preservation. Three alternative scenarios are analyzed for this option. Scenario 1 is based on full implementation of Growing Greener II, and Scenarios 2 and 3 are based on expansion of the program.

- Scenario 1: Acquire 20,000 acres/year during 2009–2012.
- Scenario 2: Acquire 20,000 acres/year every year during 2009–2020.
- Scenario 3: Acquire 20,000 acres/year during 2009–2012, increase to 40,000 acres/year during 2013–2020.

Option B:

Reduce the likelihood of forestland conversion to developed use, by providing incentives to forest landowners rather than by direct purchase of easements.

- Scenario 1: Reduce the net rate of forest conversion by 25 percent by 2020.
- Scenario 2: Reduce the net rate of forest conversion by 50 percent by 2020.
- Scenario 3: Reduce the net rate of forest conversion to zero by 2020.
- Scenario 4: Same as Scenario 2, but assume conversion threat of 20 percent (i.e., 5 acres are protected for each acre that is not developed)
- Scenario 5: Same as Scenario 2, but assume conversion threat of 10 percent (i.e., 10 acres are protected for each acre that is not developed)

Implementation Period: 2009–2020

<u>Other Involved Agencies</u>: Not available

<u>Data Sources/ Assumptions/ Methods:</u>

<u>Data Sources:</u>

- J.E. Smith et al. 2006. *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the United States*, GTR NE-343. USFS Northern Research Station. (Also published as part of the U.S. Department of Energy (DOE) Voluntary GHG Reporting Program.)
- Data provided by the USFS for the PA Forestry Inventory and Forecast (I&F); program costs provided by DCNR.
- Strong, T.F. 1997. "Harvesting intensity influences the carbon distribution in a northern hardwood ecosystem." U.S. Department of Agriculture (USDA) Forest Service North Central Forest Experiment Station Research Paper NC-329.
- Austin, K. 2007. "The Intersection of Land Use History and Exurban Development: Implications for Carbon Storage in the Northeast." Undergraduate Thesis, Brown University.

<u>Option A:</u>

Carbon savings from this option were estimated from two sources: (1) the amount of carbon that would be lost as a result of forest conversion to developed uses (i.e., “avoided emissions”); and (2) the amount of annual carbon sequestration potential that is maintained by protecting the forest area.

Analysis for each of these sources was conducted across three scenarios, each with four sets of assumptions about development threat. The three scenarios differ with regard to number of acres preserved per year (see Table F-5). In all scenarios, 50 percent of preserved forests are Oak-Hickory and 50 percent are Maple-Beech-Birch. These forest types were chosen because they are predominant in PA, each making up about 44 percent of total forest cover in PA (FIA).

Table F-5. Alternative Acreage Scenarios Used to Calculate Carbon Savings

Scenario	Acres Acquired per Year
Scenario 1	20,000 in 2009–2012
Scenario 2	20,000 in 2009–2020
Scenario 3	20,000 in 2009-2012; increase to 40,000 in 2013–2020

Each scenario was calculated under four sets of assumptions regarding the threat level for development of PA forestlands:

- Assumption A—100 percent of land acquired under the program would have been developed if the program did not exist;
- Assumption B—50 percent of acquired land would otherwise have been developed;

- Assumption C—20 percent of the acquired land would otherwise have been developed; and
- Assumption D—10 percent of the acquired land would otherwise have been developed.

(1) Avoided Emissions

Carbon savings from avoided emissions were calculated using estimates of total standing forest carbon stocks in PA, provided by the USFS as part of the Forestry I&F for PA (Table F-6).

Table F-6. Carbon Pools in Predominant PA Forests

Forest Carbon Pool	Oak-Hickory	Maple-Beech-Birch
	tC/acre	**tC/acre**
Live tree	35.8	36.7
Standing dead tree	1.6	2.6
Understory	0.7	0.7
Down dead wood	2.4	2.6
Forest floor	3.3	10.8
Soils	21.5	28.1
Total	65.3	81.5

tC = metric tons of carbon.

Loss of forests to development results in a large one-time surge of carbon emissions. In this case, it was assumed that 100 percent of the vegetation carbon stocks would be lost in the event of forest conversion to developed uses, with no appreciable carbon sequestration in soils or biomass following development. The soil carbon loss assumption is based on a study that shows about a 35 percent loss of soil carbon when woodlots are converted to developed uses (Austin, 2007). A comparison of data from the American Housing Survey[2] with land-use conversion data from the Natural Resources Inventory (NRI) suggests that, on average, two-thirds of the land area in a given residential lot is cleared during land conversion. Thus, it was assumed that, during forest conversion to developed use, 100 percent of the forest vegetation carbon and 35 percent of the soil carbon would be lost on 67 percent of the converted acreage.

To estimate avoided emissions, the total number of acres protected in a year was multiplied by the estimate of one-time carbon loss from biomass and soils due to development. In Maple-Beech-Birch forests, the estimated carbon loss was 56.2 tC/acre; in Oak-Hickory forests, it was 49.2 tC/acre. In both forest types, this estimate of carbon loss due to development is calculated as the sum of 100 percent of average standing vegetation carbon stocks (live + dead) and 35 percent of average soil carbon stocks (forest floor + mineral soil). This overall avoided carbon emissions estimate was then converted to $MMtCO_2e$ (Table F-7).

Only the acres that would have otherwise been converted to forests are considered in the avoided emissions calculation. Thus, the results are sensitive to the four sets of assumptions about conversion threat. Table F-7 shows the annual and total acres acquired by the program and

[2] U.S. Census, http://www.census.gov/hhes/www/housing/ahs/ahs.html.

associated avoided emissions that would be generated under each of the three scenarios, and for each of the four alternative assumptions regarding level of development threat. While some of the biomass lost during clearing might be used for bioenergy production, this effect was not quantified in the analysis of Forestry-3.

Table F-7. Emissions Avoided by Protecting Forestland in PA

Scenarios	**Years**	**Acres Acquired**	**Avoided Emissions ($MMtCO_2e$)**			
			Assumption A (100% development threat)	*Assumption B (50% development threat)*	*Assumption C (20% development threat)*	*Assumption D (10% development threat)*
Scenario 1	2009–2012	20,000/yr	3.19/yr	1.59/yr	0.64/yr	0.32/yr
	2013–2020	0/yr	0/yr	0/yr	0/yr	0/yr
	Total	80,000	12.74	6.37	2.55	1.27
Scenario 2	2009–2012	20,000/yr	3.19/yr	1.59/yr	0.64/yr	0.32/yr
	2013–2020	20,000/yr	3.19/yr	1.59/yr	0.64/yr	0.32/yr
	Total	240,000	38.22	19.11	7.64	3.82
Scenario 3	2009–2012	20,000/yr	3.19/yr	1.59/yr	0.64/yr	0.32/yr
	2013–2020	40,000/yr	6.37/yr	3.19/yr	1.27/yr	0.64/yr
	Total	400,000	63.70	31.85	12.74	6.37

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; yr = year.

(2) Annual Sequestration Potential in Protected Forests

The calculations in this section of the analysis used default carbon sequestration values for Oak-Hickory and Maple-Beech-Birch forest types in the northeastern United States (USFS GTR-343, Tables A2 and A3). Average annual carbon sequestration for these forest types was calculated over 125 years by subtracting carbon stocks in 125-year-old stands from carbon stocks in new stands and dividing the remainder by 125 (Table F-8). Soil carbon density was assumed constant, and is not included in the calculation because default values for soil carbon density are constant over time in USFS GTR-343.

Table F-8. Forest Carbon Sequestration Rates

Forest Types	**tC/ac (0 yr)**	**tC/ac (125 yr)**	**tC/ac/yr (average)**
Oak-Hickory	23.0	110.7	0.7
Map-Bee-Birch	25.0	88.6	0.5

tC/ac/yr = metric tons of carbon per acre/year.

The results for annual sequestration potential under each of the three scenarios and four sets of assumptions are given in Table F-9. Since forests preserved in one year continue to sequester carbon in subsequent years, annual sequestration potential includes benefits from acres preserved cumulatively under the program. Carbon sequestration in protected acreage is calculated on the cumulative acreage protected, and thus does not vary with the assumptions about development threat.

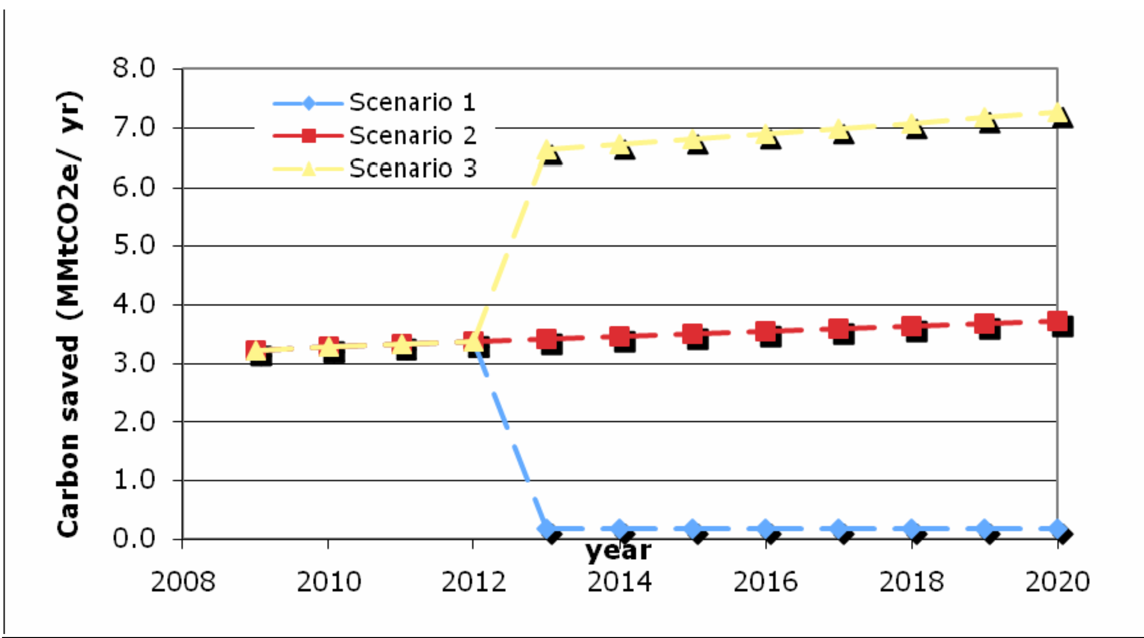
Table F-9. Annual Sequestration Potential in Protected Forests

Year	Cumulative Acres Preserved			C Storage in Protected Acreage ($MMtCO_2e$)		
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3
2009	20,000	20,000	20,000	0.044	0.044	0.044
2010	40,000	40,000	40,000	0.089	0.089	0.089
2011	60,000	60,000	60,000	0.133	0.133	0.133
2012	80,000	80,000	80,000	0.178	0.178	0.178
2013	80,000	100,000	120,000	0.178	0.222	0.266
2014	80,000	120,000	160,000	0.178	0.266	0.355
2015	80,000	140,000	200,000	0.178	0.311	0.444
2016	80,000	160,000	240,000	0.178	0.355	0.533
2017	80,000	180,000	280,000	0.178	0.399	0.621
2018	80,000	200,000	320,000	0.178	0.444	0.710
2019	80,000	220,000	360,000	0.178	0.488	0.799
2020	80,000	240,000	400,000	0.178	0.533	0.888
Total	**80,000**	**240,000**	**400,000**	**1.86**	**3.46**	**5.06**

C = carbon; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

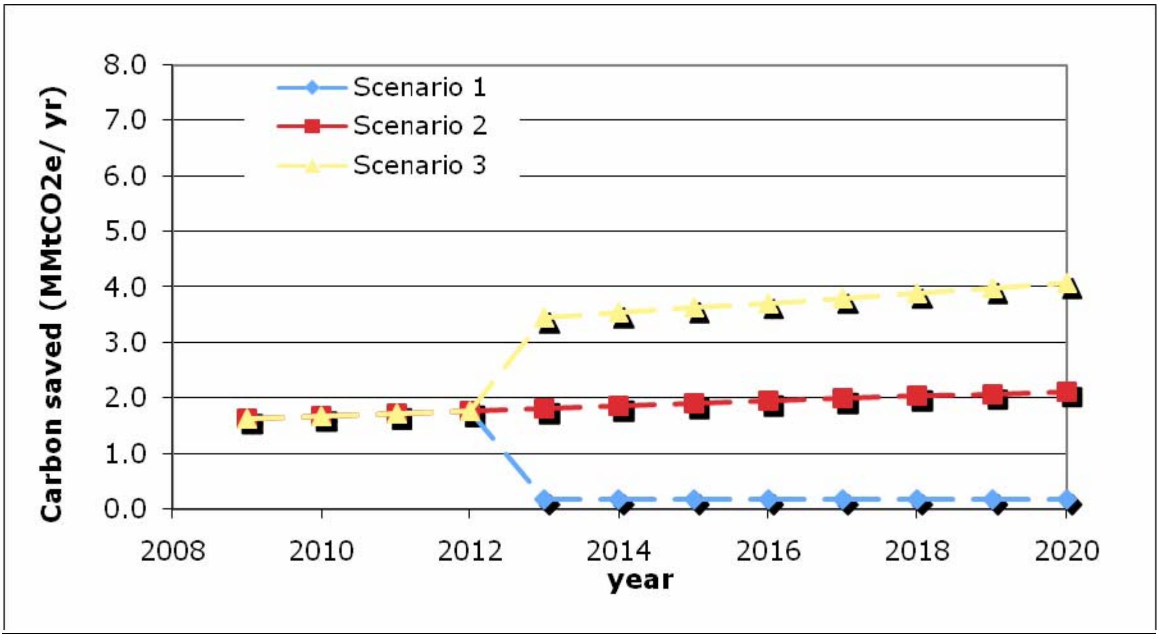
Figures F-3 through F-6 illustrate the projected total carbon savings, including both avoided emissions and sequestration potential through 2020, as a result of protecting PA forests under the three scenarios. Figure F-3 shows carbon savings under the assumption of 100 percent threat of development (Assumption A). If 50 percent threat of development is assumed (Assumption B), carbon savings are halved, to the levels illustrated in Figure F-4. Carbon savings decline further under the remaining Assumptions (C and D) about 20 percent and 10 percent development threat (Figures F-5 and F-6, respectively). Under all scenarios and assumptions, the majority of carbon savings result from avoiding emissions that would otherwise be generated by conversion.

Figure F-3. Carbon Savings Under Assumption A (100 percent development threat)



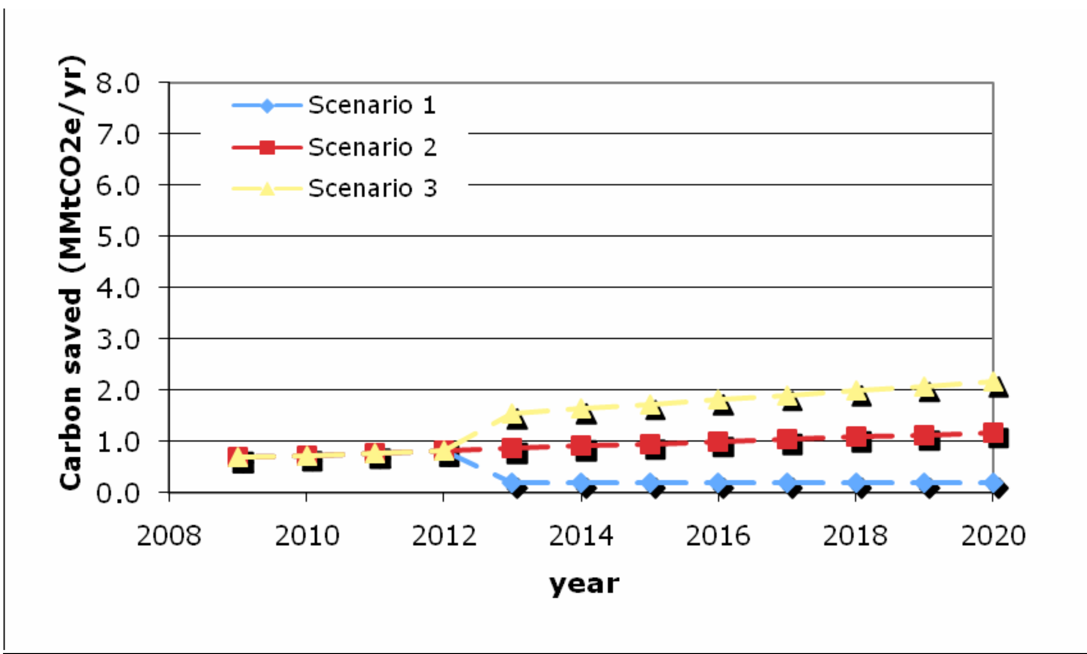
$MMtCO_2e/yr$ = million metric tons of carbon dioxide equivalent per year.

Figure F-4. Carbon Savings Under Assumption B (50 percent development threat)



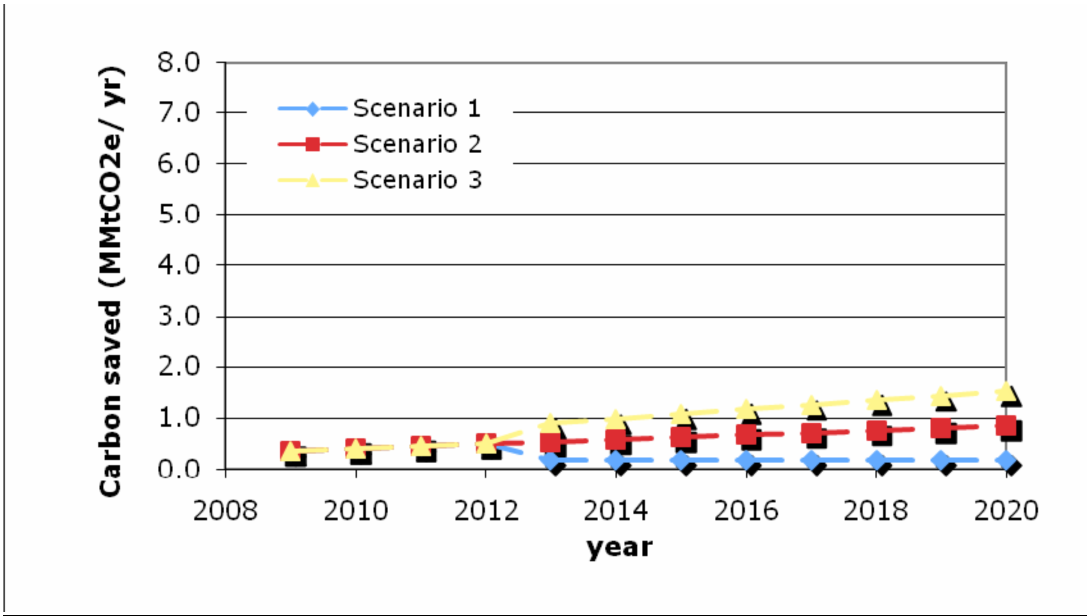
$MMtCO_2e/yr$ = million metric tons of carbon dioxide equivalent per year.

Figure F-5. Carbon Savings Under Assumption C (20 percent development threat)



$MMtCO_2e/yr$ = million metric tons of carbon dioxide equivalent per year.

Figure F-6. Carbon Savings Under Assumption D (10 percent development threat)



$MMtCO_2e$/yr = million metric tons of carbon dioxide equivalent per year.

Option B:

GHG benefits from this option were estimated from two sources: (1) the amount of carbon that would be lost as a result of forest conversion to developed uses (i.e., "avoided emissions"); and (2) the amount of annual carbon sequestration potential that is maintained by protecting the forest area.

In PA, the NRI estimated roughly 15.5 million acres of forest in 1997. Between 1982 and 1997, 902,900 acres of forest were converted to non-forest use (61,393 acres annually). Of this total, 597,900 acres were converted to developed use for a net annual loss of 39,860 forested acres to development statewide.

This corresponds to a net forest loss of 0.40 percent per year to all non-forest uses, or 0.26 percent loss annually to development alone. In this analysis, a baseline conversion rate of 39,860 acres per year was used, representing the rate at which forestland was lost to development annually between 1982 and 1997. Updated data on land conversion trends have not been released by NRI as of May 2009.

Analysis for each of these types of carbon savings (avoided emissions and sequestration on protected acreage) was conducted across five scenarios. The scenarios differ with regard to the number of acres not converted to development each year, as well as the number of acres that must be purchased to avoid land conversion to developed use (i.e., conversion threat) (see Table F-10). In all scenarios, 50 percent of preserved forests is assumed to be Oak-Hickory and 50 percent is assumed to be Maple-Beech-Birch. These forest types were used because they are predominant in PA, each making up about 44 percent of total forest cover in PA (FIA).

Table F-10. Alternative Acreage Scenarios Used to Quantify Carbon Savings From Avoided Forest Conversion to Developed Use

Scenarios	Cumulative Acreage Protected 2009–2020 (acres)	Goal Level, Protected Acreage by 2020 (acres/ year)	Annual Incremental Acreage Protected to Reach Goal (acres/ year)	Cumulative Acreage Not Developed 2009–2020 (acres)
Scenario 1: Reduce conversion rate by 25% by 2020	64,745	9,965	830	64,745
Scenario 2: Reduce conversion rate by 50% by 2020	129,556	19,930	1,661	129,556
Scenario 3: Achieve no net loss of forest to development by 2020	259,046	39,860	3,321	259,046
Scenario 4: Same as Scenario 2, but assume 20% conversion threat	129,556	19,930	1,661	25,904
Scenario 5: Same as Scenario 2, but assume 10% conversion threat	129,556	19,930	1,661	12,995

(1) Avoided Emissions

The forest carbon stocks (tons of carbon per acre) and annual carbon flux (annual change in tons of carbon per acre) data are based on default carbon sequestration values for Maple-Beech-Birch forest types in the northeastern United States (USFS GTR-343, Table A2). Annual rates of carbon sequestration (metric tons of carbon sequestered per acre per year) were calculated by subtracting total carbon stocks in forest biomass of 125-year-old stands from total carbon stocks in forest biomass of new stands and dividing the remainder by 125. Soil carbon density was assumed constant, and is not included in the annual carbon flux calculations because default values for soil carbon density are constant over time in USFS GTR-343. See Table F-5 above for an overview of forest carbon storage and sequestration information used in this analysis.

Loss of forests to development results in a large one-time surge of carbon emissions. In this case, it was assumed that 100 percent of the vegetation carbon stocks would be lost in the event of forest conversion to developed uses, with no appreciable carbon sequestration in soils or biomass following development. The soil carbon loss assumption is based on a study that shows about a 35 percent loss of soil carbon when woodlots are converted to developed uses (Austin, 2007). A comparison of data from the American Housing Survey[3] with land use conversion data from the NRI suggests that, on average, two-thirds of the land area in a given residential lot is cleared during land conversion. Thus, it was assumed that, during forest conversion to developed use, 100 percent of the forest vegetation carbon and 35 percent of the soil carbon would be lost on 67 percent of the converted acreage.

To estimate avoided emissions, the total number of acres protected in a year was multiplied by the estimate of one-time carbon loss from biomass and soils due to development. In Maple-Beech-Birch forests, this estimated C loss was 56.2 tC/ac; in Oak-Hickory forests, it was

[3] U.S. Census, http://www.census.gov/hhes/www/housing/ahs/ahs.html

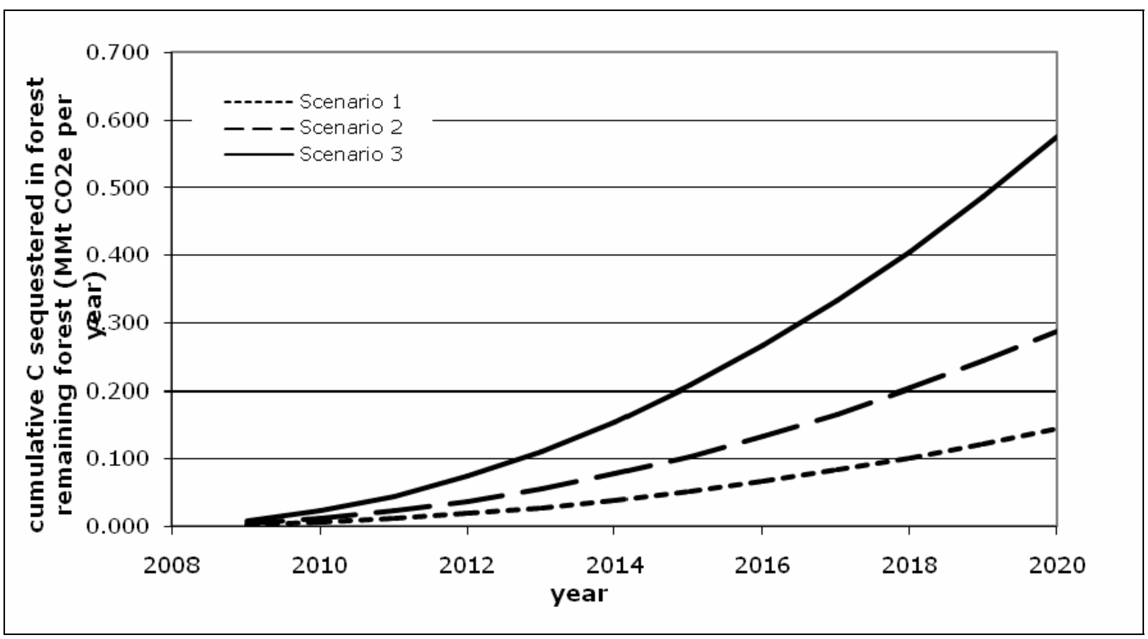
49.2 tC/ac. In both forest types, this estimate of carbon loss due to development is calculated as the sum of 100 percent of average standing vegetation carbon stocks (live + dead) and 35 percent of average soil carbon stocks (forest floor + mineral soil). This overall avoided carbon emissions estimate was then converted to $MMtCO_2e$ for inclusion in Table F-10 (below). While some of the biomass lost during clearing might be used for bioenergy production, this effect was not quantified in the analysis of Forestry-3.

For Scenarios 1–3, it was assumed that 100 percent of the protected land would otherwise have been converted to a developed use. Thus, for these scenarios the avoided emissions calculation was made on 100 percent of the protected acreage. Scenarios 4 and 5 assume that only 20 percent and 10 percent, respectively, of the land that is protected would otherwise have been developed. Calculations using these scenarios assume that the protected acreage is the same as under Scenario 2, but that avoided emissions due to land conversion occur on only a fraction of the acreage that is actually protected.

(2) Sequestration in Protected Forest

Forests not converted in a given year continue to sequester carbon each year they remain in a forested use. Thus, the carbon sequestration in protected forestland is calculated as annual sequestration in cumulative protected acreage. Annual sequestration for PA forest (tC/ac/yr) is calculated from NE-GTR-343 and is given in Table F-7 (above). As with avoided emissions from initial conversion, it is assumed that half of the protected forests is in Maple-Beech-Birch forest and half is in Oak-Hickory forest. Because acres protected in one year continue to store carbon in subsequent years, annual benefits of forest protection tend to accrue in later years of policy implementation (Figure F-7).

Figure F-7. Impact of Forest Protection From Conversion on Annual Carbon Sequestration in Cumulative Protected Acreage.



C = carbon; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

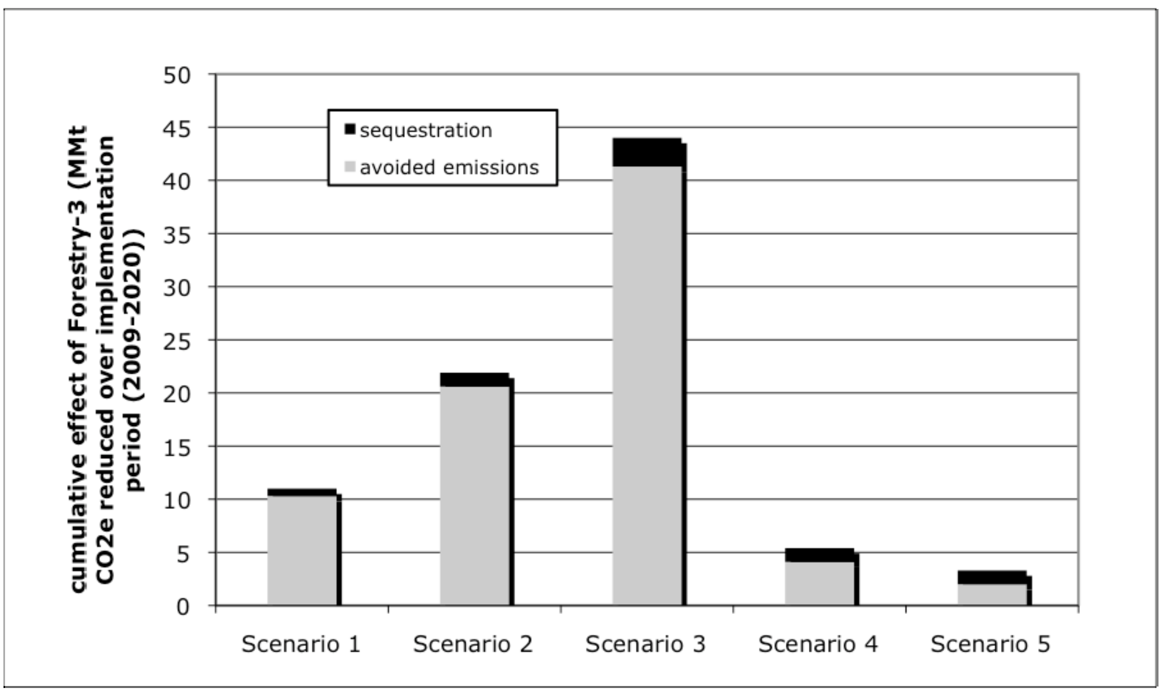
For Scenarios 1–3, the relative impact of avoided one-time emissions due to reduced forest conversion is roughly 14 times the impact of cumulative sequestration in protected acreage for all scenarios (Table F-11, Figure F-8). For Scenarios 4 and 5, the relative impact of avoided emissions from development is much smaller, consistent with the assumption that avoided emissions are effective on only a fraction of the forest land.

