THE CENTER FOR
CLIMATE STRATEGIES

Summary of Key Factors Contributing to Macroeconomic Impacts of GHG Mitigation Options

Dan Wei, Adam Rose, and Noah Dormady

I. Overview

We summarize the measurement of factors that play key roles in affecting the macroeconomic impacts of greenhouse gas mitigation options. The methodology is based primarily on a statistical analysis that extrapolates to the entire U.S. from the macroeconometric modeling of state climate action plans for four states (Florida, Pennsylvania, Michigan, and New York) using the Regional Economic Models, Inc. (REMI) Policy Insights Plus (PI^+) Model (Rose and Wei, 2011; Rose et al., 2011; Miller et al., 2010; Wei and Rose, 2011). We also use some results from other recent studies by the Center for Climate Strategies (CCS, 2010) and the general literature in energy economics to glean additional insights.

The findings can facilitate the discussion and screening of the potential macroeconomic impacts of GHG mitigation policy options under consideration. In addition, policy options should be considered malleable. Their macroeconomic performance can be improved by adjustments in policy design and implementation. In this regard, the insights provided here can be used to identify key components of policy option formulation that can promote the economic attractiveness of each option.

In the following sections, we summarize a number of key factors, as well as some general macroeconomic principles and considerations, we found to contribute most to the macroeconomic impacts. The microeconomic quantification results of the mitigation options reflect the net direct costs or savings associated with their implementation, but they do not include the direct offsetting and indirect ripple effects of decreased or increased spending on mitigation, and the interaction of demand and supply in various markets.

For example, energy efficiency reduces the demand for electricity generation from all sources, including both fossil energy and renewables. It therefore reduces the demand for fuel inputs such as coal and natural gas. Moreover, the associated investment in new equipment may partially or totally offset expenditures on ordinary plant operations and equipment. 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 use their wages and salaries to purchase more goods and services.

The extent of many types of linkages in the economy and macroeconomic impacts is extensive. It requires the use of sophisticated economic modeling tools that reflect the major structural features of an economy, the workings of its markets, and all of the interactions between them. In addition, the macroeconomic impacts of a given policy option are highly dependent on how the option is designed and implemented, such as the incentives in place to mobilize indigenous resources and to attract out-of-state investment. Factors such as state economic structure, characteristics of trade flows, and sectoral labor productivities all affect the macroeconomic impacts of implementing the mitigation policy options.

Although he impacts of a given policy option may differ significantly across states or regions, several common factors that influence their macroeconomic performance can be identified. These factors can be used reliably for initial discussion of the potential macroeconomic impacts of the policy options under consideration. In the following sections, we summarize the most significant factors individually.

II. Key Factors

1. Cost-effective Policy Options Generally Lead to More Positive Macroeconomic Impacts

The first general finding based on our macroeconomic impact analysis experience is that policy options that are cost-effective (i.e., those result in net savings) from the micro point of view generally result in a higher stimulus on jobs, income and economic growth. Cost-saving options mean that lower outlays are required to produce the same unit of output, which result in increased working capital on the business side and increased disposable income on the household side, both of which can be freed up for re-spending elsewhere in the economy. Figure 1 shows the stepwise GHG marginal mitigation cost curves for Michigan by sector. The horizontal axis represents the percentage of GHG emission reduction, and the vertical axis represents the per ton cost or savings (cost-effectiveness) of mitigation. Each horizontal segment in the cost curve represents an individual mitigation option. The width of the segment indicates the GHG emission reduction potential of the option in percentage terms. The height of the segment shows the average cost (saving) of reducing one ton of GHG with the implementation of the option. From this figure we can see that all the Residential, Commercial, and Industrial (RCI) options result in net cost savings (i.e., all the segments representing the RCI options are below the horizontal axis), while all the Energy Supply (ES) options incur net costs (i.e., all the segments representing the ES options are above the horizontal axis). The Transportation and Land Use (TLU) and Agriculture, Forest, and Waste Management (AFW) options vary from negative to positive costs. Table 1 shows the total employment impacts on a sectoral basis for these four sectors in Michigan. The