Table F-11. Summary of Avoided One-Time Emissions and Sequestration in Protected Forest Due to Reduced Forest Conversion (2009–2020)

Scenarios	Cumulative Acres Protected (2009-2020) (acres)	Cumulative GHG Benefit From Avoided One-Time Emissions (2009-2020) ($MMtCO_2e$)	Cumulative GHG Benefit From Carbon Sequestration in Protected Forest (2009–2020) ($MMtCO_2e$)
Scenario 1	64,745	10.3	0.7
Scenario 2	129,556	20.6	1.3
Scenario 3	259,046	41.3	2.7
Scenario 4	129,556	4.1	1.3
Scenario 5	129,556	2.0	1.3

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Figure F-8. Cumulative Effect of Five Scenarios on GHG Emissions Between 2009 and 2020



$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

<u>Economic Costs</u>:

<u>Option A:</u>

For Option A, the economic cost of avoiding conversion was calculated as the cost of land acquisition. This is a one-time cost per acre of protected land and is estimated at $3,500 per acre**.** This is a statewide average based on DCNR experience; however, it should be noted that this figure is not necessarily representative of those lands at most risk to development, primarily in southeastern PA.

Costs were assumed to be one-time costs applied in the year that land is acquired. Maintenance costs are assumed to be zero. The analysis does not take into account potential cost savings—e.g., avoided land-clearing costs and revenue from forest products on working forest lands that are protected under this policy. Discounted costs were estimated using a 5 percent interest rate, and costs were indexed to $2007. Total non-discounted and discounted costs under each scenario are provided in Table F-12. The cumulative cost-effectiveness of the total program was calculated by summing annual costs and dividing the total by cumulative carbon sequestration, yielding the results in Table F-13. Cost-effectiveness varies by which set of assumptions is used relative to development threat. Figure F-9 compares cumulative carbon savings and cost-effectiveness (calculated with discounted costs) for all scenarios.

Table F-12. Costs and Discounted Costs for Alternative Scenarios

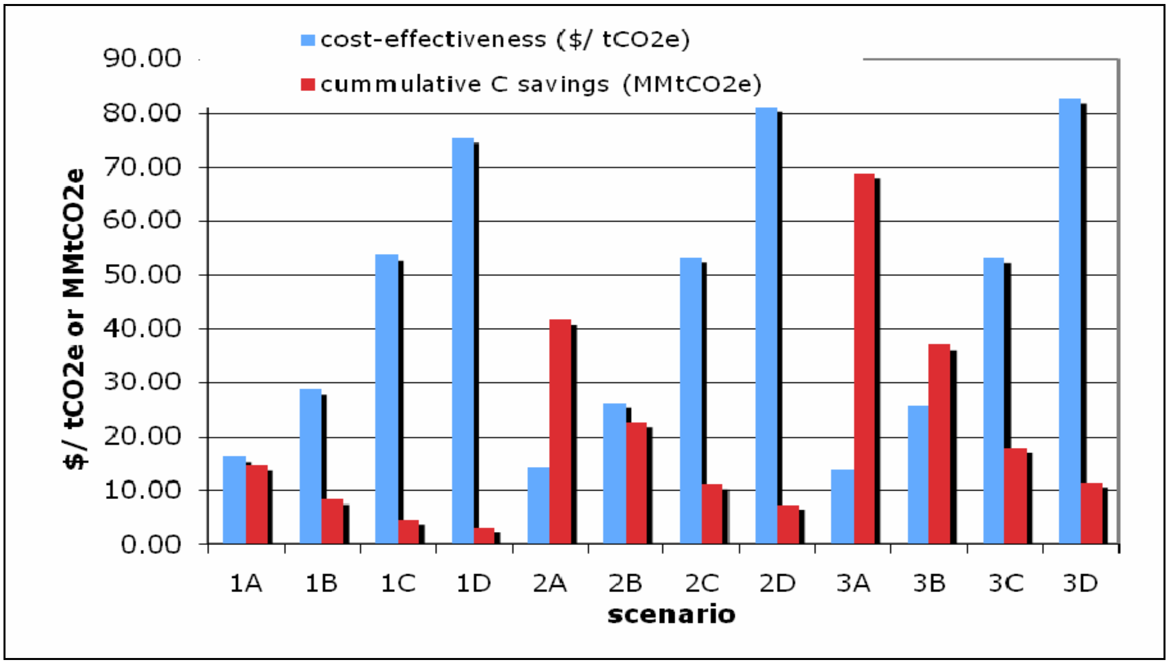
Scenarios	Total Acres Acquired	Non-Discounted Costs	Discounted Costs ($2007)
Scenario 1	80,000	$280,000,000	$236,396,700
Scenario 2	240,000	$840,000,000	$590,883,442
Scenario 3	400,000	$1,400,000,000	$945,370,185

Table F-13. Cost-Effectiveness of Alternative Scenarios

Land Acquisition Scenario	Development Threat	Cost-Effectiveness ($2007/t$CO_2$e)	Cumulative Carbon Savings (MMtCO_2e)
1	100% (A)	$16.19	14.60
1	50% (B)	$28.71	8.23
1	20% (C)	$53.58	4.41
1	10% (D)	$75.33	3.14
2	100% (A)	$14.18	41.68
2	50% (B)	$26.18	22.57
2	20% (C)	$53.20	11.11
2	10% (D)	$81.12	7.28
3	100% (A)	$13.75	68.76
3	50% (B)	$25.61	36.91
3	20% (C)	$53.11	17.80
3	10% (D)	$82.71	11.43

tCO_2e = metric tons of carbon dioxide equivalent; MMtCO_2e = million metric tons of carbon dioxide equivalent.

Figure F-9. Comparison of Scenarios in Terms of Cost-Effectiveness and Total Carbon Savings



$tCO_2e = dollars per metric ton of carbon dioxide equivalent; MMtCO_2e = million metric tons of carbon dioxide equivalent.

<u>Option B:</u>

The economic cost of avoiding conversion was calculated as the cost of acquiring conservation easements on private land. This is a one-time cost per acre of protected land and is estimated at $3,500 per acre. Half of this easement cost ($1,750) is typically paid by the state, with a 100 percent match from private funds.

The results of the economic analysis, without discounting, are shown in Table F-14. Since Scenarios 4 and 5 assume the same number of acres is purchased as in Scenario 2, the economic costs for Scenarios 2, 4, and 5 are equivalent.

A summary of the discounted and non-discounted costs is shown in Table F-15, and overall results of the analysis are given in Table F-16. Discounted costs were calculated assuming a 5 percent discount rate and 2007 dollars. The net present value (NPV) of each scenario is the sum of the discounted costs between 2009 and 2020. Levelized cost-effectiveness is calculated as the cost associated with avoiding or storing each tCO_2e. The levelized cost-effectiveness of this option is the same for Scenarios 1–3, at $14.08/$tCO_2e$. The levelized cost per tCO_2e reduced for Scenarios 4 and 5 is substantially larger, at $55.84/$tCO_2e$ and $88.75/$tCO_2e$, respectively.

Table F-14. Net Economic Costs of Avoided Forest Conversion (not discounted)

Year	Scenario 1	Scenarios 2, 4, and 5	Scenario 3
2009	$2,905,000	$5,813,500	$11,623,500
2010	$5,810,000	$11,627,000	$23,247,000
2011	$8,715,000	$17,440,500	$34,870,500
2012	$11,620,000	$23,254,000	$46,494,000
2013	$14,525,000	$29,067,500	$58,117,500
2014	$17,430,000	$34,881,000	$69,741,000
2015	$20,335,000	$40,694,500	$81,364,500
2016	$23,240,000	$46,508,000	$92,988,000
2017	$26,145,000	$52,321,500	$104,611,500
2018	$29,050,000	$58,135,000	$116,235,000
2019	$31,955,000	$63,948,500	$127,858,500
2020	$34,877,500	$69,755,000	$139,510,000
Cumulative	**$266,607,500**	**$453,446,000**	**$906,661,000**

Table F-15. Summary of Economic Costs of 5 Scenarios of Forest Preservation

Types of Economic Costs	Scenario 1	Scenarios 2, 4, and 5	Scenario 3
Total economic costs (non-discounted) ($ million)	$226.6	$453.4	$906.7
Total economic costs (NPV) ($2007) ($ million)	$145.2	$290.6	$581.0

NPV = net present value.

Table F-16. Summary of GHG Benefits and Economic Costs for 3 Scenarios Quantified Under Forestry-3, Option B

Scenarios	GHG Reduction Potential in 2010 ($MMtCO_2e$)	GHG Reduction Potential in 2020 ($MMtCO_2e$)	Cumulative GHG Reduction Potential 2009–2020 ($MMtCO_2e$)	Cost-Effectiveness ($2007 per tCO_2e)
Scenario 1: Reduce rate of conversion by 25% by 2020	0.3	1.7	11.0	$13.22
Scenario 2: Reduce rate of conversion by 50% by 2020	0.5	3.5	22.0	$13.22
Scenario 3: Achieve no net forest loss by 2020	1.1	6.9	43.9	$13.22
Scenario 4: Same as Scenario 2, but assume 20% conversion threat	0.1	0.9	5.5	$53.14
Scenario 5: Same as Scenario 2, but assume 10% conversion threat	0.1	0.6	3.4	$85.35

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent; tCO_2e = metric tons of carbon dioxide equivalent.

Key Assumptions: Forest protection will occur via easements, which cost $3,500/acre; 50 percent of protected forest will be in a Maple-Beech-Birch forest type, and 50 percent of protected forest will be in an Oak-Hickory forest type. Conversion threat values may range from 10 percent to 100 percent.

<u>Implementation Steps</u>: Develop a set of criteria for evaluating proposed projects involving the protection of existing forestland to identify potentially significant carbon sequestration opportunities at low marginal costs and with associated environmental co-benefits. Consider using criteria, such as forest type/age and related carbon values—current and projected, landscape context (e.g., size, contiguity, connectivity), threat of conversion, economic analysis (e.g., opportunity, conversion and maintenance costs, potential credit eligibility), stocking levels/regeneration rates, ecological values, etc. To the greatest extent possible, use data that are currently available (e.g., FIA, Natural Resources Conservation Service [NRCS], etc.).

There is some potential applicability of the planned PA electronic map program (PAMAP), which will use periodic (~ every 3 years) remote sensing to detect land-use/land-cover change and could also be used to estimate changes in net biomass (or ecosystem) productivity.

Through LIght Detection And Ranging (LIDAR)/high-resolution land-cover data, identify and characterize baseline information on priority carbon sinks—high-value natural sequestration areas, including the largest remaining intact blocks of ecologically and economically functional interior forest. (See also Related Policies/Programs in Place.)

Consider enabling actions to reduce leakage. Investigate ways to estimate and understand leakage issues, including improvements in data capabilities to track land-use change. Focus efforts of multiple programs/agencies to reach out to landowners in these priority areas in order to share information on funding/technical assistance/management options that create alternatives to parcelization/fragmentation. Increase state (e.g., Community Conservation Partnership Program [C2P2]) funding for acquisition of priority forestland and for working forest conservation easements to protect forestland from conversion. Consider re-tooling the state's Forest Legacy program to reward landowners for retaining carbon value. Create a state tax credit for conservation of forestland by businesses and individuals. Review the Clean and Green program to identify opportunities for improving benefits to forest landowners. Explore opportunities for converting Conservation Reserve Enhancement Program (CREP) contracts and other forested riparian buffer projects to permanent riparian easements. Encourage and assist counties and municipalities that are interested in creating funding for local forest conservation projects.

Develop a model conservation easement that would incorporate carbon sequestration and trading and that would seamlessly work with emerging state and federal laws and regulations. Incorporate the land trust community's capacity and experience in monitoring and enforcing easements into emerging carbon monitoring programs to avoid reinventing the wheel.

Create financial incentives for landowners and land trusts to accomplish the objectives described above.

Beyond the objectives described above, determine how to interweave emerging PA and federal policy and carbon management mechanisms so that PA stakeholders can act expeditiously. DEP, the Pennsylvania Department of Transportation (PennDOT), and DCNR might consider establishing a joint "Carbon Service" to assist nonprofits, businesses, and consumers in the same way that agriculture agencies assist farmers. Or perhaps the cooperative extension services, chambers of commerce, and other existing entities might assume this responsibility.

DCNR and the Pennsylvania Land Trust Association might consider creating a program to enlist private forest landowners in a PA carbon-trading co-op or similar entity.

Depending on the eventual makeup of the federal climate regulatory system, PA should consider complementary programs to enhance it and speed up its implementation. For example, if programs to avoid deforestation are insufficient at the federal level, PA should enhance that aspect to incentivize landowners to participate, much in the way that many PA counties add their own funds to the state agricultural preservation program.

Currently, the standard practice for development in wooded areas is to completely clear the land. Incentives, education, and regulations should be put in place at the state and local levels to alter this practice and require replacement sufficient to actually make a difference. This will necessitate expanding the current tree-planting infrastructure, which includes growers of native trees, recruitment of volunteers, and husbandry training for landowners in suburban and urban areas.

PA will need some adaptive structure(s) to monitor changes, disseminate information, and assist ecosystem managers as natural communities change as a result of a changing climate.

Potential Overlap: None.

Subcommittee Comments

The policy recommendations in the Landscape Preservation sector seek to examine the carbon benefit from various land conservation scenarios. Conservation might be accomplished in two ways: a) direct DCNR purchase of forest land that might otherwise be converted (see Forestry-1 for a similar approach to quantifying the impacts of this strategy), and b) incentives that seek to reduce the rate of conversion of privately owned land. The GHG benefit is twofold: avoided C emissions that might otherwise have taken place on converted acreage, and C storage on cumulative protected acreage. Note that Forestry-3 assumes direct fee-simple land acquisition as the implementation mechanism, while Forestry-1 assumes easement purchase for forest protection.

It is important to note that there are existing carbon offset protocols that acknowledge this activity. Specifically, the Climate Action Reserve (CAR) has a protocol accepting projects that relate to "Avoided Conversion". It will be important to evaluate these project protocols and encourage pilot projects within Pennsylvania to more fully understand these opportunities. Furthermore, it has a direct relationship with the costs associated with this option; as such potential revenues for entering into such projects will impact the cost effectiveness.

As in other plans, evaluation of these measures is made more challenging because we have lumped multiple practices and scenarios. I'm not sure the assessment process allows for full consideration of the relationship of a work plan to other strategies under review; for example, this work plan potentially helps make forest resources available for related and compatible initiatives, such as improved forest management, durable wood products and woody biomass. As in F-2, the benefits beyond 2020 are potentially significant, but are not considered here. Demographic factors are likely to create ongoing opportunities for forest conservation in PA during the study period, and sustained and strong interest/support for investments in land conservation can be expected. I'm still somewhat uncertain about the relationship of Option B to F-1, and would suggest that this be clarified (I recommended that F-1 include consideration of avoided emissions, which apparently was done in Option B).

Forestry-4. Reforestation, Afforestation, Regeneration

Initiative Summary: This option seeks to increase carbon stored in vegetation and soils through expanding the land base associated with terrestrial carbon sequestration. Establishing new forests ("afforestation") increases the amount of carbon in biomass and soils compared to preexisting conditions. Planting and afforestation can take place on land not currently experiencing other uses, such as abandoned mine lands (AMLs), brownfields, oil and gas well sites, marginal agricultural land, and riparian areas. In addition to planting forest cover, this policy option includes consideration of planting short-rotation woody crops and warm-season grasses on a variety of underutilized land-cover types.

This analysis focuses on the carbon sequestration benefit of afforestation only, and does not include the multiple co-benefits of afforestation (water, habitat, etc.).

Goals:
Increase carbon sequestration on land not being utilized (i.e., brownfields, AMLs, oil and gas well sites, marginal agricultural land, and riparian areas).

- Scenarios were designed for practicality, and include a scaled usage of available land in each land-use category (25 percent, 50 percent, 100 percent) for establishing one or a combination of the four vegetation types (afforestation with typical PA forest cover, warm-season grasses, short-rotation woody crops, riparian buffers) appropriate for that type of site.

Implementation Period: 2009–2020

Other Involved Agencies: DEP, Pennsylvania Department of Agriculture (PDA), Alliance for the Chesapeake Bay, Chesapeake Bay Foundation, The Western Pennsylvania Conservancy, USDA CREP

Data Sources/ Assumptions/ Methods:

Data Sources:

- J.E. Smith et al. 2006. *Methods for Calculating Forest Ecosystem and Harvested Carbon With Standards Estimates for Forest Types of the United States*, GTR NE-343. USFS Northern Research Station. (Also published as part of the DOE Voluntary GHG Reporting Program).
- USFS FIA data, provided by the USFS for the PA Forestry I&F. The carbon density data are from the Pennsylvania State Forest Carbon Inventory (Jim Smith, USFS).
- S. Walker et al. 2007. *Terrestrial Carbon Sequestration in the Northeast: Opportunities and Costs.,* Part 3A: "Opportunities for Improving Carbon Storage through Afforestation of Agricultural Lands." Available at: http://www.sampsongroup.com/Papers/carbon.htm.
- Duffy, M.D., and V.Y. Nanhou. 2002. "Costs of Producing Switchgrass for Biomass in Southern Iowa." In: *Trends in New Crops and New Uses.* J. Janick and A. Whipkey (eds.). ASHS Press, Alexandria, VA.

- Niu, X., and S.W. Duiker. 2006. Carbon sequestration potential by afforestation of marginal agricultural land in the midwestern U.S." *Forest Ecology and Management* 223: 415–427.
- N. Sampson et al. 2007. *Terrestrial Carbon Sequestration in the Northeast: Quantities and Costs,* Part 3C: "Opportunities for Sequestering Carbon and Offsetting Emissions through Production of Biomass Energy." C-5. Available at: http://www.sampsongroup.com/Papers/carbon.htm.
- Kant, Z., and B. Kreps. 2004. *Carbon Sequestration and Reforestation of Mined Lands in the Clinch and Powell River Valleys.* The Nature Conservancy Topical Report: Task 5.
- Adler, P.R., S.J. Del Grasso, and W.J. Parton. 2007. Life-cycle assessment of net greenhouse-gas flux for bioenergy cropping systems. *Ecological Applications* 17(3): 675–-691.
- Heller, M.C., G.A. Keoleian, and T.A. Volk. 2003. Life cycle assessment of a willow bioenergy cropping system. *Biomass and Bioenergy* 25:147–165.

Potential GHG Reduction (MMtCO_2e): Varies by scenario. See analysis, below.

The quantification for this option seeks to analyze the possible opportunities for planting different types of vegetation on various types of underutilized land in PA. Scenarios were designed for practicality, and to illustrate the potential benefits and costs of different options under various levels of implementation (Table F-17).

Table F-17. Summary of Scenarios Used for Quantification of Afforestation and Planting Benefits and Costs

Land-Use Category	Vegetation Type	Total Acreage Available for Planting (2009–2020)
Abandoned Minelands	Afforestation	250,000
	Short-rotation woody crops	
	Warm-season grass (switchgrass)	
Brownfields	Afforestation	2,329
	Short-rotation woody crops	
	Warm-season grass (switchgrass)	
Oil and Gas Well Sites	Afforestation	3,250
Marginal Agricultural Land	Afforestation	2,915,843
	Short-rotation woody crops	
	Warm-season grass (switchgrass)	
Riparian Areas	Afforestation	N/A

N/A = not available.

The sections below detail the methods and assumptions used for each of the vegetation types planted and the variety of land-use types considered in this option.

A. GHG Benefits of Vegetation Types

A.1. Afforestation With Typical PA Forest Cover

Forests planted on land not currently in forest cover will likely accumulate carbon at a rate consistent with the accumulation rates of average forest in the region. Therefore, carbon sequestered by afforestation activities was assumed to occur at the same rate as carbon sequestration in average PA forest. Average carbon storage was found based on USFS GTR-NE-343 assuming afforestation activity with a forest type distribution of 50 percent Maple-Beech-Birch and 50 percent Oak-Hickory. For afforestation under Option F-4, a 25-year project period was assumed, such that the average rate of forest carbon sequestration (in all forest carbon compartments, including soil, live and dead biomass, forest floor, understory, and downed wood) under afforestation projects was estimated at 5.02 tCO_2e/ac/yr (Table F-18). Forests planted in one year continue to sequester carbon in subsequent years. Thus carbon storage in a given year is calculated as the sum of annual carbon sequestration on cumulative planted acreage. While it is possible that shifts in species composition might occur as a result of continued climate change, the analysis was conducted assuming current species composition, as climate change-related species shifts are not likely to be manifested until 2100.

Table F-18. Forest Carbon Sequestration Rates for Afforestation Activity

Forest Types	tCO_2e/ac (0 yr)	tCO_2e/ac (25 yr)	tCO_2e/ac/yr (average)
Oak-Hickory	62.0	191.8	5.2
Maple-Beech-Birch	80.3	201.7	4.9

tCO_2e/ac/yr = metric tons of carbon dioxide equivalent per acre per year.

Source: J.E. Smith et al. 2006, GTR-NE-343.

In riparian buffers, the amount of carbon sequestration achieved over time was quantified using a carbon sequestration rate of 3.92 tCO_2e/ac/year. To calculate this rate, average carbon densities for Elm-Ash-Cottonwood forests (obtained from the USFS for the PA I&F) were divided by 35, based on the assumption of an average stand age of 35 years obtained from FIA data.

A.2. Biomass Crops: Switchgrass, Willow, and Hybrid Poplar

The analysis of the potential for GHG benefits due to planting biomass crops on underutilized land separated biomass crops into two categories: warm-season grasses (switchgrass) and short-rotation wood crops (SRWC), assuming an equal mix of willow and hybrid poplar. Since data about the two SRWC crops (willow and poplar) are often presented separately, their GHG benefits were analyzed independently first, and then a weighted average assuming an equal willow-poplar mix was used for building the scenarios.

For all of the biomass crops, net GHG benefit was calculated as the difference between avoided fossil fuel emissions (from substituting biomass crops for fossil-intensive energy sources) and the emissions from crop management activities. These steps were followed:

1. Quantify the expected yield (in million British thermal units [MMBtu]) per acre of vegetation in PA.[4]

[4] Yield per acre for switchgrass and poplar comes from presentation made by Greg Roth, Penn State College of Agriculture, "Energy from Biomass & Waste Conference," September 2007. Yield for willow comes from Heller et al. (2003).

2. Convert expected yield (in MMBtu per acre) to units of tCO_2e avoided per acre of biomass crop grown. This expected yield per acre (in 10^6 Btu per acre) was used to calculate the expected avoided fossil fuel use from utilizing biomass as a primary energy source. This calculation was accomplished assuming an existing fuel mix of equal parts oil, natural gas, and coal. Conversion factors were taken from the 2000 PA I&F of Greenhouse Gas Emissions (Table F-19).

Table F-19. Emission factors for fossil fuels in PA

Type of Fuel	Emission factors (tCO_2e/Btu)
Coal	93.815
Natural gas	52.455
Oil/petroleum	50.283
Wood	3.093

Btu = British thermal unit; tCO_2e = metric tons of carbon dioxide equivalent.

3. Subtract emissions attributed to management activity. Since energy is used to grow the biomass crops, this expected fuel-switching benefit must be reduced by an amount equal to the energy inputs required to produce the crops. Energy input from agricultural machinery and fertilizer production was thus subtracted from this expected fossil fuel offset benefit, to achieve an overall GHG benefit in tCO_2e/acre/year (Table F-20).

   In the scenarios analyzed here, it was calculated that each acre of switchgrass would achieve an overall GHG benefit of 3.5 tCO_2e/year. Each acre of SRWC, assuming an equal mix of willow and poplar, would achieve an intermediate benefit between the willow and the poplar estimates, for a total GHG benefit of 4.6 tCO_2e/year. Soil carbon sequestration is not considered in this analysis.

Table F-20. Net GHG Benefits of Biomass Crop Production in PA

Type of Biomass Crop	Expected Annual Yield (MMBtu/Acre)	Annual tCO_2e Offset/Acre	Annual tCO_2e Emissions From Management Activities	Net GHG Benefit (tCO_2e/acre/year)
Switchgrass[5]	54.1	3.5	0.027	3.5
Willow[6]	60.4	4.0	0.065	3.9
Poplar	82.0	5.4	0.092	5.3

GHG = greenhouse gas; MMBtu = million British thermal units; tCO_2e = metric tons of carbon dioxide equivalent.

[5] For switchgrass and hybrid poplar, yield data are from Greg Roth, Penn State University, as presented at "Energy from Biomass & Waste Conference," September 2007. Data on GHG emissions form management activities represents the sum of on-farm emissions from machinery and embodied energy in fertilizer, herbicide, and pesticide (Adler et al., 2007).

[6] For willow, yield data are from Heller et al. (2003), assuming 13.6 oven-dry tons per hectare per year. This was converted to Btus assuming a heat content of 10.977 MMBtus per short ton of biomass (Energy Information Administration, http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table10.html). Data on management emissions are from Heller et al. (2003).

The work of Adler et al. (2007), who used a modeling analysis to quantify the complete set of life-cycle benefits of various biofuel crops, provides a comparison for these methods. Adler et al. (2007) considered all fuel use, equipment use, harvesting and transport costs, and production emissions to quantify net GHG comparisons for biofuel feedstocks in PA, including corn, soybean, alfalfa, switchgrass, hybrid poplar, and reed canarygrass. Switchgrass and hybrid poplar were the most favorable of all of the crops considered by Adler et al. (2007): ethanol and biodiesel produced from these crops reduced life-cycle GHG emissions by ~115 percent below the life-cycle CO_2e emissions produced by gasoline and diesel. In their analysis, switchgrass produced a net GHG sink of around 2.9 tCO_2e/acre/year for biomass conversion to ethanol and around 5.9 tCO_2e/acre/year when used for biomass gasification for electricity generation.

Biomass yield is an important source of variation in these estimates: these results depend on expected yield, which can vary substantially from actual yield. Actual yield can change dramatically depending on species and site conditions. As yield increases, the expected GHG benefit increases dramatically as well.

A.2.a. Switchgrass

Switchgrass is a perennial warm-season grass, grown for decades on marginal lands not well suited for conventional row crops. It has been identified as a potential feedstock for cellulosic ethanol production, as well as for biomass gasification to produce electricity.

A.2.b. Short-Rotation Woody Crops

SRWCs, such as willow and hybrid poplar, can be grown on most agricultural land that is capable of producing cultivated or hay crops, but practically they may be limited to the more marginal production lands, where they can be used to reduce soil erosion and compete economically. They can also have significant water and fertilizer demands, which make them costly to produce. SRWCs are generally harvested during the dormant season on a 3- to 4-year cycle. Since they re-sprout vigorously after cutting, seven to eight harvests can be obtained from a single planting. Fertilizers may be applied in the spring following harvest, in an amount determined by site conditions (Sampson et al., 2007).

B. Land Areas Available for Afforestation and Planting

For each of the vegetation types analyzed, a scaled implementation of planting on 25 percent, 50 percent, and 100 percent of the land-use category was considered. A gradual ramp-up was assumed, such that full implementation of each scenario would be achieved in 2020.

B.1. Abandoned Minelands

With 250,000 acres of AMLs statewide,[7] these sites provide a potential opportunity for carbon sequestration. Restoring AMLs, however, can be challenging and very costly due to the need for site preparation because of uneven terrain and the legacy of their prior use. Three potential uses for AMLs were considered: afforestation with a typical PA forest cover mix (including Maple-Beech-Birch and Oak-Hickory), switchgrass production, and SRWC production.

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[7] From PA DEP information: http://www.depweb.state.pa.us/abandonedminerec/cwp/view.asp?a=1308&q=454835. Accessed October 2007.

B.2. Brownfields

The 389 brownfields in PA comprise 2,330 acres of land area.[8] Although many brownfields are remediated and used as commercial or industrial sites, they also offer potential space for carbon sequestration. Three potential uses for brownfields were considered: afforestation with a typical PA forest cover mix (including Maple-Beech-Birch and Oak-Hickory), switchgrass production, and SRWC production.

B.3. Oil And Gas Well Sites

Oil and gas well sites also occupy small one-quarter to one-half-acre sites around the state, totaling 250 acres of land area annually.[9] Because these sites are widely scattered and quite small, management activities on oil and gas well sites are probably not feasible. Only the afforestation scenario was explored for these sites.

B.4. Marginal Agricultural Land

Marginal agricultural land is restricted by various soil physical/chemical properties, or environmental factors, for crop production. Based on an analysis of the 1992 U.S. Geological Survey National Land Cover Dataset, together with soil characteristics obtained from the NRCS STATSGO (State Soil Geographic) dataset, Niu and Duiker (2006) reported that marginal agricultural land area in PA totaled 1.18 million hectares (MMha) (approximately 36 percent of all land area in the state). This land was placed in the "marginal agricultural land" category because of its combination of soil and land cover characteristics, and includes land with high water table, steep slopes (high erodibility), shallow soils, stoniness, and low fertility. For this analysis, afforestation, SRWC, and switchgrass were considered on marginal agricultural land.

C. Economic Cost

Economic analyses of vegetation planting costs typically employ four categories: opportunity cost (of planting forest rather than another, potentially more lucrative land use), conversion cost, maintenance cost, and measuring/monitoring costs (Walker et al. 2007). For this analysis, opportunity cost was assumed to be zero because the land considered in each of the scenarios is currently underutilized.

One-time costs of vegetation establishment include site preparation and vegetation planting. These costs are incurred in the year of planting, one time only. Ongoing costs of maintenance and monitoring are incurred annually on all acreage planted in all years of policy implementation. The assumed costs of site preparation, vegetation establishment, and ongoing maintenance for each site type and vegetation combination appear in Table F-21.

D. Summary

For each of the combinations of vegetation and land-use category described in the scenarios in Table F-17, a phased implementation of planting vegetation on 25 percent, 50 percent, and

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[8] From U.S. Environmental Protection Agency (EPA): http://www.epa.gov/brownfields/bfwhere.htm. Accessed October 2007.

[9] Personal communication, Ronald Gilius with J. Quigley and J. Jenkins, Center for Climate Strategies (CCS), October 2007.

100 percent of the available land in that category by 2020 was analyzed. Discounted costs to 2020 were calculated using $2007 and a 5 percent discount rate. NPV is the sum of the discounted costs—in other words, the economic cost or benefit of implementing the option between 2009 and 2020, calculated in 2007 dollars. Levelized cost-effectiveness is the NPV of a scenario divided by the cumulative GHG benefit of that scenario. This is expressed in $/t$CO_2$e sequestered or avoided, and is intended to give a sense of the cost of each scenario standardized for its actual GHG benefit across numerous scenarios and options that vary in terms of overall cost and cumulative GHG benefit.

Cumulative (2009-2020) results for afforestation, SRWCs, and switchgrass production on AMLs, brownfields, oil and gas well sites, and marginal agricultural land are presented in Table F-23. Annual results for 2020 only are presented in Table F-24.

In order to provide one value for GHG savings and economic costs associated with Forestry-4 for use in the CCAC process, the Subcommittee opted to quantify afforestation at 25 percent of the available land in all of the land use categories. Thus the cumulative GHG savings and associated economic costs were quantified for afforestation on 25 percent of the abandoned minelands, oil and gas well sites, marginal agricultural land, and brownfields. The results from this analysis were brought forward to the Summary Table on Page 1 of this Work Plan, and are described in Table F-22 below.

Table F-21. Economic Costs of Site Preparation, Vegetation Establishment, Maintenance, and Monitoring for Vegetation Planting Scenarios in Option Forestry-4

Land-Use Type	One-Time Costs		Annual Costs	
	Site Preparation	Planting	Maintenance	Monitoring[10]
Abandoned minelands[11]				
Switchgrass[12]	$2,500.00	$99.26	$103.66	$29.00
SRWC[13]	$2,500.00	$1,000.00	$261.54	$29.00
Afforestation[14]	$2,500.00	$680.00		$29.00
Oil & gas well sites				
Afforestation		$680.00		$29.00
Marginal agricultural land				
Switchgrass		$99.26	$103.66	$29.00
SRWC		$1,000.00	$261.54	$29.00
Afforestation		$680.00		$29.00
Brownfields				
Switchgrass		$99.26	$103.66	$29.00
SRWC		$1,000.00	$261.54	$29.00
Afforestation		$680.00		$29.00
Riparian areas				
Afforestation		$680.00		$29.00

[10] Monitoring costs are assumed to be $29/acre for all vegetation types, assuming 20-year project duration (Walker et al., 2007).

[11] The cost of site preparation is average for AMLs in Clinch and Powell River Valleys in VA and TN, and includes site preparation with minimal compaction, establishment of an erosion barrier, and herbicide application (Kant and Kreps, 2004, Table 2). This is the minimum cost, out of an estimated range from $2,500 to $10,500. Additional costs, such as soil amendments, or differences between assumed and actual costs will materially affect the analysis.

[12] One-time planting cost and ongoing maintenance cost for switchgrass from Duffy and Nanhou (2002), who measured the cost of switchgrass production in Iowa at $518.75/hectare (ha). This work estimates switchgrass production costs using producers' data as much as possible and incorporating their actual management techniques, including costs of planting, management, harvesting, and any inputs.

[13] One-time planting cost for SRWC is estimated to be slightly higher than the one-time planting cost for typical PA forest due to specialized planting requirements and equipment. Ongoing maintenance cost is calculated from an estimate of $43–$52 per ton of willow delivered (Volk, State University of New York College of Environmental Science and Forestry Willow Biomass Project), assuming average production yield of 13.6 tons/ha.

[14] Cost of afforestation is a $150 per-acre cost of planting, plus tree ($100), herbicide ($130), and fencing ($300) costs (Paul Roth, DCNR, personal communication).

Table F-22. GHG Savings and Economic Costs Associated with 25 percent Afforestation on all Available Land Use Types.

Year	Carbon Sequestered (MMtCO2e/yr)	Discounted Cost ($2007)	Cost Effectiveness
2009	0.33	$52,557,573	$158.37
2010	0.66	$51,709,864	$77.91
2011	1.00	$50,823,711	$51.05
2012	1.33	$49,904,698	$37.59
2013	1.66	$48,957,963	$29.50
2014	1.99	$47,988,231	$24.10
2015	2.32	$46,999,839	$20.23
2016	2.65	$45,996,762	$17.32
2017	2.99	$44,982,641	$15.06
2018	3.32	$43,960,802	$13.25
2019	3.65	$42,934,279	$11.76
2020	3.98	$41,912,582	$10.52
Cumulative	25.89	$568,728,945	$21.97

Table F-23. Cumulative Results (2009-2020) for Forestry-4 in Different Vegetation Types on Various Land-Use Types in PA

Land-Use Category	Total Acreage Available for Policy Implementation			Vegetation Type	Cumulative GHG Benefit, 2009–2020 ($MMtCO_2e$)			Net Present Value 2009–2020 ($ million (in $2007))			Levelized Cost-Effectiveness ($/$tCO_2e$)
	25%	50%	100%		25%	50%	100%	25%	50%	100%	
Abandoned Minelands	62,500	125,000	250,000	Afforestation with typical PA forest cover	2.041	4.081	8.163	$146.1	$292.1	$584.3	$71.59
				Short-rotation woody crops (willow and poplar)	1.859	3.719	7.437	$216.7	$433.5	$867.0	$116.57
				Warm-season grass production (switchgrass)	1.425	2.851	5.702	$142.98	$285.9	$571.9	$100.31
Brownfields	582	1,165	2,330	Afforestation with typical PA forest cover	0.019	0.038	0.076	$0.3	$0.7	$1.4	$17.72
				Short-rotation woody crops (willow and poplar)	0.017	0.035	0.069	$1.0	$2.0	$4.0	$57.46
				Warm-season grass production (switchgrass)	0.013	0.027	0.053	$0.3	$0.6	$1.2	$23.20
Oil and Gas Well Sites	813	1,625	3,250	Afforestation with typical PA forest cover	0.025	0.049	0.098	$0.4	$0.9	$1.7	$17.72
Marginal Agricultural Land	728,961	1,457,922	2,915,844	Afforestation with typical PA forest cover	23.80	47.60	95.21	$421.9	$843.8	$1,687.5	$17.72
				Short-rotation woody crops (willow and poplar)	21.69	43.37	86.75	$1,246.0	$2,496.1	$4,984.2	$57.46
				Warm-season grass production (switchgrass)	16.63	38.25	66.50	$385.7	$771.4	$1,542.8	$23.20

$/$tCO_2e$ = dollars per metric ton of carbon dioxide equivalent; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table F-24. Annual (2020) Results for Forestry-4 in Different Vegetation Types on Various Land-Use Types in PA

Land-Use Category	Total Acreage Available for Policy Implementation			Vegetation Type	Annual GHG Benefit, 2020 ($MMtCO_2e$)			Net Present Value, 2020 ($ million (in $2007))			Cost-Effectiveness ($/tCO_2e$)
	25%	50%	100%		25%	50%	100%	25%	50%	100%	
Abandoned Minelands	62,500	125,000	250,000	Afforestation with typical PA forest cover	0.314	0.628	1.26	$9.67	$36.47	$72.91	$30.80
				Short-rotation woody crops (willow and poplar)	0.286	0.572	1.14	$18.5	$37.0	$73.99	$64.67
				Warm-season grass production (switchgrass)	0.219	0.439	0.877	$11.2	$22.4	$44.8	$51.12
Brownfields	582	1,165	2,330	Afforestation with typical PA forest cover	0.003	0.006	0.012	$0.026	$0.051	$0.10	$8.79
				Short-rotation woody crops (willow and poplar)	0.003	0.005	0.011	$0.108	$0.216	$0.432	$40.52
				Warm-season grass production (switchgrass)	0.002	0.004	0.008	$0.040	$0.080	$0.160	$19.63
Oil and Gas Well Sites	813	1,625	3,250	Afforestation with typical PA forest cover	0.004	0.007	0.015	$0.331	$0.662	$0.132	$8.79
Marginal Agricultural Land	728,961	1,457,922	2,915,844	Afforestation with typical PA forest cover	3.66	7.32	14.65	$32.18	$64.37	$128.7	$8.79
				Short-rotation woody crops (willow and poplar)	3.33	6.67	13.34	$135.2	$270.3	$540.7	$40.52
				Warm-season grass production (switchgrass)	2.56	5.12	10.23	$50.21	$100.42	$200.83	$19.63

$/tCO_2e = dollars per metric ton of carbon dioxide equivalent; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

E. Riparian Buffers

This analysis combines projected acreage from the Tree Vitalize and CREP forest riparian establishment programs. It assumes that the Tree Vitalize[15] or similar program will establish 250 acres/year along the Chesapeake Bay drainage in 2009 and 2010, to meet the total program goal of 1,000 acres. It assumes further that the CREP will ramp up each year from 2009 to 2010 until achieving 3,500 acres in 2010, and will continue this rate through 2020. Annual carbon sequestration is based on forests planted that year and in prior years under the program. Table F-24 summarizes acres of riparian forests established annually and cumulatively, and associated carbon sequestration each year through 2020.

Table F-25. Carbon Sequestered From Establishing Riparian Buffer Forests in PA

Year	Forests Established Annually (acres)	Forests Established in Prior Years (acres)	Carbon Sequestered Annually ($MMtCO_2e$/year)
2009	2225	0	0.009
2010	4000	2225	0.024
2011	3500	6225	0.038
2012	3500	9725	0.052
2013	3500	13225	0.065
2014	3500	16725	0.079
2015	3500	20225	0.093
2016	3500	23725	0.106
2017	3500	27225	0.120
2018	3500	30725	0.134
2019	3500	34225	0.148
2020	3500	37725	0.161
Total	41225		1.029

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

A summary of the total costs of buffer establishment under this option appears in Table F-25. Note the estimate of annual carbon sequestration in Table F-25 includes carbon sequestration by all riparian buffers established as part of this option from 2009 through 2020, since they will continue to sequester carbon each year after establishment. Costs are calculated only once for each acre, in the year of establishment. The NPV (in 2007 dollars) for establishment of riparian forests under this option is roughly $19.6 million, with a levelized cost-effectiveness of $19.04/ tCO_2e reduced.

[15] See: http://www.treevitalize.net/.

Table F-26. Summary of GHG Benefits and Economic Costs of Establishing Riparian Buffer Forests in PA

Year	Acres Established Annually	Discounted Cost ($2007)	Annual Carbon Sequestration ($MMtCO_2e$/year)
2009	2,225	$1,372,336	0.009
2010	4,000	$2,349,638	0.024
2011	3,500	$1,958,032	0.038
2012	3,500	$1,864,792	0.052
2013	3,500	$1,775,993	0.065
2014	3,500	$1,691,422	0.079
2015	3,500	$1,610,878	0.093
2016	3,500	$1,534,169	0.106
2017	3,500	$1,461,114	0.120
2018	3,500	$1,391,537	0.134
2019	3,500	$1,325,273	0.148
2020	3,500	$1,262,165	0.161
Total	**41,225**	**$19,597,347**	**1.029**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent

<u>**Implementation Steps**</u>: ***Target Programs, Goals Support Full Implementation of These Programs***

- TreeVitalize[16] seeks an $8 million investment in tree planting and care in southeastern Pennsylvania over a 4-year period. Goals include planting 20,000 shade trees, restoring 1,000 acres of forests along streams and water-protection areas, and training 2,000 citizens to plant and care for trees. DCNR initiated preliminary discussions with regional stakeholders in summer of 2003, and appointed a Project Director in January 2004. Planning, assessment, and resource development continued through 2004. Tree-planting activities began in the fall of 2004 and will continue through the fall of 2007. The regional Tree Tenders program was launched in 2005. Although TreeVitalize is not a permanent entity, the collaborations created and capacity built will continue to increase tree cover and promote stewardship in the region. A Steering Committee, composed of funding entities, county governments and major technical assistance providers, identifies priorities and approves projects. Operational committees, composed of local planting partners, technical assistance providers, and/or public agencies with expertise in tree planting, will implement projects and deliver education and technical assistance. Other Committees will be formed on an as-needed basis. DCNR is examining opportunities to expand the program to other areas of the commonwealth.

- Numerous programs are in place Statewide—USDA CREP (where USDA subsidized farmers to keep highly erodible acres in warm-season grass)—that may in fact be a significant source of biofuel in switchgrass. Pennsylvania uses Growing Greener II[17]

[16] See: http://www.treevitalize.net/aboutus.aspx.

[17] See: http://www.growinggreener2.com/default.aspx?id=398

funds to enhance federal cost-share payments for installation of conservation practices. In addition to warm-season grasses, CREP subsidizes riparian forest buffer practices. One cost-shared practice is the installation of streambank fencing to exclude livestock and allow for natural forest regeneration. Another practice was riparian forest plantings.

- CREP is key to the expansion of forested riparian buffers throughout the Ohio and Chesapeake Bay drainages. From October 1, 2005, through September 30, 2006, 1,293 CREP contracts were approved on about 24,006 acres. This included the installation of over 3,406 acres of forested riparian buffers and planting another 4,799 acres of native grasses.
- Other buffer initiatives include TreeVitalize, Stream ReLeaf[18], the Chesapeake Bay Urban Tree Canopy Expansion Initiative, and a suite of initiatives offered under the guidance of cooperators, including the Alliance for the Chesapeake Bay, The Chesapeake Bay Foundation, The Western Pennsylvania Conservancy, and DEP lists. A watershed forester working in the Rural and Community Forestry (CFM) section coordinates BOF efforts in riparian projects. Bureau of Forestry (BOF) Service Foresters throughout the state work with landowners to implement watershed programs on private lands.
- Since 2000, this cooperative effort among state, federal, and nonprofit organizations has resulted in the restoration of over 2,100 miles of forested buffers in the Chesapeake Bay drainage alone.
- A Keystone Opportunity Zone model program could be created to package incentives for private investment in establishing forests on marginal lands.

Enabling Programs, Programs May Provide Relevant Information in Support of Implementation

• DEP's Bureau of Abandoned Mine Reclamation develops plans for handling AML in Pennsylvania. In the era of the Department of Environmental Resources, BOF had a program called Project 20 for mine land reclamation.[19]

Potential Overlap: None.

Subcommittee Comments

This option seeks to increase carbon stored in vegetation and soils through expanding the land base associated with terrestrial C sequestration. Establishing new forests ("afforestation") increases the amount of carbon in biomass and soils compared to preexisting conditions. Planting and afforestation can take place on land not currently experiencing other uses, such as abandoned mine lands (AML), brownfields, oil and gas well sites, marginal agricultural land, and riparian areas. In addition to planting forest cover, this policy option also includes consideration of planting short-rotation woody crops and warm season grasses on a variety of underutilized land cover types.

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[18] http://www.dep.state.pa.us/dep/deputate/watermgt/WC/Subjects/StreamReLeaf/default.htm

[19] See: http://www.depweb.state.pa.us/abandonedminerec/site/default.asp?abandonedminerec.

This analysis focuses on the C sequestration benefit of afforestation only, and does not include the multiple co-benefits of afforestation (water, habitat, etc.).

It is important to note that there are existing carbon offset protocols that acknowledge this activity. Specifically, the Climate Action Reserve (CAR), as well as the Chicago Climate Exchange (CCX) has a protocol accepting projects that engage in "reforestation". It will be important to evaluate these project protocols and encourage pilot projects within Pennsylvania to more fully understand these opportunities. Furthermore, it has a direct relationship with the costs associated with this option; as such potential revenues for entering into such projects will impact the cost effectiveness.

See comments for F-1 and F-3, regarding long term and life-cycle carbon benefits of forest practices and benefits of forest growth and protection measures to multiple work plans. Also, this is another example of a work plan which is difficult to evaluate due to the number of different scenarios and circumstances considered.

It would have been beneficial – if we are to select one value to represent cost effectiveness, to have generated a number of work plans from the information embedded within this one. The best example is having to choose between the potential benefits of reforestation with native PA forest cover or warm season grasses (switchgrass) on abandoned or marginal agricultural land. Also, given the period of analysis, the cost effectiveness of this option is most likely high, recognizing that there will be significant CO_2 benefits from these types of projects beyond the 2020 time horizon. This illustrates the need for life cycle assessments (LCAs), particularly for forest related activities.

Forestry-5. Improved Forest Management

Initiative Summary:

This option addresses the potential for increasing carbon stocks in forests. Examples are practices that increase tree density, enhance forest growth rates, alter rotation times, or decrease the chances of biomass loss from fires, pests, and disease. Increasing the transfer of biomass to long-term storage in wood products can also increase net carbon sequestration. Practices may include management of rotation length, density, and ecosystem health, and sustainable use of wood products. In addition, encouraging regeneration of existing forests through stocking/planting and restoration practices (soil preparation, erosion control, etc.) can increase carbon stocks above baseline levels and ensure conditions that support forest growth, particularly after intense disturbances. Land participating in a certified management program is eligible to generate offset credits. Option B focuses on enhancing carbon storage in existing forests through restocking.

Biomass for energy may be generated as part of this option, which can then be used to produce energy that offsets fossil fuel burning. This is accounted for in options Forestry-8 and Forestry-9, which seek to quantify the effects of a potential increase in biomass supply (due to thinning, capture of natural mortality, or harvest of poorly stocked stands, for example) on carbon emissions due to fuel switching.

Goals:

1. Sequester more carbon through sustainable forest management
    - Scenario 1: Maintain current (business-as-usual) forest management practices.
    - Scenario 2: Shift 20 percent of annual acreage harvested using even-aged techniques to uneven-aged management.
    - Scenario 3: Shift 50 percent of annual acreage harvested using even-aged techniques to uneven-aged management.
    - Scenario 4: Shift 75 percent of annual acreage harvested using even-aged techniques to uneven-aged management.
2. Restock understocked land
    - Scenario 1: Restock 100 percent of poorly stocked land statewide by 2020.
    - Scenario 2: Restock 100 percent of poorly stocked and 50 percent of moderately stocked land statewide by 2020.
    - Scenario 3: Restock 100 percent of poorly and moderately stocked land by 2020.

Implementation Period: 2009–2020

Other Involved Agencies: Not available.

Data Sources/ Assumptions/ Methods:

Data Sources/References:

- J.E. Smith et al. 2006. *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States*, GTR NE-343. USFS Northern Research Station. (Also published as part of the DOE Voluntary GHG Reporting Program.)
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- Pennsylvania DCNR, BOF. 2006. *Forest Products Statistical Report.* Available at: http://www.dcnr.state.pa.us/forestry/sfrmp/documents/Timber_BOF_Forest_Prod_Stat_Report_2006.pdf.

Goal 1: Increase carbon sequestration through sustainable forest management.

Changes in silvicultural techniques can increase carbon sequestration, while simultaneously providing multiple co-benefits associated with a variety of ecosystem services.[20] In the analysis under Goal 1, three theoretical scenarios are analyzed relative to current (business-as-usual) forest management practices to show a spectrum of options for increased carbon sequestration on Pennsylvanian timberlands based on a shift in silvicultural practices. There are currently significant challenges to regenerating forests in PA, such as controlling competing vegetation and herbivory. Costs associated with mitigating these challenges under the theoretical scenarios were not included.

Differences in carbon sequestration resulting from changes in forest management practices were calculated using data from Nunery and Keeton (2009).[21] This study modeled the carbon

[20] Ruddell, S., et al. 2007. The role for sustainably managed forests in climate change mitigation. *Journal of Forestry* 105: 314–319; Hoover, C., and S. Stout. 2007. The carbon consequences of thinning techniques: Stand structure makes a difference. *Journal of Forestry* 105: 266–270.

[21] Nunery J.S., and W.S. Keeton. 2009 (in review). Forest carbon storage in the northeastern United States: net effects of harvesting frequency, post-harvest retention, and wood products. *Ecological Applications.*

sequestration rates of nine different forest management scenarios (four even-aged, four uneven-aged management scenarios, and one no-management scenario) commonly used in northeastern North America. Annual carbon sequestration values associated with individual management prescriptions over a 160-year model simulation period are shown in Table F-27. These rates include carbon stored in live above-ground biomass, standing dead trees, down dead wood, and harvested biomass (wood products). Harvested wood products pools included in these carbon sequestration rates incorporate the complete lifetime of the product, from manufacturing to landfill. Carbon sequestration rates from this study reflect the effect of silvicultural techniques, as well as the frequency of harvests (rotation length in even-aged or entry cycle in uneven-aged forest management).

Table F-27. Carbon Sequestration Rates Used to Calculate the Impacts of Silvicultural Techniques on Carbon Sequestration Rates.[22]

Management Prescription	Management Type	Harvesting Frequency (years)	Carbon Sequestration Rate ($tCO_2e/ac/yr$)
Clearcut 1	Even-aged	80	0.341
Clearcut 2	Even-aged	120	0.119
Shelterwood 1	Even-aged	80	0.193
Shelterwood 2	Even-aged	120	0.030
Individual Tree Selection 1	Uneven-aged	15	0.104
Individual Tree Selection 2	Uneven-aged	30	0.119
Individual Tree Selection 3	Uneven-aged	15	0.208
Individual Tree Selection 4	Uneven-aged	30	0.208
No management	—		0.534
Average Even-aged	Even-aged	100	0.171
Average Uneven-aged	Uneven-aged	22.5	0.160

$tCO_2e/ac/yr$ = metric tons of carbon dioxide equivalent per acre per year.

Currently in Pennsylvania, 78 percent of state lands employ even-aged silvicultural techniques (32 percent regeneration harvests and 46 percent shelterwood systems).[23] Uneven-aged silviculture maintains higher levels of *in situ* forest biomass.[24] In this analysis, we assumed that a baseline proportion of even-aged management relative to uneven-aged management of 30 percent on private lands. Additionally, it is assumed that there is no change in harvest rates or total acreage of Pennsylvania timberlands throughout the 12-year period from 2009 to 2020. In Goal 1, three scenarios involving various levels of uneven-aged forest management implementation were quantified and compared with a fourth business-as-usual (no change in management) scenario.

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[22] Ibid.

[23] Pennsylvania Bureau of Forestry, DCNR. 2006. *Forest Products Statistical Report*. Available at: http://www.dcnr.state.pa.us/forestry/sfrmp/documents/Timber_BOF_Forest_Prod_Stat_Report_2006.pdf

[24] Nunery J.S., and W.S. Keeton (2009) (in review). Forest carbon storage in the northeastern United States: Net effects of harvesting frequency, post-harvest retention, and wood products. *Ecological Applications.*

The general methodology for all scenarios followed the following steps:

1. Calculate the total harvested acreage on state, local, and private timberlands.
2. Calculate the total acreage of even-aged and uneven-aged silvicultural treatments.
3. Calculate the carbon lost from the forest as part of the timber harvest process.
4. Calculate the cumulative *in situ* forest carbon sequestration on unharvested timberlands.
5. Calculate the cumulative carbon sequestration on both even-aged and uneven-aged harvested timberlands.
6. Compare the carbon sequestration under the new management scenario with the carbon sequestration under the business-as-usual scenario to calculate the final impact of the changed management regime.

The approach for each step is described below:

1. Total harvestable acreage was calculated using 2006 FIA data. Harvestable timberlands were defined by "overstocked" and "fully stocked" stands, as measured by FIA (see Table F-28). Calculations were restricted to harvestable timberlands on state, local, and private timberlands.

Table F-28. Harvestable Acreage Used in Calculations (FIA, 2006).

Ownership Type	Total Harvestable Timberlands (overstocked + fully stocked) (acres)	Overstocked (acres)	Fully Stocked (acres)
National Forest	275,996	10,481	265,516
Department of Defense or Energy	12,318		12,318
Other Federal	12,480		12,480
State	1,926,380	131,991	1,794,389
Local (county, municipal, etc.)	212,558	7,735	204,823
Other Non-federal Lands	0		
Total Public	*2,439,732*	*150,206*	*2,289,525*
Undifferentiated Private	5,085,674	365,322	4,720,352
Total (all owners)	**7,525,406**	**515,528**	**7,009,878**

On Pennsylvania timberlands (excluding federally owned lands), 1.84 percent of acreage is harvested annually.[25] Harvest rates on Pennsylvania timberlands were calculated as an average of harvest rates of state, local, and private timberlands as measured by FIA.

2. The total acreage of even- and uneven-aged harvests as currently practiced on state lands was calculated using proportions from the Pennsylvania BOF.[26] As mentioned above, 78 percent

[25] USFS FIA data, 2006, downloaded April 29, 2009.

[26] Pennsylvania Bureau of Forestry, DCNR. 2006. *Forest Products Statistical Report.* Available at: http://www.dcnr.state.pa.us/forestry/sfrmp/documents/Timber_BOF_Forest_Prod_Stat_Report_2006.pdf.

of annual harvests on Pennsylvania state forest timberlands currently use even-aged silvicultural techniques. Based on expert opinion, it was estimated that 30 percent of private forestlands currently practice even-aged management techniques. In baseline Scenario 1, it was assumed that current practices were continued on both state and private lands, with no change in management practices. This business-as-usual baseline is incorporated into the Forest sector of the PA Inventory and Forecast. In Scenarios 2, 3, and 4, increasing proportions of the original acreage scheduled for even-aged harvests were assumed to shift to uneven-aged harvests. The total acreage involved in this proportional shift to uneven-aged management was then calculated (Table F-29). As federal forestlands are not under PA jurisdiction, the scenarios in this option did not quantify the effect of change in federal forest management practices.

Table F-29. Acreages Involved in Shift to Uneven-Aged Management for State-Owned and Private Land for Four Scenarios

Silvicultural Treatment Type	Baseline Scenario 1: 0% Shift	Scenario 2: 20% Shift	Scenario 3: 50% Shift	Scenario 4: 75% Shift
Relative Proportion of Silvicultural Treatment Type				
Even-aged (public lands)	0.78	0.624	0.39	0.195
Even-aged (private lands)	0.30	0.24	0.15	0.075
Uneven-aged (public lands)	0	0.156	0.39	0.585
Uneven-aged (private lands)	0	0.06	0.15	0.225
Acres Managed Annually				
Even-aged (public lands)	35,088	28,071	17,544	8,772
Even-aged (private lands)	28,132	22,505	14,066	7,033
Uneven-aged (public lands)	9,897	16,914	27,441	36,213
Uneven-aged (private lands)	65,640	71,267	79,706	86,739

3. It was assumed that in even-aged forest management, 90 percent of forest biomass was removed during harvest, and in uneven-aged silvicultural practices, 52 percent of forest biomass was removed.[27] Relative residual proportions of harvested acreage were used dependent on the scenario. For example, in Scenario 2, 20 percent of even-aged silvicultural prescriptions were shifted to uneven-aged prescriptions. Thus 80 percent of the acreage harvested each year was assumed to have lost 90 percent of forest biomass, and 20 percent of the harvested acreage was assumed to have lost 52 percent of forest biomass. Increasing the proportion of uneven-aged management therefore resulted in a smaller amount of loss during harvest, as a larger amount of biomass remained stored in the forest. Forest carbon stocks for the two most dominant forest types in Pennsylvania, Oak-Hickory and Maple-Beech-Birch, were averaged to calculate the total carbon stocks in 65-year-old stands, and these standing stock values were used to quantify the carbon lost during harvest[28] (Table F-30).

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[27] Nunery, J.S., and W.S. Keeton (2009) (in review). Forest carbon storage in the northeastern United States: net effects of harvesting frequency, post-harvest retention, and wood products. *Ecological Applications*.

[28] J.E. Smith et al. 2006. *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the United States*. GTR-NE-343. USFS Northern Research Station. (Also published as part of the DOE Voluntary GHG Reporting Program.)

4. The cumulative *in situ* forest carbon sequestration for unharvested acreage is calculated using carbon sequestration rates of unmanaged forests (Table F-27).[29] It is assumed that unharvested timberlands in Pennsylvania will continue to grow each year, adding to the cumulative carbon sequestration of Pennsylvania forests. It was further assumed that the total acreage of overstocked and fully stocked timberlands on state, local, and private timberlands would remain constant throughout the 12-year period of the analysis. For consistency, the values for unharvested forests published in Nunery and Keeton (2009) were used to quantify carbon sequestration rates on unharvested acreage.

5. For each Scenario, the acreage switched annually from even-aged to uneven-aged management was quantified following the proportions described in the Scenario (20 percent, 50 percent, or 75 percent of annual even-aged harvest for Scenarios 2, 3, and 4 respectively). Carbon sequestration rates for these silvicultural treatment types (even- and uneven-aged)[30] were then applied to the annual harvested acreage. Annual values were summed to calculate cumulative carbon sequestration over the 12-year implementation period for this analysis (Tables F-31 to F-34).

6. For each Scenario, the cumulative carbon sequestered from 2009-2020 was calculated. The carbon sequestered by the business-as-usual Scenario was subtracted from the carbon sequestered under each Management Scenario to calculate the net effect of the change in management strategy on overall carbon sequestration. This net result for each Scenario was entered in the Summary Table on the first page of Appendix K.

Table F-30. Live Tree Biomass in Fully Stocked Stands

Forest Type	Forest Age (years)	Live Tree C Stock (t/ac)	Live Tree C Stock ($MMtCO_2e/ac$)
Maple Beech Birch	65	45.8	0.000168
Oak Hickory	65	62.4	0.000229
Average	65	54.1	0.000198

t/ac = metric tons per acre; $MMtCO_2e/ac$ = million metric tons of carbon dioxide equivalent per acre.

Source: J.S. Smith et al., 2006.

[29] Nunery, J.S., and W.S. Keeton. 2009 (in review). Forest carbon storage in the northeastern United States: Net effects of harvesting frequency, post-harvest retention, and wood products. *Ecological Applications*.

[30] Ibid.

Table F-31. Business-as-Usual Management Scenario 1: No Change in Current Management Regime (see Table F-29 for acreage values)

Year	C Lost During Harvest (MMtC)	Cumulative C Sequestration in Unharvested Acreage (MMtC)	Cumulative C Sequestration in Harvested Acreage (MMtC)	Cumulative Net C Sequestration (MMtC) (=C sequestration in harvested + unharvested acreage minus loss due to harvest)	Cumulative Net C sequestration ($MMtCO_2e$)
2009	5.20	1.08	0.02	-4.11	-15.05
2010	5.20	2.15	0.04	-3.01	-11.03
2011	5.20	3.23	0.06	-1.91	-7.01
2012	5.20	4.30	0.09	-0.81	-2.98
2013	5.20	5.38	0.11	0.28	1.04
2014	5.20	6.46	0.13	1.38	5.06
2015	5.20	7.53	0.15	2.48	9.09
2016	5.20	8.61	0.17	3.58	13.11
2017	5.20	9.69	0.19	4.67	17.14
2018	5.20	10.76	0.21	5.77	21.16
2019	5.20	11.84	0.23	6.87	25.18
2020	5.20	12.91	0.26	7.97	29.21

C = carbon; MMtC = million metric tons of carbon; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table F-32. Management Scenario 2: 20 percent Shift to Uneven-Aged Management (see Table F-29 for acreage values)

Year	C Lost During Harvest (MMtC)	Cumulative C Sequestration in Unharvested Acreage (MMtC)	Cumulative C Sequestration in Harvested Acreage (MMtC)	Cumulative Net C Sequestration (MMtC) (=C sequestration in harvested + unharvested acreage minus loss due to harvest)	Cumulative Net C Sequestration ($MMt\ CO_2e$)
2009	4.94	1.08	0.02	-3.85	-14.11
2010	4.94	2.15	0.04	-2.75	-10.10
2011	4.94	3.23	0.05	-1.66	-6.09
2012	4.94	4.30	0.07	-0.57	-2.07
2013	4.94	5.38	0.09	0.53	1.94
2014	4.94	6.46	0.11	1.62	5.95
2015	4.94	7.53	0.13	2.72	9.96
2016	4.94	8.61	0.15	3.81	13.98
2017	4.94	9.69	0.16	4.91	17.99
2018	4.94	10.76	0.18	6.00	22.00
2019	4.94	11.84	0.20	7.09	26.01
2020	4.94	12.91	0.22	8.19	30.03

C = carbon; MMtC = million metric tons of carbon; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table F-33. Management Scenario 3: 50 percent Shift to Uneven-Aged Management
(see Table F-29 for acreage values)

Year	C lost during harvest (MMtC)	Cumulative C sequestration in unharvested acreage (MMtC)	Cumulative C sequestration in harvested acreage (MMtC)	Cumulative Net C Sequestration (MMtC) (=C sequestration in harvested + unharvested acreage minus loss due to harvest)	Cumulative Net C sequestration (MMt CO_2e)
2009	4.55	1.08	0.01	-3.46	-12.70
2010	4.55	2.15	0.03	-2.37	-8.70
2011	4.55	3.23	0.04	-1.28	-4.71
2012	4.55	4.30	0.05	-0.19	-0.71
2013	4.55	5.38	0.07	0.90	3.28
2014	4.55	6.46	0.08	1.99	7.28
2015	4.55	7.53	0.10	3.08	11.28
2016	4.55	8.61	0.11	4.16	15.27
2017	4.55	9.69	0.12	5.25	19.27
2018	4.55	10.76	0.14	6.34	23.26
2019	4.55	11.84	0.15	7.43	27.26
2020	4.55	12.91	0.16	8.52	31.25

C = carbon; MMtC = million metric tons of carbon; MMtCO_2e = million metric tons of carbon dioxide equivalent.

Table F-34. Management Scenario 4: 75 percent Shift to Uneven-Aged Management
(see Table F-29 for acreage values)

Year	C Lost During Harvest (MMtC)	Cumulative C Sequestration in Unharvested Acreage (MMtC)	Cumulative C Sequestration in Harvested Acreage (MMtC)	Cumulative Net C Sequestration (MMtC) (=C sequestration in harvested + unharvested acreage minus loss due to harvest)	Cumulative Net C Sequestration (MMt CO_2e)
2009	4.23	1.08	0.01	-3.14	-11.52
2010	4.23	2.15	0.02	-2.06	-7.54
2011	4.23	3.23	0.03	-0.97	-3.56
2012	4.23	4.30	0.04	0.12	0.42
2013	4.23	5.38	0.05	1.20	4.41
2014	4.23	6.46	0.06	2.29	8.39
2015	4.23	7.53	0.07	3.37	12.37
2016	4.23	8.61	0.08	4.46	16.35
2017	4.23	9.69	0.09	5.55	20.33
2018	4.23	10.76	0.10	6.63	24.32
2019	4.23	11.84	0.11	7.72	28.30
2020	4.23	12.91	0.12	8.80	32.28

C = carbon; MMtC = million metric tons of carbon; MMtCO_2e = million metric tons of carbon dioxide equivalent.

Goal 2: Restock understocked forest

Forests that are not fully stocked do not grow as quickly as fully stocked stands. This option seeks to quantify the costs and benefits of restocking understocked timberland acreage in PA (timberland is defined by USFS as land that is capable of producing ≥20 cubic feet/acre/year of industrial wood). The total acreage in PA timberland currently understocked is given in Table F 52 (from USFS FIA, 2004). The scenarios developed for use in this option are described in Table F-36.

Table F-35. Acreage of Timberland by Stocking Class in PA (FIA, 2004)

Stocking Class	Area (Thousand Acres)	Proportion of Timberland Area
Poor	1,320	8%
Moderate	5,565	34%
Full	8,586	52%
Overstocked	989	6%
Total	**16,460**	

Table F-36. Scenario Design for Option Forestry-5 (Goal 2), Restocking Understocked Forestland

Scenarios	Annual Acreage Restocked (acres/year)		Total Acreage Restocked Annually (acres)	Proportion of All Timberland Restocked 2009–2020
	Poorly Stocked	Moderately Stocked		
Scenario 1: 100% of poorly stocked land	109,983	0	109,983	19%
Scenario 2: 100% of poorly and 50% of moderately stocked land	109,983	231,875	341,858	60%
Scenario 3: 100% of poorly and moderately stocked land	109,983	463,750	573,733	100%

Since the most feasible approach for restocking involves harvesting understocked forest, then replanting a fully stocked forest, the quantification assumes that forests targeted under this option will first be harvested. Harvested volume is assumed to be made available for durable wood products. Using this assumption, the carbon in the understocked forest is assumed to be emitted in the year of harvest, except for that proportion expected to remain stored in long-term pools (such as durable wood products and in landfills) 100 years after harvest. Thus, the difference between harvest emissions and long-term storage is the net carbon loss due to harvest.

The biomass not stored in these long-term pools is emitted to the atmosphere, either with or without energy production. If the harvested biomass is used for biomass energy, there could be an additional GHG benefit due to fuel switching via reduced demand for fossil fuel. This potential benefit was not quantified, but Forestry-8 contains an analysis of the overall potential for biomass energy in PA.

The total live tree carbon in understocked forest was found as a function of the average volume in each of the stocking conditions. Volume data by stocking class were found from USFS FIA data (2004). Biomass values corresponding to these wood volume numbers were obtained from GTR- NE-343 (Table F-37). It was assumed that 100 percent of the live tree biomass was lost due to harvest. It was assumed that no change took place in dead biomass carbon and soil carbon due to harvest.

Table F-37. Live Tree Biomass in Understocked Stands in PA

Forest Types	Poorly Stocked Volume (ft^3/acre)	Live Tree Carbon Stock (tC/acre)	Notes	Moderately Stocked Volume (ft^3/acre)	Live Tree Carbon Stock (tC/acre)	Notes
Maple-Beech-Birch	845.61	21.5	Table A2, corresponds to 25 years old, 830 ft^3/acre	1657.04	35.5	Table A2, corresponds to 45 years old, 1,702 ft^3/acre
Oak-Hickory	693.84	17.4	Table A3, corresponds to 15 years old, 779 ft^3/acre	1411.52	29.1	Table A3, corresponds to 25 years old, 1,368 ft^3/acre
Average		**19.45**			**32.3**	

ft^3 = cubic feet; tC = metric tons of carbon.
Source: J.E. Smith et al., 2006.

See Forestry-6 for detailed methodology to quantify the carbon stored in durable wood products 100 years after harvest. Results from that analysis suggest that of every cubic foot harvested from PA forests, 0.000708 tCO_2e are stored in long-term pools (durable wood products (DWP's) and landfills) 100 years after harvest. Thus, for this analysis, the total cubic feet harvested during the restocking process was multiplied by 0.000708 to determine the carbon eventually stored in long-term pools. This number was then subtracted from the total carbon in the understocked forest for acres cleared each year to estimate the net GHG impact of harvest (Table F-38).

Table F-38. Annual Carbon Emissions Due to Harvest for Restocking

Scenarios	Acres Harvested Annually (acres/year)		Vegetation Carbon Stock Emitted (MMtC/year)	Carbon Stored in DWPs (MMtC/year)	Net Annual Emissions Due to Harvest ($MMtCO_2e$/year)
	Poorly Stocked Stands	Moderately Stocked Stands			
Scenario 1	109,983	0	2.14	0.06	7.62
Scenario 2	109,983	231,875	9.63	0.31	34.2
Scenario 3	109,983	463,750	17.12	0.56	60.7

tC = metric tons of carbon; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

The targeted acreage is then assumed to be replanted in fully stocked plantations, such that carbon sequestration in these acres occurs at a rate consistent with average carbon sequestration in these fully stocked stands in PA. Acres replanted in one year continue to sequester carbon in subsequent years, so the carbon sequestered in a given year is calculated as the sum of carbon stored on all restocked acres. Replanted forests are assumed to be an equal mix of Spruce-Balsam-Fir and White-Red-Jack Pine stands, on a 50-year rotation. Expected carbon storage values are given in Table F-39. Overall results of the analysis of carbon storage on replanted acres are given in Table F-40.

Table F-39. Forest Carbon Sequestration Rates in Conifer Forests

Forest Types	tC/acre (0 year)	tC/acre (55 year)	tC/acre/year (average)
Spruce-Balsam Fir	22.7	46.5	0.5
White-Red-Jack Pine	14.7	42.9	0.6

tC = metric tons of carbon

Table F-40. C Storage on Restocked Acreage

Year	Scenario 1		Scenario 2		Scenario 3	
	Cumulative Planted Acreage	Annual Carbon Storage ($MMtCO_2e$/year)	Cumulative Planted Acreage	Annual Carbon Storage ($MMtCO_2e$/year)	Cumulative Planted Acreage	Annual Carbon Storage ($MMtCO_2e$/year)
2009	109,983	0.2	341,858	0.7	573,733	1.1
2010	219,967	0.4	683,717	1.3	1,147,467	2.2
2011	329,950	0.6	1,025,575	2.0	1,721,200	3.3
2012	439,933	0.8	1,367,433	2.6	2,294,933	4.4
2013	549,917	1.0	1,709,292	3.3	2,868,667	5.5
2014	659,900	1.3	2,051,150	3.9	3,442,400	6.6
2015	769,883	1.5	2,393,008	4.6	4,016,133	7.7
2016	879,867	1.7	2,734,867	5.2	4,589,867	8.8
2017	989,850	1.9	3,076,725	5.9	5,163,600	9.8
2018	1,099,833	2.1	3,418,583	6.5	5,737,333	10.9
2019	1,209,817	2.3	3,760,442	7.2	6,311,067	12.0
2020	1,319,800	2.5	4,102,300	7.8	6,884,800	13.1
Cumulative Totals	**8,578,700**	**16.4**	**26,664,950**	**50.8**	**44,751,200**	**85.3**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

The overall GHG impact of this option in a given year is calculated as the difference between emissions due to harvest and cumulative carbon storage on replanted acreage in that year (Table F-41). The numbers in Table F-38 represent net emissions rather than net GHG benefit, because the one-time loss due to harvest in a given year exceeds the carbon sequestration on cumulative planted acreage in all years of this analysis (2009–2020). If policy implementation is complete in 2020 and restocked land is allowed to continue to sequester carbon, it would take 30, 46, or 49 additional years, respectively, for carbon sequestration on restocked land to offset the one-time emissions from harvesting the understocked land in Scenario 1, 2, or 3.

Table F-41. Net Carbon Emissions From the Harvest/Replant Strategy for Achieving Fully Stocked Forest by 2020

Year	Scenario 1	Scenario 2	Scenario 3
	Net Carbon Emissions ($MMtCO_2e$/Year)		
2009	7.4	33.5	59.6
2010	7.2	32.9	58.5
2011	7.0	32.2	57.4
2012	6.8	31.6	56.3
2013	6.6	30.9	55.2
2014	6.4	30.3	54.1
2015	6.2	29.6	53.0
2016	5.9	28.9	51.9
2017	5.7	28.3	50.9
2018	5.5	27.6	49.8
2019	5.3	27.0	48.7
2020	5.1	26.3	47.6
Cumulative Total	**75.1**	**359.1**	**643.1**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Economic Cost:

Goal 1: Shift to uneven-aged management

The cost of shifting from even- to uneven-aged forest management techniques is dependent upon numerous factors; consequently, a cost analysis is difficult. Immediate revenues generated from timber sales would be reduced, as shifting away from even-aged management practices would result in a decrease in total biomass removal. However, uneven-aged management techniques require less time between harvest, and result in more sustained revenue over time. Managing for lower-intensity harvesting practices may also provide additional ecosystem services, such as water purification, late-successional wildlife habitat, and recreational benefits.

Other options may exist to provide supplementary revenue, to help offset reduced revenue from decreased harvest volumes. For example, enrolling Pennsylvania timberlands in existing carbon-trading markets may provide additional revenue to offset short-term losses as a result of decreased harvest volumes. However, not all carbon markets currently accept forest management as a viable option of sequestering carbon, including the Northeast Regional Greenhouse Gas Initiative.

Goal 2: Restock understocked forest

Costs associated with this option include the costs of harvesting target acreage, as well as the costs of replanting. Sohngen et al. (2007) estimate that the cost of harvest for a fully stocked forest is \$16.42/cubic meter (m^3), while the cost to harvest a poorly stocked stand is \$21.34/m^3 of volume. The "poorly stocked" figure of \$21.34/m^3 was used for this analysis. This is a one-time cost incurred in the year of harvest.

The cost of planting was estimated at \$680/acre.[31] This includes the cost of planting (\$150/acre), plus seedlings (\$100/acre) and herbicide (\$130/acre). Fencing for deer exclusion totals \$300/acre. For comparison, Sohngen et al. (2007) report an average cost of forest planting of \$405/acre in the Northeast. Planting costs are often higher in Pennsylvania than in the region overall, due to the high cost of deer exclusion. Planting is also a one-time cost incurred in the year of harvest.

One-time revenue from harvested wood was calculated in the year of harvest using third-quarter 2007 stumpage prices from the Pennsylvania Woodlands Timber Market Report.[32] This report divides the state into four quadrants and reports prices paid per thousand board feet (Mbf) by species. From this report, stumpage price for wood was averaged statewide by species, for an average price of \$311.86 per Mbf. Annual revenue from harvest was subtracted from the annual cost of harvest to determine the net cost of Forestry-5 (Goal 2) under each scenario.

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[31] Paul Roth, personal communication with J. Jenkins, October 2007.

[32] Pennsylvania State University. The Pennsylvania Woodlands' Timber Market Report, Third quarter 2007 stumpage prices, Available at: http://www.sfr.psu.edu/TMR/TMR.htm.

Discounted costs for this option represent the one-time cost of harvest (per m^3 harvested) less revenue from harvested wood, plus the one-time cost of planting (per acre) for land treated in a given year, discounted to represent the economic cost of each scenario in today's dollars (using a discount rate of 5 percent). Levelized cost-effectiveness is not estimated for this option, because the option results in a net carbon emission rather than avoided carbon emission or sequestration benefit. Total discounted costs (in 2007 dollars) for restocking understocked forests in PA are described in Table F-42.

Table F-42. Discounted Costs ($2007) for Implementing the Harvest/Replant Strategy for Fully Stocking Understocked Acreage

Year	Scenario 1	Scenario 2	Scenario 3
2009	$114,236,348	$452,250,723	$790,265,098
2010	$108,796,522	$430,714,974	$752,633,426
2011	$103,615,735	$410,204,737	$716,793,739
2012	$98,681,653	$390,671,178	$682,660,704
2013	$93,982,526	$372,067,789	$650,153,052
2014	$89,507,168	$354,350,275	$619,193,383
2015	$85,244,922	$337,476,453	$589,707,983
2016	$81,185,640	$321,406,145	$561,626,651
2017	$77,319,657	$306,101,091	$534,882,525
2018	$73,637,769	$291,524,848	$509,411,928
2019	$70,131,208	$277,642,713	$485,154,217
2020	$66,791,627	$264,421,631	$462,051,636
Cumulative Costs	**$1,063,130,774**	**$4,208,832,558**	**$7,354,534,342**

Implementation Steps:

- Work with PA NRCS and Forest Stewardship Program to integrate and package (Farm Bill) funding and technical assistance programs to emphasize forest carbon sequestration practices.
- Create a program to encourage forest landowners to consider forest certification by providing technical/financial support, aggregation services, and product marketing assistance.
- Expand forest certification to additional state agencies and public lands.
- Assess the feasibility of a "forest carbon leasing" program, whereby private forest landowners would be compensated for long-term rights/value of forest carbon on their properties.
- Create a state tax credit (perhaps modeled on Resource Enhancement and Protection [REAP]) for forest landowners who implement approved forest carbon enhancement practices on their lands. This also could extend to activities associated with the reforestation, afforestation, and regeneration work plan.

BOF Division of Forest Fire Protection: The Division of Forest Fire Protection is responsible for the prevention and suppression of wildfire on the 17,000,000 acres of wildland throughout the commonwealth. The division maintains a fire detection system and works with fire wardens and volunteer fire departments to ensure that they are trained in the latest advances in fire prevention and suppression. The division also enters into partnerships with other state and federal agencies to share knowledge and resources. The division contains two sections:[33]

- *Wildfire Operations Section*—The Wildfire Operations Section is responsible for fire suppression, surveillance and operations of contract aircraft. It provides support for field personnel. It is also responsible for processing and collecting all fire claims and for providing trained fire suppression personnel to other states during wildfire emergencies.
- *Wildfire Services Section*—The Wildfire Services Section is responsible for the enhancement of public safety and awareness in wildfire prevention through education, enforcement activities, and the development of new fire technology. The section conducts special investigations throughout BOF as assigned, coordinates the distribution of federal funds and equipment to local fire-fighting forces, acquires federal excess property to supplement BOF fire equipment, and maintains warehouse operations.

BOF Division of Forest Pest Management: The Division of Forest Pest Management is responsible for the protection of all forestland in the state from diseases, insects, and other forest pests. The division's objective is to manage the health of the commonwealth's forests in a manner that will limit forest value losses (http://www.dcnr.state.pa.us/forestry/foresthealth.aspx).

- *Forest Health Section*—The Forest Health Section is responsible for surveying, evaluating, and monitoring insect- and disease-related forest influences. Various projects are implemented for the prevention, detection, diagnosis, investigation, and evaluation of forest pest problems.
- *Forest Pest Suppression Section*—This section is responsible for statewide forest pest-suppression projects that involve the use of biological control agents or pesticides on state lands and forested residential lands. It develops forest pest information and technology development and transfer.

USFS Forest Stewardship Program: This program promotes the development of Stewardship Plans (10-year forest management plans) for private forestland. It is a BOF-wide, program, delivered mainly by district located Service Foresters. Policy and cost-coding procedures are administered through BOF's CFM Section (http://www.fs.fed.us/spf/coop/programs/loa/fsp.shtml).

Potential Overlap: None

Subcommittee Comments

Another example of a work plan for which the potential GHG reduction benefits are under-represented due to the time frame of this analysis. It also would have been helpful to undertake a more thorough analysis of available management options, in order to reflect the complexity of

[33] See: http://www.dcnr.state.pa.us/forestry/ffp/index.aspx.

age class representations in the stand canopy and the effect of silvicultural treatments. And going even farther, to consider attributes in addition to age class--e.g., composition, structure, regeneration, etc. which also have the potential to influence carbon stocks. In addition, it would be helpful to have a more robust analysis of potentially available restocking options--in addition to harvest and replanting, since differences in stand conditions can vary greatly. Regarding relationship to other plans and potential implementation mechanisms--an effective system of forestry-based carbon credits would, ideally, help to maintain the quality of the forests being conserved and provide opportunities for sustainable production of wood products, biomass, etc

It is important to note that there are existing carbon offset protocols that acknowledge this activity. Specifically, the Climate Action Reserve (CAR), as well as the Chicago Climate Exchange (CCX) has a protocol accepting projects that engage in "improved forest management" and "managed forest projects". It will be important to evaluate these project protocols and encourage pilot projects within Pennsylvania to more fully understand these opportunities. Furthermore, it has a direct relationship with the costs associated with this option; as such potential revenues for entering into such projects will impact the cost effectiveness.

Durable wood products credits should have been generated from the harvested material in the restocking option. This would generate a noticeable change in the analysis.

The analysis timeline does not display the potential long term benefits of this option.

Forestry-6. Sequestering Carbon in Durable Wood Products

Initiative Summary:

This option seeks to enhance the use and lifetime of durable wood products. Durable products made from wood prolong the length of time forest carbon is stored and not emitted to the atmosphere. Wood products disposed of in landfills may store carbon for long periods under conditions that minimize decomposition, especially when methane gas is captured from landfills (carbon originally stored in wood products becomes methane during decomposition). Substituting products made from wood for products with higher embodied energy in building materials can reduce life-cycle GHG emissions from other products. This can be achieved through improvements in production efficiency, product substitution, expanded product lifetimes, and other practices. Increasing the efficiency of the manufacturing life cycle for wood products will enhance GHG benefits. To quantify the categories for disposition of carbon in harvested wood, the analysis relied on USDA USFS Northern Research Station GTR-NE-343, *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States.*[34] This methodology demonstrates the eventual destination of carbon from harvested wood in five broad categories: products in use, in landfills, emitted with energy capture, emitted without energy capture, and emitted at harvest.

Goals:

Enhance management activities and timber sales to provide a reliable supply of timber for durable wood products.

- Scenario 1: Calculate disposition categories for 2006 estimate for level of harvest (1.12 Bbf/yr) through 2020
- Scenario 2: Calculate disposition categories for statewide wood harvest levels at 1.5 Bbf/yr through 2020
- Scenario 3: Calculate GHG impact of current harvest level of 80 MMbf/yr on PA state forest land through 2020

Implementation Period: 2009–2020

Other Involved Agencies: PDA—Hardwoods Development Council, PennDOT

Data Sources/ Methods/ Assumptions:

Data Sources:

- Sampson and Kamp. 2007. *The Nature Conservancy Conservation Partnership Agreement*. Part 2: "Recent Trends in Sinks and Sources of Carbon."

[34] J.E. Smith et al. 2006. *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the United States*. GTR-NE-343. USFS Northern Research Station. (Also published as part of the DOE Voluntary GHG Reporting Program.)

- J.E. Smith et al. 2006. *Methods for Calculating Forest Ecosystem and Harvested Carbon with Standards Estimates for Forest Types of the United States.* GTR-NE-343. USFS Northern Research Station. (Also published as part of the DOE Voluntary GHG Reporting Program..
- Miner, Reid. 2006. The 100-year Method for Forecasting Carbon Sequestration in Forest Products in Use. Mitigation and Adaptation Strategies for Global Change.
- USDA Northeastern FIA tables at: http://www.fs.fed.us/ne/fia//pa/.
- Lumber Production and Mill Stocks data from U.S. Census at: http://www.census.gov/industry/1/ma321t06.pdf

Quantification Methods:

Carbon sequestration in harvested wood products was calculated following guidelines published by USFS in GTR-NE-343 (Smith et al., 2006). Details on each step of the analysis can be found in the guidelines, following the methodology referred to as “Product-based estimates.”

To quantify carbon stored in long-term products, forest harvest is used as a starting point. The methodology calculates the proportion of harvested wood that is diverted to each of four pools after 100 years: wood in use (i.e., building materials, furniture), wood in landfills (i.e., products that were previously in use and have been discarded), wood burned for energy capture, and wood that has decayed or burned without energy capture. The wood that has not been burned or decayed (i.e., the wood in the “in use” or “landfill” pools) is assumed to remain stored 100 years after harvest.

Most of the carbon stored in harvested wood products is emitted to the atmosphere over time. Because this method quantifies the amount of carbon in this year’s harvest that is expected to remain stored (or “in use”) for a defined period of time, rather than accounting instantaneously for the carbon stored in various products each year, this 100-year approach likely underestimates slightly the carbon stored over the 12-year implementation period of this analysis. Despite its conservatism, the 100-year method has the advantage of being simple and consistent, and has compared well with other accounting methods (Miner, 2006).

The general methodology for all scenarios in this option followed these steps:

1. Find the proportion of harvested volume that is in softwood or hardwood logs.
2. For each of the species types (hardwood and softwood), find the proportion of harvested volume in sawtimber and pulpwood.
3. Calculate tons of carbon in harvested volume.
4. Project carbon stored in long-term storage pools 100 years after harvest for each scenario.

The approach for each of the steps is described below.

1. The U.S. Census estimates that 1,121 MMbf were harvested from PA forests in 2006,[35] of which 1,055 MMbf (94 percent) was hardwood and 66 MMbf (6 percent) was softwood. These values were used directly for Scenario 1, and the total volume of hardwood and softwood harvested for Scenarios 2 and 3 was calculated assuming the same proportions.

2. The fraction of growing-stock volume in hardwood and softwood that occurs in each of the size classes (sawtimber and pulpwood) is given by GTR-NE-343. The distribution of harvest volume was assumed to follow the distribution of growing-stock volume presented in the guidelines. An average mix of 50 percent Maple-Beech-Birch and 50 percent Oak-Hickory forest was assumed (Table F-43).

Table F-43. Factors Used to Apportion Harvest Volume Into Sawtimber and Pulpwood Classes for PA Forests

Forest Type	Fraction of Softwood Volume That Is Sawtimber	Pulpwood (1 – Sawtimber)	Fraction of Hardwood Volume That Is Sawtimber	Pulpwood (1 – Sawtimber)
Maple-Beech-Birch	0.604	0.396	0.526	0.474
Oak-Hickory	0.706	0.294	0.667	0.333
Average	**0.655**	**0.345**	**0.597**	**0.403**

Source: Table 4, USDA, GTR-NE-343.

3. The fractions above were used to determine the total harvest (MMbf) in each of the four categories (hardwood sawtimber, hardwood pulpwood, softwood sawtimber, softwood pulpwood) under each scenario. These values were converted to m^3, and then multiplied by average specific gravity (from Table 4, GTR-NE-343) to find total carbon in harvested volume (Table F-44).

Table F-44. Carbon in Harvested Volume Under Three Scenarios in PA

Wood Categories	tC in Harvested Volume (tC/year)		
	Scenario 1: Current Statewide Harvest (1.12 Bbfyr)	Scenario 2: 1.5 Bbf/yr	Scenario 3: 80 MMbf/yr on State Forest Land
Softwoods			
Sawtimber	19,306	25,833	1,378
Pulpwood	10,169	13,607	726
Hardwoods			
Sawtimber	390,555	522,598	20,056
Pulpwood	264,189	353,509	13,567
Total (MMt/year)	**0.684**	**0.916**	**0.036**

Bbf/yr = billion board feet per year; MMbf/yr = million board feet per year; MMt = million metric tons.

[35] From U.S. Census: http://www.census.gov/industry/1/ma321t06.pdf.

4. Methods described in GTR-NE-343 were used to calculate the proportions of harvested carbon that were stored in each of the four disposition categories after 100 years (Table F-45). These proportions were used to calculate the proportion of harvested carbon remaining in use or in landfills after 100 years.

Table F-45. Proportion of Harvested Carbon Remaining in Various Pools 100 Years After Harvest

Disposition Categories	Disposition Factor
Softwoods–Sawlogs	
In use	0.095
Landfill	0.223
Energy	0.338
Emitted w/o energy	0.344
Softwoods–Pulpwood	
In use	0.006
Landfill	0.084
Energy	0.51
Emitted w/o energy	0.4
Hardwoods–Sawlogs	
In use	0.035
Landfill	0.281
Energy	0.387
Emitted w/o energy	0.296
Hardwoods–Pulpwood	
In use	0.103
Landfill	0.158
Energy	0.336
Emitted w/o energy	0.403

Source: USDA, GTR-NE-343, Table 6.

Summary results for all three scenarios, describing the total carbon stored in each long-term pool 100 years after harvest, are listed in Table F-46.

The cumulative results of the GHG savings from implementing these three scenarios over the full policy implementation period (2009–2020) are summarized in Table F-47.

Table F-46. Total Carbon Stored in Harvested Wood Products After 100 Years for Three Scenarios

Disposition Categories	Scenario 1: Current Statewide Harvest (tC/year)	Scenario 2: Increase Harvest to 1.5 Bbf (tC/year)	Scenario 3: Maintain Current State Forest Land Harvest (tC/year)
Softwoods-Sawlog			
In use	1,834.03	2,454.10	130.88
Landfill	4,305.16	5,760.69	307.23
Softwoods-Pulpwood			
In use	61.01	81.63	4.35
Landfill	854.16	1,142.95	60.95
Hardwoods-Sawlog			
In use	13,669.42	18,290.93	701.96
Landfill	109,745.96	146,850.09	5,635.76
Hardwoods-Pulpwood			
In use	27,211.50	36,411.47	1,397.38
Landfill	41,741.92	55,854.48	2,143.56
Total stored C 100 years post harvest (tC/year)	**199,423.20**	**266,846.38**	**10,382.12**
Total stored C 100 years post harvest ($MMtCO_2e$/year)	**0.731**	**0.978**	**0.038**

Bbf = billion board feet; tCe = metric tons of carbon; tCO_2e = million metric tons of carbon dioxide equivalent; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table F-47. Cumulative Carbon Stored by Durable Wood Products Under Three Scenarios for Option F-5, 2009–2020

Scenarios	Annual GHG Savings ($MMtCO_2e$/year)	2009–2020 GHG Savings ($MMtCO_2e$)
Scenario 1: 2006 statewide harvest held constant (1.1 Bbf/yr)	0.73	8.77
Scenario 2: Statewide harvest increased to 1.5 billion board feet/year in 2009, maintained through 2020	0.98	11.74
Scenario 3: PA state forest harvest held constant (80 MMbf/yr)	0.04	0.46

Bbf/yr = billion board feet per year; MMbf/yr = million board feet per year; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Economic Cost

The cost of durable wood products production is dependent upon various factors, which make a cost analysis difficult and uncertain. An increase in carbon sequestration in durable wood products can be approached from various angles, including production efficiency, product substitution, expanded product lifetimes, and other practices. However, in this analysis, only an estimate of GHG savings was provided for scenarios that increase supply of high-quality wood for the manufacture of durable wood products.

A cost analysis for this option would depend upon how these harvest levels are met (i.e., through afforestation or more intensive management of existing forest resources). Forestry-4 and Forestry-5 report provide cost analyses for afforestation and forest management options.

Additional costs might include development of marketing materials and program administration meant to promote the use of durable wood products. These costs are not currently included in the analysis.

Implementation Steps:

LEED standards to recognize the carbon value of using wood building materials, support revising green building standards to give more credit for the utilization of wood products (including revising state building standards). Promote state lead-by-example programs and promotions that greater utilization locally and sustainably produced wood products in DCNR and other state construction projects. Continue and enhance management activities and timber sales on state forestlands that provide a reliable supply of timber for production of wood products.

Potential Overlap: Forestry-2, Woodnet

Subcommittee Comments

This option seeks to enhance the use and lifetime of durable wood products. Durable products made from wood prolong the length of time forest carbon is stored and not emitted to the atmosphere. Wood products disposed of in landfills may store carbon for long periods under conditions that minimize decomposition, especially when methane gas is captured from landfills (carbon originally stored in wood products becomes methane during decomposition). Substituting products made from wood for products with higher embodied energy in building materials can reduce life cycle GHG emissions from other products. This can be achieved through improvements in production efficiency, product substitution, expanded product lifetimes, and other practices. Increasing the efficiency of the manufacturing lifecycle for wood products will enhance greenhouse gas benefits. To quantify the categories for disposition of carbon in harvested wood, the analysis relied on USDA USFS Northern Research Station GTR-343, ***Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States.*** This methodology demonstrates the eventual destination of carbon from harvested wood in five broad categories: products in use, in landfills, emitted with energy capture, emitted without energy capture, and emitted at harvest.

It is important to note that there are existing carbon offset protocols that acknowledge this activity. Specifically, the Chicago Climate Exchange (CCX) has a protocol accepting projects that generate “durable wood products”. It will be important to evaluate these project protocols and encourage pilot projects within Pennsylvania to more fully understand these opportunities. Furthermore, it has a direct relationship with the costs associated with this option; as such potential revenues for entering into such projects will impact the cost effectiveness.

Forestry-7. Urban Forestry

Initiative Summary: This option seeks to increase carbon stored in urban forests, and thereby to reduce residential, commercial, and institutional energy use for heating and cooling. Carbon stocks in trees and soils in urban land uses—such as in parks, along roadways, and in residential settings—can be enhanced in a number of ways, including planting additional trees, reducing the mortality and increasing the growth of existing trees, and avoiding tree removal (or deforestation). Forest canopy cover, properly designed, can also reduce energy demand by reducing building heating and cooling needs.

Goals:

Scenario 1: Increment existing tree cover in PA urban and suburban forests by 10 percent by 2020.
Scenario 2: Increment existing tree cover by 25 percent by 2020.
Scenario 3: Increment existing tree cover by 50 percent by 2020.

Implementation Period: 2009–2020

Other Involved Agencies: DCNR, BOF, DEP, Alliance for the Chesapeake Bay, The Chesapeake Bay Foundation, The Western Pennsylvania Conservancy

Data Sources/ Assumptions/Methods:

Data Sources:

- Information about current numbers of trees in urban forest and annual carbon storage in urban trees in PA from D.J. Nowak et al., USFS, Northern Research Station, *Urban Forest Effects on Environmental Quality*, State Summary data for Washington (http://www.fs.fed.us/ne/syracuse/Data/State/data_PA.htm).
- Fossil fuel reductions through reduced demand for cooling and protection from wind from: E. McPherson and J.R. Simpson. 1999. *Carbon Dioxide Reduction Through Urban Forestry: Guidelines for Professional and Volunteer Tree Planters*. USFS GTR-PSW-171. USFS, Pacific Southwest Research Station.
- Data on the costs of tree planting and maintenance from Peper, P.J., et al. 2007. *New York City, New York Municipal Forest Resource Analysis*. Center for Urban Forest Research, USFS Pacific Southwest Research Station.
- Additional data on benefits of tree canopy in PA are from D.J. Nowak et al. 2007. *Assessing Urban Forest Effects and Values: Philadelphia's Urban Forest.* Resource Bulletin NRS-7. USFS, Northern Research Station

Potential GHG Reduction (MMtCO_2e):
This option quantifies the cumulative impact on carbon sequestration and avoided fossil fuel emissions of adding trees to existing canopy cover in PA. Specifically, Scenarios 1, 2, and 3 seek to increase the total number of trees in PA by 10 percent, 25 percent, or 50 percent, respectively, by 2020. Currently, PA contains 139 million urban trees: thus this option quantifies the effect of

adding 13.9, 34.8, and 69.5 million trees by 2020. The number of trees planted each year is constant, with the target number of trees planted by 2020. GHG benefits are twofold: direct carbon sequestration by planted trees and avoided GHG emissions from strategic tree planting to reduce energy demand due to heating and cooling.

A. Direct Carbon Sequestration in Urban Trees

A linear rate of increase in tree planting was assumed, with full scenario implementation occurring in 2020 for all three scenarios. Annual carbon sequestration per urban tree is calculated as 0.006 tC/tree/year, based on statewide average data reported by USFS. This is the average annual per-tree carbon sequestration value when the total estimated urban forest carbon accumulation in PA (863,000 tC/year) is divided by the total number of urban trees in PA (139.0 million). Since trees planted in one year continue to accumulate carbon in subsequent years, annual carbon sequestration in any given year is calculated as the sum of carbon stored in trees planted in that year, plus the sequestration by trees that were planted in prior years.

B. Avoided Fossil Fuel Emissions

Offsets from avoided fossil fuel use for heating and cooling are the sum of three different types of savings: avoided emissions from reduced cooling demand, avoided emissions from reduced demand for heating due to wind reduction (this benefit is only available for evergreen trees), and enhanced fossil fuel emissions needed for heat due to wintertime shading. Calculations for avoided fossil fuel offsets are based on calculations presented by McPherson et al. in GTR-PSW-171 (Table F-47). For this analysis, it is assumed that the trees planted are evenly split among residential settings with pre-1950, 1950–1980, and post-1980 homes, and that all trees planted are medium-sized, with 50 percent deciduous and 50 percent evergreen. These avoided emission factors assume average tree distribution around buildings (i.e., these fossil fuel reduction factors are average for existing buildings, but do not necessarily assume that trees are optimally placed around buildings to maximize energy efficiency). These factors are also dependent on the fuel mix (coal, hydroelectric, nuclear, etc.) in the region, and are thus likely to change if the electricity mix changes from its 1999 distribution.

C. Overall GHG Benefit of Urban Tree Planting

Total GHG benefits are calculated as the sum of direct carbon sequestration plus fossil fuel offset from reduced cooling demand and wind reduction (Tables F-48, F-49, and F-50).

Table F-47. Factors Used to Calculate CO_2e Savings ($MMtCO_2$e/Tree/Year) From Reduced Need for Fossil Fuel for Heating and Cooling, and From Windbreak Effect of Evergreen Trees

Fossil Fuel Offsets: Evergreen Trees (Mid-Atlantic Climate Region)				
Housing Vintage	*Shade–Cooling*	*Shade–Heating*	*Wind–Heating*	*Net Effect*
Pre-1950	0.0168	–0.0315	0.1294	0.1147
1950–1980	0.0275	–0.0403	0.1555	0.1427
Post-1980	0.0232	–0.0324	0.133	0.1238
Average	**0.0225**	**–0.0347**	**0.1393**	**0.1271**
Average ($MMtCO_2$e)				**0.127075**
Fossil Fuel Offsets: Deciduous Trees (Mid-Atlantic Climate Region)				
Housing Vintage	*Shade–cooling*	*Shade–Heating*	*Wind–Heating*	*Net Effect*
Pre-1950	0.0260	–0.0320		–0.0060
1950–1980	0.0425	–0.0409		0.0016
Post-1980	0.0358	–0.0329		0.0029
Average	**0.0348**	**–0.0353**		**–0.0005**
Average ($MMtCO_2$e)				**0.0632875**

Source: McPherson et al., 1999.

$MMtCO_2$e = million metric tons of carbon dioxide equivalent.

Table F-48. Overall GHG Benefit ($MMtCO_2$e/year) of Scenario 1: Increase Existing PA Urban Tree Canopy by 10 percent

Year	Trees Planted This Year	Trees Planted in Previous Years	GHG Sequestered	GHG Avoided	Overall GHG Savings
2009	1,158,500	0	0.026	0.073	0.100
2010	1,158,500	1,158,500	0.053	0.147	0.199
2011	1,158,500	2,317,000	0.079	0.220	0.299
2012	1,158,500	3,475,500	0.105	0.293	0.399
2013	1,158,500	4,634,000	0.132	0.367	0.498
2014	1,158,500	5,792,500	0.158	0.440	0.598
2015	1,158,500	6,951,000	0.185	0.513	0.698
2016	1,158,500	8,109,500	0.211	0.587	0.797
2017	1,158,500	9,268,000	0.237	0.660	0.897
2018	1,158,500	10,426,500	0.264	0.733	0.997
2019	1,158,500	11,585,000	0.290	0.806	1.097
2020	1,158,500	12,743,500	0.316	0.880	1.196
Cumulative Totals		**13,902,000**	**2.057**	**5.718**	**7.775**

$MMtCO_2$e = million metric tons of carbon dioxide equivalent.

Table F-49. Overall GHG Benefit ($MMtCO_2e$/year) of Scenario 2: Increase Existing PA Urban Tree Canopy by 25 percent

Year	Trees Planted This Year	Trees Planted in Previous Years	GHG Sequestered	GHG Avoided	Overall GHG Savings
2009	2,896,250	0	0.066	0.183	0.249
2010	2,896,250	2,896,250	0.132	0.367	0.498
2011	2,896,250	5,792,500	0.198	0.550	0.748
2012	2,896,250	8,688,750	0.264	0.733	0.997
2013	2,896,250	11,585,000	0.330	0.916	1.246
2014	2,896,250	14,481,250	0.396	1.100	1.495
2015	2,896,250	17,377,500	0.461	1.283	1.744
2016	2,896,250	20,273,750	0.527	1.466	1.994
2017	2,896,250	23,170,000	0.593	1.650	2.243
2018	2,896,250	26,066,250	0.659	1.833	2.492
2019	2,896,250	28,962,500	0.725	2.016	2.741
2020	2,896,250	31,858,750	0.791	2.199	2.990
Cumulative Totals		**34,755,000**	**5.142**	**14.296**	**19.438**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Table F-50. Overall GHG Benefit ($MMtCO_2e$/year) of Scenario 3: Increase Existing PA Urban Tree Canopy by 50 percent

Year	Trees Planted This Year	Trees Planted in Previous Years	GHG Sequestered	GHG Avoided	Overall GHG Savings
2009	5,792,500	0	0.132	0.367	0.498
2010	5,792,500	5,792,500	0.264	0.733	0.997
2011	5,792,500	11,585,000	0.396	1.100	1.495
2012	5,792,500	17,377,500	0.527	1.466	1.994
2013	5,792,500	23,170,000	0.659	1.833	2.492
2014	5,792,500	28,962,500	0.791	2.199	2.990
2015	5,792,500	34,755,000	0.923	2.566	3.489
2016	5,792,500	40,547,500	1.055	2.933	3.987
2017	5,792,500	46,340,000	1.187	3.299	4.486
2018	5,792,500	52,132,500	1.318	3.666	4.984
2019	5,792,500	57,925,000	1.450	4.032	5.483
2020	5,792,500	63,717,500	1.582	4.399	5.981
Cumulative Totals		**69,510,000**	**10.284**	**28.592**	**38.876**

$MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Economic Cost:

Economic costs of tree planting are calculated as the sum of tree planting and annual maintenance, including the costs of program administration and waste disposal. Economic benefits of tree planting include the cost offset from reduced energy use, as well as the estimated economic benefits of services, such as provision of clean air, hydrologic benefits such as storm water control, and aesthetic enhancement.

Data were not available to assess the cost of tree planting specifically in PA communities. As a result, the cost of planting urban trees in PA is taken from Peper et al. (2007), whose analysis was conducted in New York City. The average annualized cost per tree is estimated at $37.28, and includes planting, pruning, pest management, administration, removal, and infrastructure repair due to damage from trees.

Two types of data were available to quantify the economic benefit of planting urban trees. The first data source is the New York City analysis of Peper et al. (2007). Average annual cost savings of –$206.91 per tree from this work is the average of all trees in the city, and includes benefits of energy savings, improved air quality, improved storm water quality, and improved aesthetics.

A second estimate of economic benefit per tree, specifically for Philadelphia, PA, was also used (Nowak et al., 2007). This analysis quantified the structural benefit of urban trees (i.e., replacement costs) as well as the annual functional benefits of urban trees (i.e., pollution abatement, energy savings). Total structural benefit of Philadelphia's 2.1 million urban trees was estimated at $1.8 billion. To determine the annual structural benefit of the urban tree canopy, this total citywide structural benefit was divided by 50 (the average lifetime of an urban tree). Annual functional economic benefits for the urban tree canopy were calculated as the value of pollution abatement ($3.9 million) plus the value of avoided energy costs ($1.19 million). The citywide structural and functional benefits were divided by the number of trees to estimate the annual economic benefit per tree in PA. From this source, the average annual (structural + functional) benefit per tree per year in PA was calculated at –$19.57.

For this analysis, –$206.91/tree/year and –$19.57/tree/year were averaged to estimate the economic benefits of planting urban trees (–$113.24/tree/year). While these values clearly diverge substantially from one another, the methods used to estimate economic benefits of non-market services, such as clean air and water and pollution abatement, are inexact and variable. The value of –$113.24/tree/year is consistent with results obtained for similar analyses in other states.

Net economic costs for this option are calculated as the difference between costs of planting + maintenance and economic benefit realized by urban trees. Negative costs therefore refer to net economic benefits, where estimated benefits exceed overall costs. For this analysis, net economic benefit per tree was estimated at –$75.96/tree/year. Discounted costs were calculated in 2007 dollars and assuming a 5 percent discount rate. For all scenarios, the cost-effectiveness of implementing F-6 is –$565.74/tCO2e, which indicates a net cost savings per tCO_2e reduced.

Implementation Steps:

- Leverage/expand TreeVitalize program.
- Consider a comprehensive approach to school tree planting.
- Provide incentives for private landowners to plant trees in residential areas.

Goals Support Full Implementation of Target Programs

TreeVitalize seeks an $8 million investment in tree planting and care in southeastern Pennsylvania over a 4-year period. Goals include planting 20,000 shade trees, restoring 1,000 acres of forests along streams and water-protection areas, and training 2,000 citizens to plant and care for trees. DCNR initiated preliminary discussions with regional stakeholders in the summer of 2003, and appointed a Project Director in January 2004. Planning, assessment, and resource development continued through 2004. Tree-planting activities began in the fall of 2004 and will continue through the fall of 2007. The regional Tree Tenders program was launched in 2005. Although TreeVitalize is not a permanent entity, the collaborations created and capacity built will continue to increase tree cover and promote stewardship in the region. A Steering Committee, composed of funding entities, county governments, and major technical assistance providers, identifies priorities and approves projects. Operational committees, composed of local planting partners, technical assistance providers, and/or public agencies with expertise in tree planting, will implement projects, and deliver education and technical assistance. Other committees will be formed as needed. DCNR is examining opportunities to expand the program statewide. See: http://www.treevitalize.net/aboutus.aspx.

Enabling Programs May Provide Relevant Information in Support of Implementation

The Rural & Community Forestry Section provides professional forestry leadership and technical assistance promoting forestry and the knowledge of forestry by advising and assisting other government agencies, communities, landowners, the forest industry, and the general public in the wise stewardship and utilization of forest resources. The section also coordinates BOF's conservation education efforts, and provides professional forestry leadership and technical assistance to rural communities and urban areas. Efforts include coordination with Penn State's regional urban foresters, Arbor Day activities, Tree City USA, Penn ReLeaf, the Harrisburg Greenbelt project, the Municipal Tree Restoration program, and the Urban & Community Forestry Council. See: http://www.dcnr.state.pa.us/forestry/rural/index.aspx.

Major funding streams are through USFS state and private forestry through urban forestry funds. These support the work at Penn State by the Statewide Urban and Community Forestry Committee, which also receives some funding from the Bureau of Recreation and Conservation, as well other smaller grants from utilities.

There is also currently a Northeast Pennsylvania Urban & Community Forestry Program, which is funded through the 10th congressional district. This northeast area does not include Scranton/Wilkes Barre. Williamsport is the largest city included in this area.

A $650,000 open grant for the City of Philadelphia Neighborhood Transformation Initiative supports reclaiming abandoned properties and vacant land as open space.

The Animal Plant and Health Inspection Service (http://www.aphis.usda.gov/) gets involved in and makes funds available to combat specific issues, such as protection of urban forests from disease, fire, other risks, and proper management of urban forests and street trees.

A federal bill being considered—H.R. 3933/S.941, the Suburban and Community Forestry and Open Space Program Act—provides $50 million annually in federal matching funds for assistance.

Develop a package of incentives and programs to encourage retention/enhancement of tree cover on new developments (e.g., Department of Community and Economic Development planning/technical assistance, state funding bonus/priority, model SALDOs for carbon sequestration maintenance/offset requirements associated with tree cover, tax breaks for tree-friendly development, etc.).

Re-greening underutilized/abandoned properties through targeted tree planting programs and comprehensive local/county planning for urban/suburban terrestrial carbon sequestration.

Explore opportunities to use a portion of federal transportation funding (infrastructure and enhancement) to support community-scale tree planting for carbon sequestration.

Potential Overlap: None.

Subcommittee Comments

This option seeks to increase carbon stored in urban forests, and thereby to reduce residential, commercial and institutional energy use for heating and cooling. Carbon stocks in trees and soils in urban land uses—such as in parks, along roadways, and in residential settings—can be enhanced in a number of ways, including planting additional trees, reducing mortality and increasing growth of existing trees, and avoiding tree removal (or deforestation). Forest canopy cover, properly designed, can also reduce energy demand by reducing building heating and cooling needs.

It is important to note that there are existing carbon offset protocols that acknowledge this activity. Specifically, the Climate Action Reserve (CAR) has a protocol accepting projects that engage in “Urban Forestry”. It will be important to evaluate these project protocols and encourage pilot projects within Pennsylvania to more fully understand these opportunities. Furthermore, it has a direct relationship with the costs associated with this option; as such potential revenues for entering into such projects will impact the cost effectiveness.

Forestry-8. Wood to Electricity

Initiative Summary:

Market and policy forces are driving the expanding use of forest biomass energy. Biomass can be used to generate renewable energy in the form of liquid fuels (such as cellulosic ethanol, which is close to being market-ready), or through direct combustion to generate electricity, heat, or steam. Carbon in forest biomass is considered biogenic under sustainable systems; CO_2 emissions from biomass energy combustion are replaced by future carbon sequestration. Expanded use of biomass energy in place of fossil fuels results in net emissions reduction by shifting from high- to low-carbon fuels (when sustainably managed), provided the full life cycle of energy requirements for producing fuels does not exceed the energy content of the renewable resource. Expanded use of biomass energy can be promoted through increasing the amount of biomass produced and used for renewable energy, and providing incentives for the production and use of renewable energy supplies.

Goals:

- Increase wood utilization for sustainably generated electricity to 0.8025 MMt/yr by 2020.

Implementation Period: 2009–2020

Other Involved Agencies: DEP, PDA

Possible New Measure(s):

In 2005, biomass plants using wood as a primary fuel generated about 320,000 megawatt-hours (MWh) of electricity annually,[36] or about 0.22 percent of the total electricity used in PA.[37] Biomass can be co-fired with coal under certain circumstances as well, so a larger proportion of the PA electricity demand would likely be met if wood as a secondary fuel is included in the analysis of biomass use. A large group of locally financed small projects spread widely across the commonwealth could capture the value of replacing high-cost fuel imports and gain carbon benefits, while limiting the transportation costs of the feedstock. This model has been shown to allow displacement of significant quantities of current or projected fossil carbon release from a broad range of users—including industry, public institutions, commercial offices, and multi-family buildings—through reduced electrically driven cooling and distributed generation of electricity through combined heat and power (CHP) facilities.

Data Sources/ Assumptions/ Methods:

Biomass Supply:

The amount of biomass available for use in Forestry-8 was calculated from existing supply estimates, accounting for access and availability of forest biomass as well as for ecological concerns. First, the midpoint was selected between a high and low estimate generated by the

[36] Personal communication, J. Sherrick with J. Jenkins, October 2007.

[37] Total electricity demand in PA (2005) is 148,273 MWh (Energy Information Administration).

Blue Ribbon Task Force on the Low-Use Wood Resource in Pennsylvania.[38] The high estimate of biomass availability for energy purposes from PA forests is 6 million dry tons biomass/year, and the low estimate is 3 million tons/year. The midpoint of this range, 4.5 million tons dry-weight biomass/year, was used as the baseline feedstock. This value was reduced by 24 percent to account for practical restrictions on access and availability,[39] and by an additional 22.5 percent to account for ecological considerations.[40] Thus, annual total biomass availability in PA was estimated at 2.4075 million dry tons/year. To facilitate side-by-side analysis of cost and desirability for various uses of biomass, this estimate of annual harvest was allocated equally among three types of biomass uses: wood for electricity (quantified in Forestry-8), wood for thermal uses (including CHP systems, quantified in Forestry-9), and cellulosic ethanol (quantified in Agriculture-2). In Forestry-8, the goal level for implementation is 0.8025 MMt/year, or one-third of the available supply.

Quantification Methodology:

A linear ramp-up to the goal level between 2009 and 2020 was assumed. In 2020, Forestry-8 meets 0.6 percent of statewide electricity demand with biomass fuels.[41]

To quantify the GHG benefit of fuel switching, the heat content of wood was assumed to be 9.961 million Btus per short ton.[42] The most efficient coal-fired power plants are, on average, 36 percent efficient at converting coal to electricity.[43] To account for this difference between raw energy availability in wood and the net energy obtained when wood is converted to electricity, the heat content of wood was multiplied by 0.36 to quantify the effective Btus that would be produced from wood in a co-firing application. This value was used to estimate the Btu contribution per unit of wood biomass, and then the annual increment in electricity Btu from wood biomass needed to ramp up to the goal level for biomass usage in 2020 was calculated. Btus produced using wood biomass would reduce the electricity produced using other fuels. The emissions avoided by producing electricity using wood were calculated using the emission factors in Table F-51, which include emissions of methane, nitrous oxide, and CO_2, and were calculated from the PA I&F.

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[38] The Pennsylvania Hardwoods Development Council. 2008. *Report of the Blue Ribbon Task Force on the Low-Use Wood Resource in Pennsylvania*.

[39] Personal communication, Dr. James Finley, Pennsylvania State University School of Forest Resources, June 2009.

[40] 22.5% is the midpoint of the suggested values based on the "Guidance on Harvesting Woody Biomass for Energy in Pennsylvania," which states that "A range of 15-30% of pre-harvest biomass—depending on soil type, forest composition, and other factors—should always be left on site to buffer against nutrient depletion, erosion, loss of wildlife habitat and other factors." See: http://www.dcnr.state.pa.us/PA_Biomass_guidance_final.pdf

[41] Baseline electricity demand data for 2020 taken from PA I&F (CCS, 2006).

[42] From U.S. Energy Information Administration, http://www.eia.doe.gov/cneaf/solar.renewables//trends/.html.

[43] Data cited in Hansson, J., G. Berndes, F. Johnsson, and J. Kjarstad. 2009. Co-firing biomass with coal for electricity generation: An assessment of the potential in EU27. *Energy Policy* 37(4): 1444-1455.

Table F-51. Emission Factors for Fossil Fuels in PA

Fossil Fuels	Emission factors (tCO_2e/Btu)
Coal	93.815
Natural gas	52.455
Oil/petroleum	50.283
Wood	3.093

Btu = British thermal unit; tCO_2e = metric tons of carbon dioxide equivalent.

The GHG benefit of this option was quantified as the avoided GHG emissions from fuel switching for electricity production, assuming that avoided fuels were equally divided between coal, natural gas, and oil (Table F-52).

Table F-52. Annual Electricity Production and Avoided Emissions to Reach Goal Level in Forestry-8 (Use 0.8025 MMt of Biomass/Year by 2020)

Year	Additional Electricity Produced From Wood (BBtu/year)	Cumulative Electricity Produced From Wood (BBtu/ year)	Emissions From Wood (tCO_2e/year)	Emissions Avoided From Fossil Fuel (tCO_2e/year)	Net GHG Benefit (tCO_2e/year)	Net GHG Benefit ($MMtCO_2e$/year)
2009	264	264	817	22,710	21,893	0.02
2010	264	529	1,635	45,420	43,785	0.04
2011	264	793	2,452	68,131	65,678	0.07
2012	264	1,057	3,270	90,841	87,571	0.09
2013	264	1,321	4,087	113,551	109,464	0.11
2014	264	1,586	4,905	136,261	131,356	0.13
2015	264	1,850	5,722	158,971	153,249	0.15
2016	264	2,114	6,540	181,681	175,142	0.18
2017	264	2,378	7,357	204,392	197,034	0.20
2018	264	2,643	8,175	227,102	218,927	0.22
2019	264	2,907	8,992	249,812	240,820	0.24
2020	264	3,171	9,810	272,522	262,713	0.26
Cumulative Totals		**3,436**	**63,762**	**1,771,394**	**1,707,631**	**1.71**

MMt = million metric tons

Economic Cost:

Costs associated with biomass co-firing are the capital costs of plant retrofitting and the annual operating costs. It was assumed that co-firing capacity might reasonably be added at four existing coal plants in PA (expert opinion). The cost of installing a biomass boiler at each coal plant was estimated at $1 million.[44] Assuming a boiler lifetime of 30 years, the annualized capital cost for retrofitting four coal plants over the policy implementation period was estimated at $133,333. Operating costs are difficult to determine and will likely vary with feedstock type

[44] Nelson, H.T. April 17, 2006. "Coal-to-Biomass Cofiring at the Boardman Pulverized Coal Plant." Capital costs for boiler installations range from $112,500 to $3,450,000, based on the type of coal plant. A midpoint estimate of $1 million was chosen for practicality, and was verified by expert opinion.

and power plant technology. An annual estimate of $50,000 per plant was used, assuming that each plant will require one additional full-time equivalent position to accommodate the additional feedstock. Based on these input assumptions, the NPV for Forestry-8 was calculated (in 2007 dollars) at $2,813,731. The levelized cost-effectiveness of this option is $4.18/tCO$_2$e.

Additional costs might include feedstock preparation expenses, costs of changes in harvest practices, or transportation. Offsetting benefits might include tax credits, especially for production of renewable electricity, reduced costs if biomass feedstock is less costly than coal, and cost savings if biomass would have originally been destined for a landfill.

Implementation Steps:

Interest and opportunities exist in current legislation, such as Act 213 of 2004, the Alterntaive Energy Portfolio Standards Act; House Bill (HB) 2200; and Act 129.

Potential Overlap: None

Subcommittee Comments

Market and policy forces are driving the expanding use of forest biomass energy. Biomass can be used to generate renewable energy in the form of liquid fuels (such as cellulosic ethanol, which is close to being market-ready), or through direct combustion to generate electricity, heat, or steam. Carbon in forest biomass is considered biogenic under sustainable systems; carbon dioxide emissions from biomass energy combustion are replaced by future carbon sequestration. Expanded use of biomass energy in place of fossil fuels results in net emissions reductions by shifting from high to low carbon fuels (when sustainably managed), provided the full lifecycle of energy requirements for producing fuels does not exceed the energy content of the renewable resource. Expanded use of biomass energy can be promoted through increasing the amount of biomass produced and used for renewable energy, and providing incentives for the production and use of renewable energy supplies.

In 2005, biomass plants using wood as a primary fuel generated about 320,000 MWH of electricity annually,[45] or about 0.22 percent of the total electricity used in PA.[46] Biomass can be co-fired with coal under certain circumstances as well, so a larger proportion of the PA electricity demand would likely be met if wood as a secondary fuel is included in the analysis of biomass use. A large group of locally financed small projects spread widely across the commonwealth could capture the value of replacing high-cost fuel imports and gain carbon benefits while limiting transportation costs of the feedstock. This model has been shown to allow displacement of significant quantities of current or projected fossil carbon release from a broad range of users - including industry, public institutions, commercial offices, and multi-family buildings – through reduced electrically driven cooling and distributed generation of electricity through combined heat and power facilities.

We need to ensure that the harvesting of wood biomass for this and F-9 is done in an ecologically sustainable manner, and that we account for availability of timber resources for other purposes, both of which are addressed through the discounts applied to the total availability figure.

[45] Personal communication, J. Sherrick with J. Jenkins, October 2007.

[46] Total electricity demand in PA (2005) is 148,273 thousand MWh (Energy Information Administration).

Forestry-9. Biomass Thermal Energy Initiatives

Initiative Summary: Increase the state's utilization of carbon-neutral, forested biomass-based energy production on the community level through CHP energy production systems. This can be accomplished via Pennsylvania Fuels for Schools and Beyond or similar initiatives. The Fuels for Schools and Beyond Working Group is focusing on using wood residues and warm-season grasses to displace fuel oil and natural gas in schools, hospitals, other institutions, and commercial and industrial boilers/furnaces.

Goals:

- Utilize 0.8025 million dry tons of biomass annually in CHP installations in Pennsylvania. Include thermally activated cooling technology where appropriate.
- Implement wood chip burning heating systems at 20 percent of school buildings (20 percent of 3,303 school buildings in 722 districts adds up to 661 installations total) in Pennsylvania by 2020.
- Maximize, within the limits of resource sustainability, local, highly efficient installations for the utilization of biomass to displace fossil-sourced heat, cooling, and electricity.

Implementation Period: 2009–2020

Other Involved Agencies: PDA, DEP

Possible New Measure(s): Increase the number of community-based and district-scale energy initiatives that reduce net carbon emissions through the utilization of forested woody biomass and other clean wood source material. This will be accomplished through:

- Providing state leadership to encourage these facilities as part of an energy independence strategy;
- Providing technical assistance to communities on project design and development and biomass procurement;
- Providing access to capital financing for the development of such projects; and
- Addressing policy issues needed to ensure adequate and affordable procurement of biomass material for these projects.

Utilization of woody biomass for small-scale electric and thermal production is a proven technology. At present, it is more viable and environmentally sustainable than large, unproven cellulosic ethanol initiatives.

The forest products industry is the nation's largest source of renewable biomass energy, generating 80 percent of the nation's biomass energy output. Paper and larger wood product companies generate an average of 65 percent of their energy needs from carbon-neutral biomass, mostly woody mill residuals.

A large group of locally financed small projects spread widely across the commonwealth could capture the value of replacing high-cost fuel imports and gain carbon benefits while limiting transportation costs of the feedstock. This model has been shown to allow displacement of significant quantities of current or projected fossil carbon release from a broad range of users—including industry, public institutions, commercial offices, and multi-family buildings—through reduced electrically driven cooling and distributed generation of electricity through CHP facilities.

Additional benefits may be garnered by slightly larger, district energy systems that could utilize locally procured biomass to generate 10 megawatts (MW) of electricity and associated heat benefits. This would supply not just a single facility, but would serve all or part of an entire rural community. The volume of material for such a project would be larger than for a single institution, but still significantly smaller than a large-scale ethanol project, making it both economically and ecologically viable. Successful versions of this district energy concept are common in Europe.

The Pennsylvania Fuels for Schools and Beyond program is the catalyst for promoting community-based initiatives across the commonwealth. Other initiatives are being driven by local communities and dedicated private citizens.

Data Sources/ Assumptions/ Methods:

Goal 1: Utilize 0.8025 million tons of biomass annually in CHP installations in PA by 2020, including thermally activated cooling technology where appropriate.

Methodology:

This analysis focuses on the incremental GHG benefits associated with the utilization of biomass to offset the consumption of fossil fuels for heating and electricity in CHP systems. As a result, there are two types of GHG benefits from this option. The first is offsetting electricity and the second is offsetting other fossil fuels that would have otherwise been used for heating and/or steam (e.g., natural gas or oil).

To reach the target level of 802,500 dry tons of biomass utilizing this technology by 2020, a linear ramp-up to the goal level was assumed. For these CHP plants, it was assumed that 80 percent of the available energy in the biomass feedstock would be converted to electricity or steam. Further, it was assumed that the energy would be evenly split between the two uses, such that half of the available energy (40 percent of the energy content in the biomass feedstock) would offset electricity use, and half of the available energy would offset heating applications (such as natural gas or heating oil).[47] Assuming a standard biomass heat content of 10.98 MMBtu/t,[48] 8.78 MMBtu/t would ultimately be available for energy use in CHP plants. Thus, in energy terms, in 2020 (at the goal biomass utilization level of 802,500 dry tons/year), a total of 7,047 BBtus would be generated for energy uses from biomass. At a standard level of

[47] The assumed thermal efficiency rate of a biomass cogeneration facility is 80% with 40% being converted into electricity and 40% being derived from the waste heat; based on advice from the Michigan AFW Technical Working Group.

[48] http://www.eia.doe.gov/cneaf/solar.renewables/page/trends/table10.html

20,000 dry tons biomass/year per CHP plant,[49] the target biomass utilization level amounts to 40 CHP plants statewide by 2020 or, on average, an addition of 3.3 new CHP plants in PA per year.

The GHG benefits from electricity were calculated by assuming that using biomass reduces emissions (in CO_2e) by the Pennsylvania-specific emission factors (Table F-51). The CO_2e associated with this amount of electricity in each year is estimated by multiplying the energy produced from biomass (in Btus) by the Pennsylvania-specific emission factor for electricity production from the PA I&F (Table F-53).

In addition to the electricity generation, it is assumed that 40 percent of the biomass feedstock energy is converted into usable steam/heat (in MMBtu). It is assumed that this waste heat is used to offset energy that would have otherwise been generated from natural gas. The GHG benefits were calculated by the difference in emissions associated with each of the input fuels (Table F 48).[50]

Table F-53. GHG Savings From Implementing CHP Technology in PA

Year	Energy From Wood Added This Year (BBtu/year)	Total Energy From Wood (BBtu/year)	Emissions From Wood (tCO_2e/year)	Emissions Avoided From Electricity Production (tCO_2e/ year)	Emissions Avoided From Heat Production (tCO_2e/year)	Net Emission Reductions (tCO_2e/year)	Net Emissions Reductions ($MMtCO_2e$/year)
2009	587	587	1,817	25,234	15,403	38,820	0.039
2010	587	1,175	3,633	50,467	30,805	77,639	0.078
2011	587	1,762	5,450	75,701	46,208	116,459	0.116
2012	587	2,349	7,266	100,934	61,611	155,279	0.155
2013	587	2,936	9,083	126,168	77,014	194,098	0.194
2014	587	3,524	10,900	151,401	92,416	232,918	0.233
2015	587	4,111	12,716	176,635	107,819	271,737	0.272
2016	587	4,698	14,533	201,868	123,222	310,557	0.311
2017	587	5,285	16,349	227,102	138,624	349,377	0.349
2018	587	5,873	18,166	252,335	154,027	388,196	0.388
2019	587	6,460	19,982	277,569	169,430	427,016	0.427
2020	587	7,047	21,799	302,802	184,832	465,836	0.466
cumulative totals		45,807	141,694	1,968,215	1,201,411	3,027,932	3.028

BBtu = billion British thermal units; tCO_2e = metric tons of carbon dioxide equivalent; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

<u>Cost to Regulated Entities:</u> Funding for the technical assistance coordination and capital financing is available from existing programs funded by Growing Greener and the new Energy

[49] Personal communication, John Karakash, Resource Professionals Group with PA Agriculture and Forestry Subcommittee, June 12, 2009. Note that at the 7000 hour/ year operating level necessary for a plant to be economically viable, this level of biomass use amounts to 69 tons/ day.

Independence Strategy. Capital outlays for projects vary from $300,000 to more than $3 million, depending on size.

Economic Cost:

The cost calculation has two main components: capital/operational/maintenance costs and fuel costs. The assumed capital costs are based on the costs associated with building the CHP infrastructure (feedstock preparation and processing, electricity and steam production), and are a one-time cost incurred in the year of construction. For the 20,000 ton/year plants envisioned as part of Forestry-9, the capital costs likely range from $750,000 to $1.3 million.[51] A midpoint estimate of $1 million per plant was assumed.[52] Assuming that four full-time employees are required to keep such a plant operating, annual operation and maintenance (O&M) costs were estimated at $200,000 per plant per year. The results of the capital and O&M cost analysis are outlined in Table F-54.

Table F-54. Capital and Annual Operating Costs Associated with Implementing CHP Technology in PA

Year	Number of Plants Added This Year	Cumulative Number of Plants	Dry Biomass Used (tons/year)	Capital Cost of Construction	Annual Operating Costs	Total Capital and O&M Cost
2009	3.34	3.34	66,875	$3,343,750	$668,750	$4,012,500
2010	3.34	6.69	133,750	$3,343,750	$1,337,500	$4,681,250
2011	3.34	10.03	200,625	$3,343,750	$2,006,250	$5,350,000
2012	3.34	13.38	267,500	$3,343,750	$2,675,000	$6,018,750
2013	3.34	16.72	334,375	$3,343,750	$3,343,750	$6,687,500
2014	3.34	20.06	401,250	$3,343,750	$4,012,500	$7,356,250
2015	3.34	23.41	468,125	$3,343,750	$4,681,250	$8,025,000
2016	3.34	26.75	535,000	$3,343,750	$5,350,000	$8,693,750
2017	3.34	30.09	601,875	$3,343,750	$6,018,750	$9,362,500
2018	3.34	33.44	668,750	$3,343,750	$6,687,500	$10,031,250
2019	3.34	36.78	735,625	$3,343,750	$7,356,250	$10,700,000
2020	3.34	40.13	802,500	$3,343,750	$8,025,000	$11,368,750
Cumulative	**40.13**					

CHP = combined heat and power; O&M = operation and maintenance.

The fuel cost component is based on the difference in costs between supply of biomass fuel and the assumed fossil fuel that it is replacing. The assumed biomass fuel cost used in this analysis is $1.84/MMBtu, and the assumed fossil fuel cost is $7.48/MMBtu.[53] The cost of implementing Goal 1 is estimated by assuming the replacement of fossil fuel-generated electricity with biomass-generated electricity (Table F-55).

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[51] Personal communication, John Karakash, Resource Professionals Group, public expert advising the Agriculture and Forestry Subcommittee, June 12, 2009.

[52] The capital costs associated with using biomass as an alternative to fossil-based generation are dependent on many factors, including the end use (i.e., electricity, heat or steam), the design and size of the systems, the technology employed, and the configuration specifications of the system. Each system implemented under this policy would require a detailed analysis (incorporating specific engineering design and costs aspects) to provide a more accurate cost estimate of the system.

[53] As used in the Electricity Supply subcommittee analysis; data from PA-specific sources.

Table F-55. Fuel Costs Associated With Implementing CHP Technology in PA

Year	Avoided Cost of Electricity ($/year)	Avoided Cost of Heating Fuel ($/year)	Cost of Biomass Feedstock ($/year)	Net Economic Benefit From Fuel Switching
2009	$2,196,392	$3,147,771	$1,080,578	$4,263,585
2010	$4,392,785	$6,295,542	$2,161,156	$8,527,170
2011	$6,589,177	$9,443,312	$3,241,734	$12,790,755
2012	$8,785,569	$12,591,083	$4,322,312	$17,054,340
2013	$10,981,962	$15,738,854	$5,402,890	$21,317,926
2014	$13,178,354	$18,886,625	$6,483,468	$25,581,511
2015	$15,374,746	$22,034,396	$7,564,046	$29,845,096
2016	$17,571,139	$25,182,167	$8,644,624	$34,108,681
2017	$19,767,531	$28,329,937	$9,725,202	$38,372,266
2018	$21,963,923	$31,477,708	$10,805,780	$42,635,851
2019	$24,160,316	$34,625,479	$11,886,359	$46,899,436
2020	$26,356,708	$37,773,250	$12,966,937	$51,163,021

The overall economic cost of implementing CHP technology is the difference between the capital cost of construction and annual O&M costs, offset by the fuel cost savings associated with switching to biomass feedstock for production of the same amount of energy. Results of the economic analysis are shown in Table F-56. The NPV (in 2007 dollars) of Goal 1 is –$151,473,053, suggesting that there is a net economic benefit to implementing this option. The levelized cost-effectiveness of this option is –$50.03/tCO$_2$e avoided.

Table F-56. Overall Economic Costs of Implementing CHP Technology in PA

Year	Total Capital/ O&M Costs ($/year)	Fuel/Feedstock Savings ($/year)	Net Economic Cost ($/year) (not discounted)	Discounted Costs ($2007) ($/year)
2009	$4,012,500	$4,263,585	–$251,085	–$227,742
2010	$4,681,250	$8,527,170	–$3,845,920	–$3,322,250
2011	$5,350,000	$12,790,755	–$7,440,755	–$6,121,528
2012	$6,018,750	$17,054,340	–$11,035,590	–$8,646,674
2013	$6,687,500	$21,317,926	–$14,630,426	–$10,917,449
2014	$7,356,250	$25,581,511	–$18,225,261	–$12,952,353
2015	$8,025,000	$29,845,096	–$21,820,096	–$14,768,700
2016	$8,693,750	$34,108,681	–$25,414,931	–$16,382,691
2017	$9,362,500	$38,372,266	–$29,009,766	–$17,809,480
2018	$10,031,250	$42,635,851	–$32,604,601	–$19,063,235
2019	$10,700,000	$46,899,436	–$36,199,436	–$20,157,201
2020	$11,368,750	$51,163,021	–$39,794,271	–$21,103,752

It is important to note that the energy costs associated with producing electricity and steam via CHP technology are included in the estimate of 80 percent overall efficiency from the wood feedstock. If the energy load associated with electricity and steam production is significantly higher than this, the energy yield and avoided emissions will decline, and economic costs per unit of energy production will increase. Also, additional data on energy costs and benefits at the local level will enhance the accuracy of these estimates.[54]

Thermally activated cooling:

It is envisioned that thermally activated cooling technology will be incorporated as part of this CHP technology, where appropriate. GHG reductions and economic costs were not quantified separately for this component, and are assumed to be embedded in the overall estimates described above. Thermally activated cooling would likely be appropriate for use at roughly half of the PA installations where CHP technology is installed.[55]

That cooling can meet needs for space conditioning or process in such locations as data-processing server rooms. Ideal users include full-year operating facilities in commerce, hotels, health care, industry, and education. Many of those applications use a chilled water medium. The value depends on case specifics.

Combining technologies, such as with thermal storage for both heat and chilling, and diversifying chiller makeup to cover swinging loads and trim may also be helpful. Also, absorption chillers eliminate the need for chlorofluorocarbon-based refrigerants, which reduces GHG emissions. Cost-only competitiveness versus electricity systems will grow with less expensive wood and higher marginal rates for electricity.

Illustrative model: For example, assume implementation of a wood-fueled steam boiler energizing a 450-ton chiller, and 6,500 operating hours per year at full or part load. Also assume for illustration, the unit displaced is base loaded, with an overall running scenario of 80 percent loading during operational hours. Electrical energy consumed would be 13.3 million kWh/yr (0.8*256*6,500). Carbon produced using a PA rate of 1.55 lb CO_2 /kWh would be 20.6 million lb or 10,000 tons. In the case of air-cooled chillers, the consumption is roughly doubled (Table F-57).

Table F-57. Illustrative example of CO2e savings from absorption cooling technology.[56]

Chiller Unit	Rating (tons)	kW Demand	kWh/Year	tons CO_2	Dry tons Wood/Year
Absorption, Wood Steam	450	<10	<65,000	<51	6,650
Electrical, Water Cooled	450	256	1,331,200	1,032	—
Electrical, Air Cooled	450	540	2,808,000	2,176	—

kW = kilowatt; kWh = kilowatt-hour.

[54] For example, one case study estimate finds that a community with 1,000 households, county seat buildings (courthouse, jail, county home, etc.), schools, and main street businesses = 1.3 million square feet of heating need with an annual electric consumption of 16.3 MWh (2006 expenditures = $1,087,147—both of which could be replaced with wood to energy CHP technology. Personal communication, Paul Roth, DCNR with J. Jenkins, CCS. May 2009.

[55] Personal communication, John Karakash, Resource Professionals Group, public expert advising the Agriculture and Forestry Subcommittee, June 2009.

[56] Ibid.

Scaling applications across Pennsylvania at the rate of one installation per county for the next 2 years, in the third year 892,000 tons of low-use wood is displacing 178,381 MWh and reducing demand on the grid by 24 MW (conservative scaling at 70 percent) or more. These numbers are against water-cooled chillers; against air-cooled units the numbers again double to a 50 MW reduction in demand. Carbon emissions would be reduced by approximately 138,288 tons.[57]

Goal 2: Implement wood chip burning heating systems at 20 percent of the school buildings (20 percent of 3,303 school buildings in 522 districts adds up to 661 installations total) in Pennsylvania by 2020.

In 2008, the Pennsylvania Fuels for Schools and Beyond Working Group surveyed school districts throughout Pennsylvania to evaluate and quantify the desire to install heating systems fired from sustainably available wood residues. The results of that survey indicated that 52 school districts with 415 buildings are interested moving forward with some type of biomass heating system.

With the detailed energy data from each school district, it has been calculated that the fossil energy demands for heating these buildings can be offset by approximately 154,000 tons of wood. The working group is establishing a plan to prioritize assistance with each of these school districts. As part of this plan, the DEP has provided some financial assistance through the Energy Harvest and Pennsylvania Energy Development Authority (PEDA) grant programs. In doing so, these grant programs place an emphasis on energy efficiency of buildings prior to consideration of funding.

The displacement of the fossil fuels with wood to heat these buildings would result in an annual reduction of 0.12 $MMtCO_2e$. This does not include the use of biomass heating systems by other institutions (hospitals, prisons, etc.), commercial facilities, and even some industrial facilities.

This analysis assumes that biomass is carbon neutral in its life cycle and does not account for GHG emissions that may result from transportation of the wood.

The reductions are based on calculations from the results of a survey initiated by the Pennsylvania Fuels for Schools and Beyond Working Group. The survey was sent out to all school districts in the commonwealth. The survey results provide detailed information regarding the heating systems of each school, including the boiler age, fuel type and quantity used, square footage of buildings heated, etc. The surveys were used to prioritize technical assistance and outreach. The data were used to calculate the total emissions of GHGs. Calculations were made to estimate the equivalent volume of wood or other biomass resources that would be necessary to replace these older boilers with biomass boiler systems. These calculations assumed an energy content for wood of 8,500 Btu at a moisture content of 40 percent.

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[57] Data and specifications on thermally activated cooling provided by John Karakash, Resource Professionals Group, to Agriculture and Forestry Subcommittee, May 2009.

Methodology:

This quantification is based on Goal 2, which is to implement wood-chip-based heating systems at 20 percent of PA school buildings by 2020. The total number of schools in PA is 3,303, thus 20 percent of schools totals 661 installations by 2020. A linear ramp-up to the goal level was assumed, such that 55 new installations would be completed each year. To calculate the GHG savings associated with each installation, the energy (8,960 MMBtu per heating season) associated with heating in the Clearfield Middle School case study[58] was applied. The amount of fossil fuel that would be offset by substituting wood energy for heating oil or natural gas in each installation was calculated, and this value represents the avoided emissions associated with using wood instead of fossil fuel for heat. It was assumed that wood chip technology would replace heating oil and natural gas in equal proportions. Results of the GHG emissions analysis are in Table F-58.

Table F-58. Emission Reductions Associated With Implementation of Fuels for Schools

Year	Number of Installations	Cumulative Number of Installations	Heating Consumption (MMBtu/heating season)	Emissions From wood (tCO_2e/ year)	Avoided Fossil Fuel Emissions (tCO_2e/ year)	Net Avoided Emissions ($MMtCO_2e$/ year)
2009	55	55	493,248	1,526	52,738	0.05
2010	55	110	986,496	3,051	105,477	0.10
2011	55	165	1,479,744	4,577	158,215	0.15
2012	55	220	1,972,992	6,103	210,953	0.20
2013	55	275	2,466,240	7,629	263,692	0.26
2014	55	330	2,959,488	9,154	316,430	0.31
2015	55	385	3,452,736	10,680	369,168	0.36
2016	55	440	3,945,984	12,206	421,907	0.41
2017	55	495	4,439,232	13,732	474,645	0.46
2018	55	551	4,932,480	15,257	527,383	0.51
2019	55	606	5,425,728	16,783	580,122	0.56
2020	55	661	5,918,976	18,309	632,860	0.61
Cumulative Totals			**38,473,344**	**119,008**	**4,113,589**	**3.99**

MMBtu = million British thermal units; tCO_2e = metric tons of carbon dioxide equivalent; $MMtCO_2e$ = million metric tons of carbon dioxide equivalent.

Economic Cost:

Capital costs are associated with operating wood-fired heating systems in school buildings. The net economic benefit associated with fuel switching is the difference between the cost of wood chips and the avoided cost of the fossil fuel that is replaced. In this analysis, no change in annual operating and maintenance costs was assumed, because typically the existing maintenance staff can accommodate the new wood chip technology.

[58] http://www.pafuelsforschools.psu.edu/case_studies/default.asp

Capital costs were assumed to be $1 million per installation.[59] Assuming a 30-year boiler lifetime, annualized capital costs per plant were thus $33,333. The cost of wood chips was assumed to be $30.67 per ton, the average cost in three case studies reported by PA Fuels for Schools to date. Results of the economic cost analysis are shown in Table F-59. The difference between the feedstock costs is an important driver of the cost-effectiveness of this option, and leads to a net economic savings in all years of implementation. The net present value (NPV) of this option in $2007 is -$258.8, with a levelized cost-effectiveness of -$64.78/ tCO2e reduced.

Table F-59. Economic costs of implementing wood chip heat at 20 percent of PA schools

Year	Total number of installations	Annualized capital costs ($/ year)	Avoided fossil fuel cost (oil and gas) ($/ year)	Chip consumption (tons/ year)	Cost of chips ($/ year)	Net economic cost ($/ year)	Discounted cost ($2007)
2009	55	$1,835,000	$6,566,744	35,232	$1,080,448	-$3,651,296	-$3,311,833
2010	110	$1,835,000	$13,133,488	70,464	$2,160,896	-$9,137,592	-$7,893,396
2011	165	$1,835,000	$19,700,233	105,696	$3,241,344	-$14,623,889	-$12,031,109
2012	220	$1,835,000	$26,266,977	140,928	$4,321,792	-$20,110,185	-$15,756,856
2013	275	$1,835,000	$32,833,721	176,160	$5,402,240	-$25,596,481	-$19,100,488
2014	330	$1,835,000	$39,400,465	211,392	$6,482,688	-$31,082,777	-$22,089,949
2015	385	$1,835,000	$45,967,209	246,624	$7,563,136	-$36,569,073	-$24,751,388
2016	440	$1,835,000	$52,533,953	281,856	$8,643,584	-$42,055,369	-$27,109,266
2017	495	$1,835,000	$59,100,698	317,088	$9,724,032	-$47,541,666	-$29,186,459
2018	551	$1,835,000	$65,667,442	352,320	$10,804,480	-$53,027,962	-$31,004,351
2019	606	$1,835,000	$72,234,186	387,552	$11,884,928	-$58,514,258	-$32,582,928
2020	661	$1,835,000	$78,800,930	422,784	$12,965,376	-$64,000,554	-$33,940,860
cumulative totals		$22,020,000	$512,206,046	2,748,096	$84,274,944	-$405,911,102	-$258,758,884

Implementation Steps:

- Maintain Pennsylvania Fuels for Schools and Beyond Working Group.
- Continue to or increase funding for capital financing programs that are already in place, such as DEP's Energy Harvest and PEDA grant programs.
- Facilitate communication between the school districts and USDA Rural Development. There are significant funding opportunities within a number of program areas within the Farm Bill to support projects like this.
- PA HB 1040, an Act establishing the Pennsylvania Fuels for Schools and Beyond Program, would provide up to $5 million annually for the installation of these systems.

Potential Overlap: Forestry-8, Wood to Electricity. Also Electricity-9, Promote Use of CHP. Overlaps have been resolved, as Forestry-8 and Forestry-9 each use only a third of the available biomass supply. Forestry-9 does not overlap with similar options in the electricity sector because those options contemplate the implementation of CHP with traditional fossil fuel sources rather than biomass.

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[59] Belchertown, MA school installation had capital cost of $1.13 million (http://www.nrbp.org/pdfs/pub22.pdf). Other installed systems in Vermont have costs of less than $1 million (http://www.biomasscenter.org/pdfs/Wood-Chip-Heating-Guide.pdf). $1 million was thus used as a starting point for this analysis.

Subcommittee Comments

Increase the number of community-based and district-scale energy initiatives that reduce net carbon emissions through the utilization of forested woody biomass and other clean wood source material. This will be accomplished through:

- Provide state leadership to encourage these facilities as part of energy independence strategy;
- Provide technical assistance to communities on project design and development and biomass procurement;
- Provide access to capital financing for the development of such projects;
- Address policy issues needed to ensure adequate and affordable procurement of biomass material for these projects;
- Maximize, within the limits of resource sustainability, local, highly efficient installations for the utilization of biomass to displace fossil sourced heat, cooling, and electricity.

We need to ensure that the harvesting of wood biomass for this and F-9 is done in an ecologically sustainable manner, and that we account for availability of timber resources for other purposes, both of which are addressed through the discounts applied to the total availability figure.

APPENDIX L

Macroeconomic Assessment of Action Plan

A. The REMI Macroeconometric Model

Several modeling approaches can be used to estimate the total regional economic impacts of environmental policy, including both direct (on-site) effects and various types of indirect (off-site) effects. These include: input-output (I-O), computable generated equilibrium (CGE), mathematical programming (MP), and macroeconometric (ME) models. Each has its own strengths and weaknesses.

The choice of which model to use depends on the purpose of the analysis and various considerations that can be considered as performance criteria, such as accuracy, transparency, manageability, and costs. After careful consideration of these criteria, we chose to use a form of econometric model known as the REMI PI+ Model (REMI, 2009). The REMI Model is superior to all the others in terms of its forecasting ability and is comparable to CGE models in terms of analytical power and accuracy. The availability of this model for the state of Pennsylvania made it, along with an I-O model, the least costly. With careful explanation of the model, its application, and its results, it can be made as transparent as any of the others.

The REMI Model has evolved over the course of 30 years of refinement (see, e.g., Treyz, 1993). It is a (packaged) program, but is built with data that is region-specific. Government agencies in practically every state in the U.S. have used a REMI Model for a variety of purposes, including evaluating the impacts of the change in tax rates, the exit or entry of major businesses in particular or economic programs in general, and, more recently, the impacts of energy and/or environmental policy actions.

A macroeconometric forecasting model covers the entire economy, typically in a "top-down" manner, based on macroeconomic aggregate relationships such as consumption and investment. REMI differs in that it includes these key relationships but is based on a more bottom-up approach. In fact, it makes use of the finely-grained sectoring detail of an I-O model, i.e., it divides the economy into 169 sectors, thereby allowing important differentials between them. This is especially important in a context like the Pennsylvania Action Plan, where various work plans were fine-tuned to a given sector or where they directly affect several sectors somewhat differently.

The macroeconomic character of the model is able to analyze the interactions between sectors (ordinary multiplier effects) but with some refinement for price changes not found in I-O models. The REMI Model also brings into play features of labor and capital markets, as well as trade with other states or countries, including changes in competitiveness.

The econometric feature of the model refers to two considerations. The first is that the model is based on inferential statistical estimation of key parameters based on a time series (historical) data for Pennsylvania (the other candidate models use "calibration," based on a single year's data). This gives the REMI model an additional capability of being better able to extrapolate or forecast the future course of the economy, a capability the other models lack. The major limitation of the REMI model versus the others is that it is pre-packaged and not readily adjustable to any unique features of the case in point. The other models, because they are based on less data and a less formal estimation procedure, can more readily accommodate data changes in technology that might be inferred, for example from engineering data. However, our assessment of the REMI Model is that these adjustments were not needed for the purpose at hand.

The use of the REMI Model involves the generation of a baseline forecast of the economy through 2020. Then simulations are run of the changes brought about through the implementation of the various work plans included in the *Pennsylvania Climate Action Plan*. Again, this includes the direct effects in the sectors in which the work plans are implemented, and then the combination of multiplier (purely quantitative interactions) general equilibrium (price-quantity interactions) and macroeconomic (aggregate interactions) impacts. The differences between the baseline and the “counter-factual” simulation represent the total regional economic impacts of the Climate Action Plan.

B. REMI Model Input Development

Before undertaking any economic simulations, the key quantification results for each work plan conducted by the Subcommittees are translated to model inputs that can be utilized in the Model. This step involves the selection of appropriate policy levers in the REMI Model to simulate the policy’s changes. The input data include sectoral spending and savings over the full time horizon (2009-2020) of the analysis. In Tables L1-L3, we choose one example work plan from each of the Rec/Com, Forestry, and Transportation sectors to illustrate how we translate, or map, the Subcommittees’ results into REMI economic variable inputs.

Using Res/Com-10 Demand-Side Management (DSM) (Natural Gas) as an example, the first two columns of Table L1 show the quantification analysis results of this mitigation work plan according to their applicability to business (commercial and industrial) sectors and the household (residential) sector provided by the Res/Com Subcommittee. The last column of Table L1 presents the corresponding economic variables in the REMI Model and their position within the Model (i.e., in which one of the five major blocks, as introduced in Section D of this Appendix, the policy variables can be found):

DSM refers to programs implemented by the utilities aimed at reducing electricity consumptions in the business and household sectors. For both the commercial and household sectors, the selected REMI policy variables to represent energy savings are from the “Compensation, Prices, and Costs Block” and “Output and Demand Block” respectively. For the former, the energy savings are simulated as the decrease of “Electricity Fuel Cost for the Commercial Sector”. For the latter, the energy savings are simulated as the “Consumer Spending” decrease of Gas.

The natural gas consumption reduction from this mitigation work plan would result in a decrease in demand from the Gas Distribution sector. This is simulated by reducing the “Exogenous Final Demand” from the Gas Distribution sector in REMI. This variable can be found in the “Output and Demand Block”.

Table L1. Mapping the Quantification Results of Res/Com-10 Demand-Side Management (Natural Gas) into REMI Inputs

Quantification Results		Policy Variable Selection in REMI
Natural Gas Savings of the Customers	Commercial Sectors	Compensation, Prices, and Costs Block→ Natural Gas (Commercial Sectors) Fuel Cost (amount) of All Commercial Sectors→Decrease
	Households (Residential Sector)	Output and Demand Block→Consumer Spending (amount)→Gas→Decrease
		Output and Demand Block →Consumption Reallocation (amount)→All Consumption Sectors →Increase
Natural Gas Demand Decrease from the NG Distribution Sector		Output and Demand Block →Exogenous Final Demand (amount) for Natural Gas Distribution sector→Decrease
NG Customer Outlay on Energy Efficiency (EE)	Commercial Sectors	Compensation, Prices, and Costs Block →Production Cost (amount)→Increase
	Households (Residential Sector)	Output and Demand Block→Consumer Spending (amount)→Kitchen & other household appliances→Increase
		Output and Demand Block→Consumer Spending (amount)→Owner-occupied nonfarm dwellings→Increase
		Output and Demand Block →Consumption Reallocation (amount)→All Consumption Sectors →Decrease
Investment on EE Technologies		Output and Demand Block →Exogenous Final Demand (amount) for Construction sector and Ventilation, Heating, Air-conditioning, and Commercial Refrigeration Equipment Manufacturing sector→Increase

The costs of this work plan are the levelized cost of saved natural gas. For commercial sector, the costs would include improved HVAC equipment, controls and building shell measures, and efficient cooking equipment. The total costs are distributed among the individual commercial sectors based on the reference case natural gas sales to the corresponding sectors. This is simulated in REMI by increasing the value of the "Production Cost" variable of individual commercial sectors under the "Compensation, Prices, and Costs Block". For the residential sector, the costs would involve improvement in space heating efficiency (including adopting insulation measures of the home envelope and investing in more efficient heating and ventilation equipment and systems). These are simulated in REMI by increasing the "Consumer Spending" on "Owner-occupied Nonfarm Dwellings" and "Kitchen & Other Household Appliances" (and decrease in all the other consumptions correspondingly). The "Consumer Spending" variable can be found in the "Output and Demand Block" in the REMI model.

Finally, the DSM program would increase the demand for goods and services from the industries that supply energy-efficiency equipment and appliances and the construction sector. We simulated this in REMI by increasing the "Exogenous Final Demand" from the Ventilation, Heating, Air-conditioning, and Commercial Refrigeration Equipment Manufacturing sector and Construction sector.

Table L2. Mapping the Quantification Results of Forestry-7 Urban Forestry into REMI Inputs

Quantification Results	Policy Variable Selection in REMI
Spending Stimulation	Output and Demand Block →Exogenous Final Demand (amount) for Forestry; Fishing, Hunting, Trapping sector →Increase[a] Output and Demand Block (Exogenous Final Demand (amount) for Support Activities for Agriculture and Forestry sector (Increasea Output and Demand Block (Exogenous Final Demand (amount) for Waste Collection; Waste Treatment and Disposal and Waste Management Services sector(Increasea
Cost of Urban Forestryb	Reduction of Government Spending Elsewhere: Output and Demand Block →State Government spending (amount) (Decrease
	Commercial Sector: Compensation, Prices, and Costs Block(Production Cost of Individual Commercial Sectors(Increase
	Residential Sector: Output and Demand Block(Consumer Spending (amount)(Other household operation(Increase Output and Demand Block (Consumption Reallocation (amount)(All Consumption Categories (Decrease
Energy Savings (reduction in electricity consumption)	Compensation, Prices, and Costs Block(Electricity (Commercial Sectors) Fuel Cost (amount) of All Commercial Sectors (Decrease Output and Demand Block(Consumer Spending (amount)(Electricity(Decrease Output and Demand Block (Consumption Reallocation (amount)(All Consumption Categories (Increase
Electricity Demand Decrease from the Utility Sector	Output and Demand Block (Exogenous Final Demand (amount) for Electric Power Generation, Transmission, and Distribution sector(Decrease

[a] The total program spending of urban forestry includes tree planting and annual maintenance, program administration and waste disposal. In the REMI analysis, we simulate these as final demand increases distributed evenly among the following three sectors: Forestry; Fishing, Hunting, Trapping sector, Support Activities for Agriculture and Forestry sector, and Waste Collection; Waste Treatment and Disposal and Waste Management Services Sector.

[b] We assume that one-third of the program funding comes from the state government budget. The other two-thirds will be borne by the commercial sector and residential sector.

Table L3. Mapping the Quantification Results of Transportation-8 Cutting Emissions From Freight Transportation into REMI Inputs

TWGs Quantification Results	Policy Variable Selection in REMI
Cost of Cutting Emissions from Freight Transportation	Compensation, Prices, and Costs Block→Production Cost of Truck Transportation sector→Increase Compensation, Prices, and Costs Block(Production Cost of Rail Transportation sector(Increase
Investment to Improve Freight Movement Efficiencies	Output and Demand Block (Exogenous Final Demand (amount) for Motor Vehicle Body and Trailer Manufacturing sector(Increase Output and Demand Block (Exogenous Final Demand (amount) for Other Fabricated Metal Product Manufacturing sector(Increase
Fuel Savings from Improved Freight Movement Efficiencies	Compensation, Prices, and Costs Block (Residual Fuel Cost for Truck Transportation sector(Decrease Compensation, Prices, and Costs Block (Residual Fuel Cost for Rail Transportation sector(Decrease
Fuel Demand Decrease	Output and Demand Block (Exogenous Final Demand (amount) for Petroleum and Coal Products Manufacturing sector(Decrease

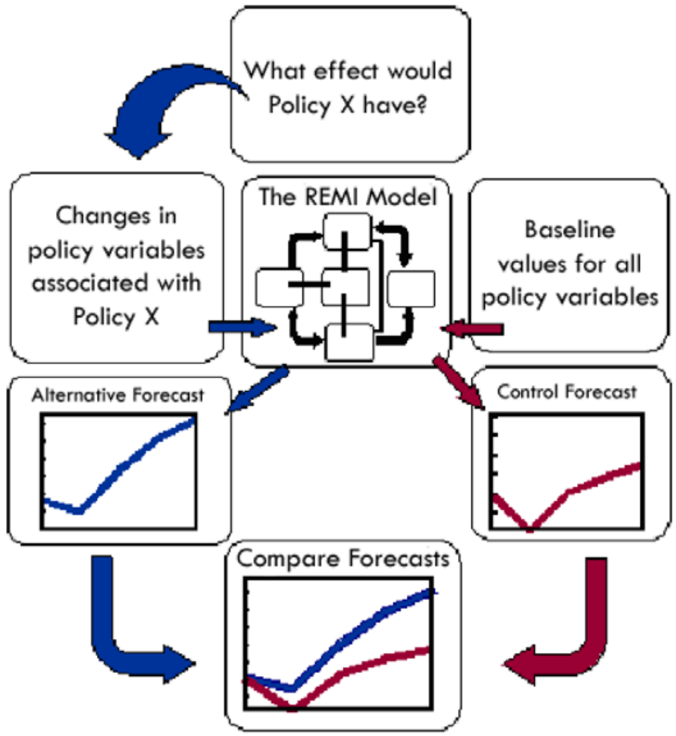
C. Simulation Set-up in REMI

Figure L1 shows how a policy simulation process is undertaken in the REMI model. First, a policy question is formulated (e.g., what would be the economic impacts of implementing DSM (natural gas) in the state). Second, external policy variables that would embody the effects of the policy are identified (take DSM (natural gas) as an example, relevant policy variables would include incremental costs and investment in energy efficient appliances; final demand increase in the sectors that produce the equipments and appliances; and the avoided consumption of natural gas). Third, baseline values for all the policy variables are used to generate the control forecast (baseline forecast). In REMI, the baseline forecast uses the most recent data available (i.e., 2006 data) for the study region and the external policy variables are set equal to their baseline values. Fourth, an alternative forecast is generated by changing the values of the external policy variables. Usually, the changing values of these variables represent the direct effects of the simulated policy scenario. For example, in our analysis of the DSM (natural gas) work plan, the costs to the commercial and residential sectors and the avoided consumption of natural gas were based on the technical assessment of implementing this mitigation work plan by the Res/Com Subcommittee of Pennsylvania. Fifth, the effects of the policy scenario are measured by comparing the baseline forecast and the alternative forecast. Sensitivity analysis can be undertaken by running a series of alternative forecasts with different assumptions on the values of the policy variables.

In this study, we first run the REMI model for each of the 42 recommended Pennsylvania mitigation work plans individually in a comparative static manner, i.e., one at a time, holding everything else constant. Next, we run a simultaneous simulation in which we assume that all the work plans are implemented together. Then the simple summation of the effects of individual work plans is compared to the simultaneous simulation results to determine whether the "whole" is different from the "sum" of the parts. Differences can arise from non-linearities and/or synergies. The latter would stem from complex functional relationships in the REMI Model.

Before performing the simulations in REMI, overlaps between work plans within the same sector and across different sectors are eliminated.

Figure L1. Process of Policy Simulation in REMI



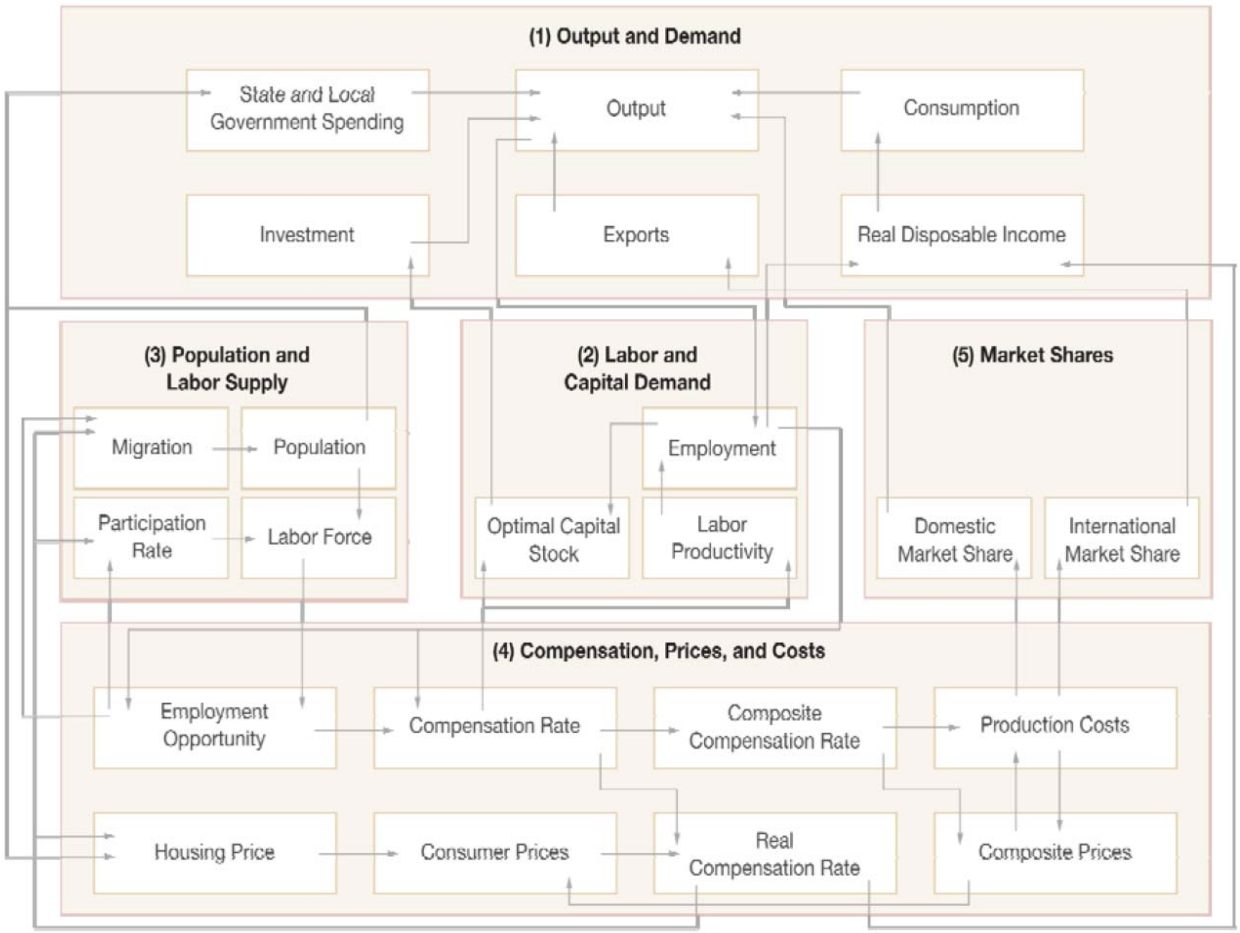
D. Description of the REMI PI+ Model

REMI PI+ is a structural economic forecasting and policy analysis model. It integrates input-output, computable general equilibrium, econometric and economic geography methodologies. The model is dynamic, with forecasts and simulations generated on an annual basis and behavioral responses to wage, price, and other economic factors.

The REMI model consists of thousands of simultaneous equations with a structure that is relatively straightforward. The exact number of equations used varies depending on the extent of industry, demographic, demand, and other detail in the model. The overall structure of the model can be summarized in five major blocks: (1) Output and Demand, (2) Labor and Capital Demand, (3) Population and Labor Supply, (4) Compensation, Prices, and Costs, and (5) Market Shares. The blocks and their key interactions are shown in Figures L2 and L3.

The Output and Demand block includes output, demand, consumption, investment, government spending, import, product access, and export concepts. Output for each industry is determined by industry demand in a given region and its trade with the US market, and international imports and exports. For each industry, demand is determined by the amount of output, consumption, investment, and capital demand on that industry. Consumption depends on real disposable income per capita, relative prices, differential income elasticities and population. Input productivity depends on access to inputs because the larger the choice set of inputs, the more likely that the input with the specific characteristics required for the job will be formed. In the capital stock adjustment process, investment occurs to fill the difference between optimal and actual capital stock for residential, non-residential, and equipment investment. Government spending changes are determined by changes in the population.

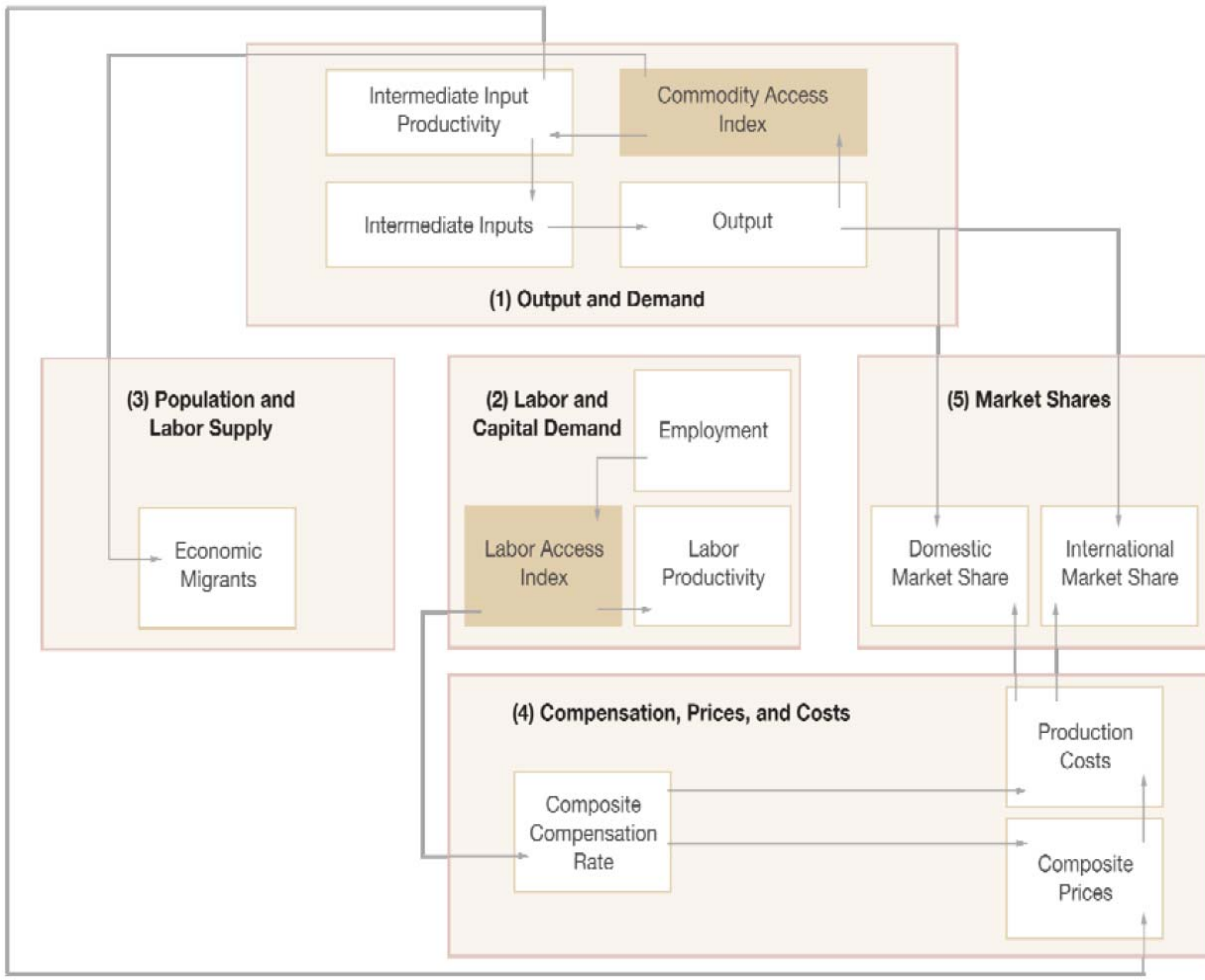
Figure L2. REMI Model Linkages (Excluding Economic Geography Linkages)



The Labor and Capital Demand block includes the determination of labor productivity, labor intensity and the optimal capital stocks. Industry-specific labor productivity depends on the availability of workers with differentiated skills for the occupations used in each industry. The occupational labor supply and commuting costs determine firms' access to a specialized labor force.

Labor intensity is determined by the cost of labor relative to the other factor inputs, capital and fuel. Demand for capital is driven by the optimal capital stock equation for both non-residential capital and equipment. Optimal capital stock for each industry depends on the relative cost of labor and capital, and the employment weighted by capital use for each industry. Employment in private industries is determined by the value added and employment per unit of value added in each industry.

Figure L3. Economic Geography Linkages



The Population and Labor Supply block includes detailed demographic information about the region. Population data is given for age and gender, with birth and survival rates for each group. The size and labor force participation rate of each group determines the labor supply. These participation rates respond to changes in employment relative to the potential labor force and to changes in the real after tax compensation rate. Migration includes retirement, military, international and economic migration. Economic migration is determined by the relative real after tax compensation rate, relative employment opportunity and consumer access to variety.

The Compensation, Prices, and Costs block includes delivered prices, production costs, equipment cost, the consumption deflator, consumer prices, the price of housing, and the wage equation. Economic geography concepts account for the productivity and price effects of access to specialized labor, goods and services.

These prices measure the value of the industry output, taking into account the access to production locations. This access is important due to the specialization of production that takes place within each industry, and because transportation and transaction costs associated with distance are significant. Composite prices for each industry are then calculated based on the production costs of supplying regions, the effective distance to these regions, and the index of access to the variety of output in the industry relative to the access by other uses of the product.

The cost of production for each industry is determined by cost of labor, capital, fuel and intermediate inputs. Labor costs reflect a productivity adjustment to account for access to specialized labor, as well as underlying compensation rates. Capital costs include costs of non-residential structures and equipment, while fuel costs incorporate electricity, natural gas and residual fuels.

The consumption deflator converts industry prices to prices for consumption commodities. For potential migrants, the consumer price is additionally calculated to include housing prices. Housing price changes from their initial level depend on changes in income and population density. Regional employee compensation changes are due to changes in labor demand and supply conditions, and changes in the national compensation rate. Changes in employment opportunities relative to the labor force and occupational demand change determine compensation rates by industry.

The Market Shares equations measure the proportion of local and export markets that are captured by each industry. These depend on relative production costs, the estimated price elasticity of demand, and effective distance between the home region and each of the other regions. The change in share of a specific area in any region depends on changes in its delivered price and the quantity it produces compared with the same factors for competitors in that market. The share of local and external markets then drives the exports from and imports to the home economy.

As shown in Figure L3, the Labor and Capital Demand block includes labor intensity and productivity, as well as demand for labor and capital. Labor force participation rate and migration equations are in the Population and Labor Supply block. The Compensation, Prices, and Costs block includes composite prices, determinants of production costs, the consumption price deflator, housing prices, and the wage equations. The proportion of local, interregional and international markets captured by each region is included in the Market Shares block.

E. Detailed REMI Model Simulation Results of Selected Work Plans

Tables L4 and L5 show the detailed simulation results of two work plans, Res/Com-5 Commission Buildings and Electricity-9 CHP, for each year between 2009 and 2020.

Table L4. Detailed Simulation Results of Work Plan Res/Com-5 Commission Buildings

Differences from the BAU Levels

Variable	2009	2010	2011	2012	2013	2014
Total Employment (Thous)	0.000	0.449	0.979	1.592	2.283	3.044
Gross Domestic Product (Bil Fixed 2007$)	0.000	0.028	0.065	0.111	0.169	0.234
Output (Bil Fixed 2007$)	0.000	0.042	0.097	0.169	0.255	0.356
Population (Thous)	0.000	0.180	0.524	1.036	1.707	2.532
Real Disp Personal Income (Bil Fixed 2007$)	0.000	0.041	0.087	0.140	0.200	0.267
PCE-Price Index	0.000	-0.007	-0.013	-0.020	-0.028	-0.036

Levels

Variable	2009	2010	2011	2012	2013	2014
Total Employment (Thous)	7,273.085	7,183.965	7,210.849	7,241.439	7,270.845	7,297.195
Gross Domestic Product (Bil Fixed 2007$)	536.248	539.235	554.152	569.682	585.373	601.275
Output (Bil Fixed 2007$)	852.131	857.928	880.771	904.349	928.108	952.137
Population (Thous)	12,561.072	12,622.453	12,687.569	12,759.436	12,837.543	12,919.966
Real Disp Personal Income (Bil Fixed 2007$)	477.094	472.531	484.022	497.470	510.704	524.822
PCE-Price Index	114.571	117.029	120.575	124.237	128.177	132.141

Percent Change from BAU Levels

Variable	2009	2010	2011	2012	2013	2014
Total Employment	0.000%	0.006%	0.014%	0.022%	0.031%	0.042%
Gross Domestic Product	0.000%	0.005%	0.012%	0.020%	0.029%	0.039%
Output	0.000%	0.005%	0.011%	0.019%	0.028%	0.038%
Population	0.000%	0.001%	0.004%	0.008%	0.013%	0.020%
Real Disposable Personal Income	0.000%	0.009%	0.018%	0.028%	0.039%	0.051%
PCE-Price Index	0.000%	-0.006%	-0.011%	-0.016%	-0.022%	-0.028%

Differences from the BAU Levels

Variable	2015	2016	2017	2018	2019	2020	esent Value
Total Employment (Thous)	3.865	4.755	5.641	6.557	7.500	7.801	N/A
Gross Domestic Product (Bil Fixed 2007$)	0.311	0.398	0.489	0.587	0.694	0.755	$2.47
Output (Bil Fixed 2007$)	0.474	0.606	0.746	0.899	1.063	1.159	$3.77
Population (Thous)	3.517	4.656	5.926	7.314	8.826	10.204	N/A
Real Disp Personal Income (Bil Fixed 2007$)	0.342	0.426	0.511	0.600	0.696	0.721	$2.62
PCE-Price Index	-0.045	-0.055	-0.065	-0.075	-0.086	-0.085	N/A

Levels

Variable	2015	2016	2017	2018	2019	2020
Total Employment (Thous)	7,320.206	7,347.621	7,377.311	7,412.560	7,451.490	7,479.334
Gross Domestic Product (Bil Fixed 2007$)	617.177	633.766	649.816	666.537	683.808	700.277
Output (Bil Fixed 2007$)	976.076	1,001.044	1,027.203	1,053.910	1,081.152	1,106.817
Population (Thous)	13,006.421	13,097.261	13,194.157	13,297.397	13,406.915	13,523.764
Real Disp Personal Income (Bil Fixed 2007$)	539.011	554.021	568.090	582.948	598.181	612.598
PCE-Price Index	136.272	140.583	145.088	149.694	154.482	159.459

Percent Change from BAU Levels

Variable	2015	2016	2017	2018	2019	2020
Total Employment	0.053%	0.065%	0.077%	0.089%	0.101%	0.104%
Gross Domestic Product	0.050%	0.063%	0.075%	0.088%	0.102%	0.108%
Output	0.049%	0.061%	0.073%	0.085%	0.098%	0.105%
Population	0.027%	0.036%	0.045%	0.055%	0.066%	0.076%
Real Disposable Personal Income	0.063%	0.077%	0.090%	0.103%	0.116%	0.118%
PCE-Price Index	-0.033%	-0.039%	-0.045%	-0.050%	-0.056%	-0.054%

Table L5. Detailed Simulation Results of Work Plan Electricity-9 CHP

Differences from the BAU Levels						
Variable	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Total Employment (Thous)	-0.010	-0.308	-0.995	-1.730	-2.451	-3.148
Gross Domestic Product (Bil Fixed 2007$)	-0.001	-0.032	-0.098	-0.172	-0.249	-0.330
Output (Bil Fixed 2007$)	-0.001	-0.047	-0.142	-0.249	-0.361	-0.477
Population (Thous)	-0.003	-0.107	-0.439	-0.957	-1.611	-2.377
Real Disp Personal Income (Bil Fixed 2007$)	-0.001	-0.026	-0.086	-0.147	-0.205	-0.261
PCE-Price Index	0.000	0.003	0.011	0.017	0.022	0.027

Levels						
Variable	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Total Employment (Thous)	7,273.075	7,183.209	7,208.875	7,238.117	7,266.110	7,291.003
Gross Domestic Product (Bil Fixed 2007$)	536.247	539.175	553.990	569.399	584.955	600.710
Output (Bil Fixed 2007$)	852.130	857.839	880.532	903.932	927.492	951.303
Population (Thous)	12,561.069	12,622.166	12,686.605	12,757.442	12,834.225	12,915.057
Real Disp Personal Income (Bil Fixed 2007$)	477.094	472.463	483.849	497.184	510.301	524.293
PCE-Price Index	114.571	117.039	120.599	124.274	128.227	132.204

Percent Change from BAU Levels						
Variable	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Total Employment	0.000%	-0.004%	-0.014%	-0.024%	-0.034%	-0.043%
Gross Domestic Product	0.000%	-0.006%	-0.018%	-0.030%	-0.043%	-0.055%
Output	0.000%	-0.005%	-0.016%	-0.028%	-0.039%	-0.050%
Population	0.000%	-0.001%	-0.003%	-0.008%	-0.013%	-0.018%
Real Disposable Personal Income	0.000%	-0.006%	-0.018%	-0.029%	-0.040%	-0.050%
PCE-Price Index	0.000%	0.003%	0.009%	0.014%	0.017%	0.020%

Differences from the BAU Levels							
Variable	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**NPV**
Total Employment (Thous)	-3.802	-4.661	-5.414	-6.043	-6.622	-7.059	N/A
Gross Domestic Product (Bil Fixed 2007$)	-0.413	-0.527	-0.639	-0.745	-0.847	-0.944	-$3.24
Output (Bil Fixed 2007$)	-0.594	-0.753	-0.907	-1.049	-1.184	-1.308	-$4.59
Population (Thous)	-3.220	-4.192	-5.240	-6.306	-7.398	-8.464	N/A
Real Disp Personal Income (Bil Fixed 2007$)	-0.317	-0.395	-0.463	-0.520	-0.581	-0.626	-$2.37
PCE-Price Index	0.031	0.037	0.042	0.044	0.048	0.049	N/A

Levels						
Variable	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Total Employment (Thous)	7,312.539	7,338.206	7,366.256	7,399.960	7,437.368	7,464.475
Gross Domestic Product (Bil Fixed 2007$)	616.453	632.842	648.689	665.204	682.268	698.579
Output (Bil Fixed 2007$)	975.008	999.684	1,025.550	1,051.962	1,078.904	1,104.351
Population (Thous)	12,999.685	13,088.412	13,182.991	13,283.777	13,390.690	13,505.096
Real Disp Personal Income (Bil Fixed 2007$)	538.353	553.200	567.118	581.829	596.904	611.252
PCE-Price Index	136.348	140.676	145.195	149.813	154.616	159.594

Percent Change from BAU Levels						
Variable	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Total Employment	-0.052%	-0.063%	-0.073%	-0.082%	-0.089%	-0.094%
Gross Domestic Product	-0.067%	-0.083%	-0.098%	-0.112%	-0.124%	-0.135%
Output	-0.061%	-0.075%	-0.088%	-0.100%	-0.110%	-0.118%
Population	-0.025%	-0.032%	-0.040%	-0.047%	-0.055%	-0.063%
Real Disposable Personal Income	-0.059%	-0.071%	-0.082%	-0.089%	-0.097%	-0.102%
PCE-Price Index	0.023%	0.026%	0.029%	0.029%	0.031%	0.031%

F. GSP and Employment Impacts of Individual Economic Sectors

Table L6. Sectoral GSP Impacts of the Pennsylvania Climate Action Plan—Simultaneous Simulation (in 2007 fixed billion $)

Sector	NAICS Code	2010	2015	2020	NPV
Forestry; Fishing, hunting, trapping	1131, 1132, 114	$0.009	$0.016	$0.011	$0.114
Logging	1133	$0.000	$0.000	$0.000	$0.000
Support activities for agriculture and forestry	115	$0.024	$0.089	$0.161	$0.675
Oil and gas extraction	211	-$0.001	-$0.003	-$0.003	-$0.016
Coal mining	2121	-$0.005	-$0.009	-$0.029	-$0.079
Metal ore mining	2122	$0.000	$0.000	$0.000	$0.000
Nonmetallic mineral mining and quarrying	2123	$0.000	$0.001	$0.003	$0.009
Support activities for mining	213	$0.000	-$0.001	-$0.002	-$0.001
Electric power generation, transmission, and distribution	2211	-$0.207	-$1.104	-$2.068	-$7.379
Natural gas distribution	2212	-$0.004	-$0.011	-$0.003	-$0.094
Water, sewage, and other systems	2213	-$0.002	-$0.010	-$0.018	-$0.072
Construction	23	-$0.032	$0.127	$0.411	$0.698
Sawmills and wood preservation	3211	$0.000	$0.000	$0.001	$0.004
Veneer, plywood, and engineered wood product manufacturing	3212	$0.000	$0.000	$0.001	$0.003
Other wood product manufacturing	3219	$0.000	$0.002	$0.006	$0.017
Clay product and refractory manufacturing	3271	$0.000	$0.001	$0.004	$0.011
Glass and glass product manufacturing	3272	$0.000	$0.002	$0.006	$0.023
Cement and concrete product manufacturing	3273	-$0.001	$0.002	$0.008	$0.019
Lime, gypsum product manufacturing; Other nonmetallic mineral product manufacturing	3274, 3279	$0.000	$0.001	$0.005	$0.017
Iron and steel mills and ferroalloy manufacturing	3311	$0.000	$0.005	$0.022	$0.076
Steel product manufacturing from purchased steel	3312	$0.000	$0.001	$0.004	$0.010
Alumina and aluminum production and processing	3313	$0.000	$0.001	$0.002	$0.012
Nonferrous metal (except aluminum) production and processing	3314	$0.000	$0.001	$0.004	$0.014
Foundries	3315	$0.000	$0.003	$0.010	$0.023
Forging and stamping	3321	$0.000	$0.001	$0.005	$0.013
Cutlery and handtool manufacturing	3322	$0.000	$0.000	$0.001	$0.004
Architectural and structural metals manufacturing	3323	-$0.002	$0.003	$0.011	$0.023
Boiler, tank, and shipping container manufacturing	3324	$0.001	$0.002	$0.003	$0.011
Hardware manufacturing	3325	$0.000	$0.000	$0.001	$0.004
Spring and wire product manufacturing	3326	$0.000	$0.000	$0.001	$0.004
Machine shops; turned product; and screw, nut, and bolt manufacturing	3327	$0.000	$0.003	$0.008	$0.029
Coating, engraving, heat treating, and allied activities	3328	$0.000	$0.001	$0.003	$0.009
Other fabricated metal product manufacturing	3329	$0.000	$0.003	$0.008	$0.029
Agriculture, construction, and mining machinery manufacturing	3331	$0.000	-$0.001	-$0.002	$0.006
Industrial machinery manufacturing	3332	$0.002	$0.006	$0.007	$0.024
Commercial and service industry machinery manufacturing	3333	$0.000	$0.001	$0.004	$0.008

Sector	NAICS Code	2010	2015	2020	NPV
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing	3334	$0.001	$0.009	$0.019	$0.068
Metalworking machinery manufacturing	3335	$0.000	-$0.001	-$0.004	$0.000
Engine, turbine, power transmission equipment manufacturing	3336	$0.002	$0.018	$0.109	$0.091
Other general purpose machinery manufacturing	3339	-$0.001	-$0.001	-$0.004	$0.005
Computer and peripheral equipment manufacturing	3341	-$0.001	-$0.004	-$0.013	-$0.006
Communications equipment manufacturing	3342	$0.000	-$0.002	-$0.007	-$0.001
Audio and video equipment manufacturing	3343	$0.000	$0.000	$0.002	$0.006
Semiconductor and other electronic component manufacturing	3344	-$0.001	$0.003	$0.008	$0.038
Navigational, measuring, electromedical, and control instruments manufacturing	3345	-$0.001	-$0.003	-$0.012	-$0.010
Manufacturing and reproducing magnetic and optical media	3346	$0.000	$0.000	$0.001	$0.006
Electric lighting equipment manufacturing	3351	$0.015	$0.050	$0.056	$0.400
Household appliance manufacturing	3352	$0.001	$0.002	$0.003	$0.015
Electrical equipment manufacturing	3353	$0.000	$0.004	$0.009	$0.025
Other electrical equipment and component manufacturing	3359	$0.000	$0.006	$0.017	$0.043
Motor vehicle manufacturing	3361	-$0.001	$0.000	$0.000	$0.004
Motor vehicle body and trailer manufacturing	3362	$0.009	$0.010	$0.006	$0.077
Motor vehicle parts manufacturing	3363	$0.001	$0.004	$0.009	$0.037
Aerospace product and parts manufacturing	3364	$0.000	$0.000	$0.002	$0.009
Railroad rolling stock manufacturing	3365	$0.000	$0.000	$0.002	$0.005
Ship and boat building	3366	$0.000	$0.000	$0.001	$0.004
Other transportation equipment manufacturing	3369	$0.000	$0.001	$0.005	$0.016
Household and institutional furniture and kitchen cabinet manufacturing	3371	-$0.002	$0.001	$0.005	$0.015
Office furniture (including fixtures) manufacturing	3372	-$0.001	-$0.002	-$0.005	-$0.010
Other furniture related product manufacturing	3379	$0.000	$0.000	$0.002	$0.004
Medical equipment and supplies manufacturing	3391	-$0.003	$0.000	$0.002	$0.018
Other miscellaneous manufacturing	3399	$0.000	$0.005	$0.020	$0.064
Animal food manufacturing	3111	$0.000	$0.000	$0.002	$0.004
Grain and oilseed milling	3112	$0.000	$0.000	$0.001	$0.004
Sugar and confectionery product manufacturing	3113	$0.000	$0.002	$0.009	$0.029
Fruit and vegetable preserving and specialty food manufacturing	3114	-$0.001	$0.002	$0.008	$0.021
Dairy product manufacturing	3115	-$0.001	$0.001	$0.004	$0.011
Animal slaughtering and processing	3116	-$0.001	$0.001	$0.007	$0.019
Seafood product preparation and packaging	3117	$0.000	$0.000	$0.000	$0.000
Bakeries and tortilla manufacturing	3118	-$0.001	$0.002	$0.009	$0.023
Other food manufacturing	3119	-$0.001	$0.003	$0.011	$0.030
Beverage manufacturing	3121	-$0.001	$0.002	$0.010	$0.026
Tobacco manufacturing	3122	$0.000	$0.000	$0.001	$0.003
Fiber, yarn, and thread mills	3131	$0.000	$0.000	$0.000	$0.000
Fabric mills	3132	$0.000	$0.000	$0.001	$0.004
Textile and fabric finishing and fabric coating mills	3133	$0.000	$0.000	$0.000	$0.000

Sector	NAICS Code	2010	2015	2020	NPV
Textile furnishings mills	3141	$0.000	$0.001	$0.003	$0.009
Other textile product mills	3149	$0.000	$0.000	$0.001	$0.005
Apparel knitting mills	3151	$0.000	$0.000	$0.000	$0.001
Cut and sew apparel manufacturing	3152	$0.000	$0.002	$0.003	$0.024
Apparel accessories and other apparel manufacturing	3159	$0.000	$0.000	$0.000	$0.001
Leather, hide tanning, finishing; Other leather, allied product manufacturing	3161, 3169	$0.000	$0.000	$0.000	$0.001
Footwear manufacturing	3162	$0.000	$0.000	$0.001	$0.003
Pulp, paper, and paperboard mills	3221	-$0.001	$0.002	$0.008	$0.032
Converted paper product manufacturing	3222	-$0.001	$0.003	$0.012	$0.034
Printing and related support activities	323	-$0.002	$0.003	$0.010	$0.030
Petroleum and coal products manufacturing	324	-$0.020	-$0.040	-$0.057	-$0.305
Basic chemical manufacturing	3251	-$0.001	$0.009	$0.057	$0.116
Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing	3252	$0.000	$0.003	$0.013	$0.038
Pesticide, fertilizer, and other agricultural chemical manufacturing	3253	$0.001	$0.003	$0.005	$0.026
Pharmaceutical and medicine manufacturing	3254	-$0.006	$0.012	$0.048	$0.127
Paint, coating, and adhesive manufacturing	3255	$0.000	$0.002	$0.007	$0.017
Soap, cleaning compound, and toilet preparation manufacturing	3256	$0.000	$0.003	$0.010	$0.030
Other chemical product and preparation manufacturing	3259	-$0.001	$0.002	$0.009	$0.021
Plastics product manufacturing	3261	-$0.003	$0.010	$0.039	$0.110
Rubber product manufacturing	3262	$0.000	$0.001	$0.004	$0.014
Wholesale trade	42	-$0.044	$0.021	$0.116	$0.328
Retail trade	44-45	-$0.112	-$0.031	$0.146	-$0.004
Air transportation	481	-$0.003	$0.003	$0.013	$0.033
Rail transportation	482	-$0.003	-$0.008	-$0.011	-$0.046
Water transportation	483	$0.000	$0.000	$0.000	$0.000
Truck transportation	484	$0.022	$0.077	$0.184	$0.646
Couriers and messengers	492	-$0.001	$0.011	$0.028	$0.090
Transit and ground passenger transportation	485	$0.194	$0.196	$0.199	$1.551
Pipeline transportation	486	-$0.003	-$0.009	-$0.013	-$0.060
Scenic and sightseeing transportation and support activities for transportation	487, 488	$0.000	$0.001	$0.003	$0.011
Warehousing and storage	493	$0.000	$0.015	$0.044	$0.132
Newspaper, periodical, book, and directory publishers	5111	-$0.003	$0.006	$0.011	$0.038
Software publishers	5112	-$0.002	-$0.011	-$0.037	-$0.037
Motion picture and sound recording industries	512	-$0.001	$0.002	$0.006	$0.015
Internet and other information services	516, 518, 519	-$0.004	$0.010	$0.041	$0.105
Broadcasting (except internet)	515	-$0.001	$0.003	$0.009	$0.024
Telecommunications	517	-$0.017	$0.028	$0.105	$0.276
Monetary authorities, credit intermediation	521, 522	-$0.037	$0.083	$0.270	$0.717
Funds, trusts, and other financial vehicles	525	-$0.001	$0.002	$0.006	$0.016
Securities, commodity contracts, and other financial investments and related activities	523	-$0.018	$0.033	$0.134	$0.319

Sector	NAICS Code	2010	2015	2020	NPV
Insurance carriers	5241	-$0.006	$0.019	$0.053	$0.156
Agencies, brokerages, and other insurance related activities	5242	-$0.003	$0.014	$0.044	$0.122
Real estate	531	-$0.031	$0.317	$0.972	$2.849
Automotive equipment rental and leasing	5321	$0.000	$0.005	$0.013	$0.038
Consumer goods rental and general rental centers	5322, 5323	$0.000	$0.006	$0.014	$0.047
Commercial and industrial machinery and equipment rental and leasing	5324	-$0.001	$0.002	$0.006	$0.016
Lessors of nonfinancial intangible assets	533	-$0.002	$0.009	$0.034	$0.095
Legal services	5411	-$0.006	$0.010	$0.038	$0.094
Accounting, tax preparation, bookkeeping, and payroll services	5412	-$0.001	$0.008	$0.021	$0.068
Architectural, engineering, and related services	5413	-$0.009	$0.007	$0.033	$0.069
Specialized design services	5414	$0.001	$0.010	$0.020	$0.076
Computer systems design and related services	5415	-$0.003	-$0.011	-$0.037	-$0.038
Management, scientific, and technical consulting services	5416	-$0.006	$0.013	$0.056	$0.134
Scientific research and development services; Other professional, scientific, and technical services	5417, 5419	-$0.003	$0.030	$0.098	$0.275
Advertising and related services	5418	-$0.001	$0.004	$0.013	$0.037
Management of companies and enterprises	55	-$0.005	$0.058	$0.190	$0.556
Office administrative services; Facilities support services	5611, 5612	-$0.004	$0.004	$0.022	$0.048
Employment services	5613	-$0.005	$0.006	$0.025	$0.061
Business support services; Investigation and security services; Other support services	5614, 5616, 5619	-$0.002	$0.032	$0.083	$0.262
Travel arrangement and reservation services	5615	$0.001	$0.003	$0.006	$0.022
Services to buildings and dwellings	5617	-$0.002	$0.025	$0.065	$0.199
Waste collection; Waste treatment and disposal and waste management services	562	$0.036	$0.150	$0.266	$1.131
Elementary and secondary schools; Junior colleges, colleges, universities, and professional schools; Other educational services	61	-$0.004	$0.025	$0.077	$0.220
Offices of health practitioners	6211-6213	-$0.050	$0.105	$0.307	$0.795
Outpatient, laboratory, and other ambulatory care services	6214-6216	-$0.003	$0.019	$0.056	$0.150
Home health care services	6219	-$0.001	$0.009	$0.028	$0.076
Hospitals	622	-$0.006	$0.047	$0.138	$0.391
Nursing care facilities	6231	$0.000	$0.011	$0.029	$0.093
Residential care facilities	6232, 6233, 6239	-$0.001	$0.013	$0.035	$0.106
Individual, family, community, and vocational rehabilitation services	6241-6243	$0.000	$0.026	$0.075	$0.213
Child day care services	6244	-$0.001	$0.007	$0.020	$0.056
Performing arts companies; Promoters of events, and agents and managers	7111, 7113, 7114	$0.000	$0.001	$0.004	$0.014
Spectator sports	7112	-$0.001	$0.004	$0.012	$0.033
Independent artists, writers, and performers	7115	$0.000	$0.000	$0.001	$0.004
Museums, historical sites, and similar institutions	712	$0.000	$0.001	$0.004	$0.010
Amusement, gambling, and recreation industries	713	-$0.001	$0.020	$0.071	$0.194

Sector	NAICS Code	2010	2015	2020	NPV
Accommodation	721	-$0.001	$0.013	$0.041	$0.116
Food services and drinking places	722	-$0.007	$0.044	$0.117	$0.376
Automotive repair and maintenance	8111	-$0.001	$0.011	$0.033	$0.099
Electronic and precision equipment repair and maintenance	8112	$0.000	$0.003	$0.007	$0.024
Commercial and industrial equipment (except automotive and electronic) repair and maintenance	8113	$0.000	$0.008	$0.022	$0.071
Personal and household goods repair and maintenance	8114	$0.001	$0.011	$0.025	$0.090
Personal care services	8121	-$0.004	$0.014	$0.037	$0.108
Death care services	8122	$0.000	$0.001	$0.003	$0.009
Drycleaning and laundry services	8123	-$0.001	$0.005	$0.012	$0.035
Other personal services	8129	-$0.003	$0.012	$0.034	$0.096
Religious organizations; Grantmaking and giving services, and social advocacy organizations	8131-8133	-$0.001	$0.010	$0.027	$0.077
Civic, social, professional, and similar organizations	8134, 8139	-$0.001	$0.006	$0.017	$0.048
Private households	814	-$0.001	$0.002	$0.006	$0.014
Total*		**-$0.418**	**$0.845**	**$3.591**	**$9.665**

* The total represents the sum of all the sectoral effects. The totals shown in this table differ from the simultaneous solutions shown in the last row of Table 1 in Chapter 11. The gap between the two is farm value added and government compensation, as well as rounding error.

Table L7. Sectoral Employment Impacts of the Pennsylvania Climate Action Plan — Simultaneous Simulation (in thousands)

Sector	NAICS Code	2010	2015	2020
Forestry; Fishing, hunting, trapping	1131, 1132, 114	0.32	0.60	0.42
Logging	1133	0.00	0.01	0.02
Support activities for agriculture and forestry	115	2.80	9.38	15.56
Oil and gas extraction	211	-0.01	-0.04	-0.04
Coal mining	2121	-0.03	-0.06	-0.17
Metal ore mining	2122	0.00	0.00	0.00
Nonmetallic mineral mining and quarrying	2123	0.00	0.00	0.01
Support activities for mining	213	0.00	-0.01	-0.02
Electric power generation, transmission, and distribution	2211	-0.33	-1.45	-2.22
Natural gas distribution	2212	-0.02	-0.07	-0.06
Water, sewage, and other systems	2213	-0.01	-0.05	-0.09
Construction	23	-0.56	2.69	5.46
Sawmills and wood preservation	3211	0.00	0.01	0.02
Veneer, plywood, and engineered wood product manufacturing	3212	0.00	0.01	0.02
Other wood product manufacturing	3219	-0.01	0.03	0.09
Clay product and refractory manufacturing	3271	0.00	0.01	0.03
Glass and glass product manufacturing	3272	0.00	0.01	0.03
Cement and concrete product manufacturing	3273	-0.01	0.02	0.08
Lime, gypsum product manufacturing; Other nonmetallic mineral product manufacturing	3274, 3279	0.00	0.01	0.03
Iron and steel mills and ferroalloy manufacturing	3311	0.00	0.02	0.06
Steel product manufacturing from purchased steel	3312	0.00	0.01	0.03
Alumina and aluminum production and processing	3313	0.00	0.01	0.02
Nonferrous metal (except aluminum) production and processing	3314	0.00	0.01	0.03
Foundries	3315	0.00	0.02	0.06
Forging and stamping	3321	0.00	0.02	0.04
Cutlery and handtool manufacturing	3322	0.00	0.01	0.01
Architectural and structural metals manufacturing	3323	-0.02	0.04	0.12
Boiler, tank, and shipping container manufacturing	3324	0.00	0.01	0.03
Hardware manufacturing	3325	0.00	0.00	0.01
Spring and wire product manufacturing	3326	0.00	0.01	0.02
Machine shops; turned product; and screw, nut, and bolt manufacturing	3327	0.00	0.03	0.07
Coating, engraving, heat treating, and allied activities	3328	0.00	0.01	0.02
Other fabricated metal product manufacturing	3329	0.00	0.03	0.08
Agriculture, construction, and mining machinery manufacturing	3331	0.00	0.00	0.01
Industrial machinery manufacturing	3332	0.01	0.02	0.04
Commercial and service industry machinery manufacturing	3333	-0.01	0.01	0.03
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing	3334	0.02	0.06	0.08
Metalworking machinery manufacturing	3335	0.00	0.00	-0.01
Engine, turbine, power transmission equipment manufacturing	3336	0.01	0.04	0.17
Other general purpose machinery manufacturing	3339	0.00	0.00	0.01

Sector	**NAICS Code**	**2010**	**2015**	**2020**
Computer and peripheral equipment manufacturing	3341	0.00	0.00	0.00
Communications equipment manufacturing	3342	0.00	0.00	0.00
Audio and video equipment manufacturing	3343	0.00	0.00	0.01
Semiconductor and other electronic component manufacturing	3344	0.00	0.01	0.02
Navigational, measuring, electromedical, and control instruments manufacturing	3345	-0.01	-0.01	-0.02
Manufacturing and reproducing magnetic and optical media	3346	0.00	0.01	0.01
Electric lighting equipment manufacturing	3351	0.15	0.37	0.31
Household appliance manufacturing	3352	0.00	0.01	0.01
Electrical equipment manufacturing	3353	0.00	0.02	0.05
Other electrical equipment and component manufacturing	3359	0.00	0.03	0.08
Motor vehicle manufacturing	3361	0.00	0.00	0.00
Motor vehicle body and trailer manufacturing	3362	0.19	0.16	0.09
Motor vehicle parts manufacturing	3363	0.01	0.05	0.09
Aerospace product and parts manufacturing	3364	0.00	0.00	0.02
Railroad rolling stock manufacturing	3365	0.00	0.00	0.01
Ship and boat building	3366	0.00	0.00	0.01
Other transportation equipment manufacturing	3369	0.00	0.01	0.03
Household and institutional furniture and kitchen cabinet manufacturing	3371	-0.03	0.03	0.08
Office furniture (including fixtures) manufacturing	3372	-0.01	-0.01	-0.01
Other furniture related product manufacturing	3379	-0.01	0.01	0.02
Medical equipment and supplies manufacturing	3391	-0.02	0.01	0.03
Other miscellaneous manufacturing	3399	0.00	0.03	0.09
Animal food manufacturing	3111	0.00	0.01	0.01
Grain and oilseed milling	3112	0.00	0.00	0.01
Sugar and confectionery product manufacturing	3113	0.00	0.02	0.04
Fruit and vegetable preserving and specialty food manufacturing	3114	-0.01	0.01	0.04
Dairy product manufacturing	3115	-0.01	0.01	0.03
Animal slaughtering and processing	3116	-0.01	0.03	0.10
Seafood product preparation and packaging	3117	0.00	0.00	0.00
Bakeries and tortilla manufacturing	3118	-0.01	0.03	0.09
Other food manufacturing	3119	-0.01	0.02	0.06
Beverage manufacturing	3121	-0.01	0.01	0.04
Tobacco manufacturing	3122	0.00	0.00	0.00
Fiber, yarn, and thread mills	3131	0.00	0.00	0.01
Fabric mills	3132	0.00	0.01	0.02
Textile and fabric finishing and fabric coating mills	3133	0.00	0.00	0.01
Textile furnishings mills	3141	0.00	0.01	0.02
Other textile product mills	3149	0.00	0.01	0.03
Apparel knitting mills	3151	0.00	0.00	0.01
Cut and sew apparel manufacturing	3152	-0.01	0.04	0.08
Apparel accessories and other apparel manufacturing	3159	0.00	0.00	0.01
Leather, hide tanning, finishing; Other leather, allied product manufacturing	3161, 3169	0.00	0.00	0.01
Footwear manufacturing	3162	0.00	0.01	0.03
Pulp, paper, and paperboard mills	3221	0.00	0.01	0.02

Sector	NAICS Code	2010	2015	2020
Converted paper product manufacturing	3222	-0.01	0.04	0.11
Printing and related support activities	323	-0.03	0.06	0.16
Petroleum and coal products manufacturing	324	-0.05	-0.08	-0.08
Basic chemical manufacturing	3251	0.00	0.03	0.12
Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing	3252	0.00	0.01	0.03
Pesticide, fertilizer, and other agricultural chemical manufacturing	3253	0.00	0.02	0.02
Pharmaceutical and medicine manufacturing	3254	-0.03	0.05	0.17
Paint, coating, and adhesive manufacturing	3255	0.00	0.01	0.03
Soap, cleaning compound, and toilet preparation manufacturing	3256	0.00	0.01	0.02
Other chemical product and preparation manufacturing	3259	0.00	0.01	0.03
Plastics product manufacturing	3261	-0.02	0.08	0.24
Rubber product manufacturing	3262	0.00	0.02	0.04
Wholesale trade	42	-0.29	0.23	0.76
Retail trade	44-45	-2.14	-0.12	2.48
Air transportation	481	-0.02	0.02	0.05
Rail transportation	482	-0.01	-0.03	-0.03
Water transportation	483	0.00	0.00	0.00
Truck transportation	484	0.12	-0.39	-1.00
Couriers and messengers	492	-0.01	0.11	0.24
Transit and ground passenger transportation	485	6.10	5.72	5.46
Pipeline transportation	486	-0.01	-0.03	-0.04
Scenic and sightseeing transportation and support activities for transportation	487, 488	0.00	0.04	0.10
Warehousing and storage	493	-0.02	0.04	0.04
Newspaper, periodical, book, and directory publishers	5111	-0.05	0.05	0.08
Software publishers	5112	-0.01	-0.01	-0.02
Motion picture and sound recording industries	512	-0.02	0.03	0.07
Internet and other information services	516, 518, 519	-0.03	0.06	0.15
Broadcasting (except internet)	515	-0.02	0.02	0.06
Telecommunications	517	-0.05	0.07	0.17
Monetary authorities, credit intermediation	521, 522	-0.22	0.47	1.22
Funds, trusts, and other financial vehicles	525	-0.01	0.01	0.03
Securities, commodity contracts, and other financial investments and related activities	523	-0.17	0.26	0.72
Insurance carriers	5241	-0.06	0.19	0.49
Agencies, brokerages, and other insurance related activities	5242	-0.03	0.13	0.33
Real estate	531	-0.15	1.27	3.46
Automotive equipment rental and leasing	5321	0.00	0.03	0.06
Consumer goods rental and general rental centers	5322, 5323	-0.01	0.14	0.24
Commercial and industrial machinery and equipment rental and leasing	5324	-0.01	0.01	0.02
Lessors of nonfinancial intangible assets	533	0.00	0.00	0.01
Legal services	5411	-0.07	0.12	0.39
Accounting, tax preparation, bookkeeping, and payroll services	5412	-0.02	0.15	0.37
Architectural, engineering, and related services	5413	-0.12	0.13	0.39

Sector	NAICS Code	2010	2015	2020
Specialized design services	5414	0.02	0.19	0.33
Computer systems design and related services	5415	-0.05	-0.08	-0.23
Management, scientific, and technical consulting services	5416	-0.08	0.16	0.62
Scientific research and development services; Other professional, scientific, and technical services	5417, 5419	-0.02	0.16	0.41
Advertising and related services	5418	-0.03	0.06	0.18
Management of companies and enterprises	55	-0.04	0.18	0.52
Office administrative services; Facilities support services	5611, 5612	-0.04	0.04	0.13
Employment services	5613	-0.14	0.21	0.64
Business support services; Investigation and security services; Other support services	5614, 5616, 5619	-0.06	0.54	1.11
Travel arrangement and reservation services	5615	0.02	0.05	0.08
Services to buildings and dwellings	5617	-0.09	0.81	1.68
Waste collection; Waste treatment and disposal and waste management services	562	0.47	1.80	2.91
Elementary and secondary schools; Junior colleges, colleges, universities, and professional schools; Other educational services	61	-0.15	0.48	1.39
Offices of health practitioners	6211-6213	-0.53	0.98	2.28
Outpatient, laboratory, and other ambulatory care services	6214-6216	-0.05	0.16	0.39
Home health care services	6219	-0.03	0.20	0.55
Hospitals	622	-0.13	0.52	1.26
Nursing care facilities	6231	-0.03	0.22	0.47
Residential care facilities	6232, 6233, 6239	-0.03	0.32	0.77
Individual, family, community, and vocational rehabilitation services	6241-6243	-0.02	0.71	1.73
Child day care services	6244	-0.04	0.25	0.61
Performing arts companies; Promoters of events, and agents and managers	7111, 7113, 7114	-0.02	0.05	0.14
Spectator sports	7112	-0.01	0.04	0.11
Independent artists, writers, and performers	7115	-0.02	0.07	0.17
Museums, historical sites, and similar institutions	712	0.00	0.03	0.07
Amusement, gambling, and recreation industries	713	-0.03	0.32	0.93
Accommodation	721	-0.03	0.21	0.58
Food services and drinking places	722	-0.41	1.23	2.91
Automotive repair and maintenance	8111	-0.04	0.20	0.51
Electronic and precision equipment repair and maintenance	8112	-0.01	0.03	0.07
Commercial and industrial equipment (except automotive and electronic) repair and maintenance	8113	0.00	0.08	0.16
Personal and household goods repair and maintenance	8114	0.01	0.14	0.25
Personal care services	8121	-0.16	0.47	0.99
Death care services	8122	-0.01	0.01	0.03
Drycleaning and laundry services	8123	-0.03	0.07	0.15
Other personal services	8129	-0.03	0.09	0.18
Religious organizations; Grantmaking and giving services, and social advocacy organizations	8131-8133	-0.04	0.41	0.98

Sector	NAICS Code	2010	2015	2020
Civic, social, professional, and similar organizations	8134, 8139	-0.04	0.12	0.33
Private households	814	-0.30	0.45	1.10
Total		**2.68**	**33.30**	**66.33**

* The total represents the sum of all the sectoral effects. The totals shown in this table differ from the simultaneous solutions shown in the last row of Table 2 in Chapter 11. The gap between the two is public employment, as well as rounding error.

APPENDIX M
Public Comment & Response Document

Acknowledgements

The Pennsylvania Climate Action Committee (CCAC) would like to acknowledge the PA General Assembly and Governor Rendell for their leadership and forward thinking in passing and signing the Pennsylvania Climate Change Act (Act 70) that required the Pennsylvania Department of Environmental Protection (DEP) to prepare this plan and constituted the Advisory Committee to advise the DEP in its preparation. The CCAC gratefully acknowledges the following individuals and organizations who contributed significantly to the successful completion of the CCAC process and the publication of this report:

Special thanks to John Hanger Secretary of the Pennsylvania DEP for his commitment and leadership to the Committee, the process and the work; and to John Quigley, Acting Secretary of Pennsylvania Department of Conservation and Natural Resources for his leadership in serving as Vice Chair, and former Secretary of DCNR Michael DiBerardinis. We would also like to thank the Pennsylvania Department of Transportation (PennDOT) for their commitment to the process and for offering the service of Michael Baker Corporation for technical analysis related to transportation and land uses issues. Many thanks to Sarah Hetznecker for her leadership and dedicated efforts in serving as Chair.

Our great appreciation also goes to Joe Sherrick who supervised and coordinated all state activities associated with the implementation of Act 70, and Christine Simeone; to Kim Hoover and Paula Sviben who coordinated and arranged our meetings, public announcements; facilitated and recorded meetings, and provided other meeting support logistics throughout the process. Many thanks go to William Martin who used his skill and quiet contribution to facilitate our meetings. The CCAC also recognizes the many individuals from the public who participated in the sector-based subcommittees and the DEP and other agency technical staff support for each subcommittee: Joe Sherrick and Krishnan Ramamurthy (Electricity); Denise Brinley, Maureen Guttman and Dennis Maloskey (Residential & Commercial); Kim Hoover, Ken Beard and Malcolm Furman (Industry & Waste); Chris Trostle and Danielle Spila (Land Use and Transportation); Paul Roth and Michael Pechart (Agriculture and Forestry).

Thanks goes out to the Pennsylvania State University and Dr. James Shortle for preparing the Impacts Assessment Report which informed the work of the committee in its recommendations for this Climate Action Plan.

Thomas D. Peterson, Executive Director, and Randy Strait, Sr. Project Manager of the Center for Climate Strategies (CCS), led the dedicated CCS team of professionals, and contributed extraordinary amounts of time, energy, and expertise in providing technical analysis for the CCAC process. Special thanks to Hal Nelson, Verinder Singh, Rachel Anderson, Alison Bailie, Greg Powell, Jackson Schriber, Jim Wilson, Rachel Anderson, Adam Rose and Dan Wei who coordinated the production and editing of this report.

Finally, we recognize and express appreciation to each volunteer member of the CCAC for the long hours and tireless efforts spent in discussing, studying, deliberating, and formulating recommendations during this process and for ensuring the openness of the process and soliciting public participation and comment along the way.

Special thanks to the subcommittee chairs for their efforts in consensus building and leadership:Terry Bossert, Vivan Lofness, Wayne Williams, David Cannon, John Quiqley, Paul Roth and Nathan Willcox.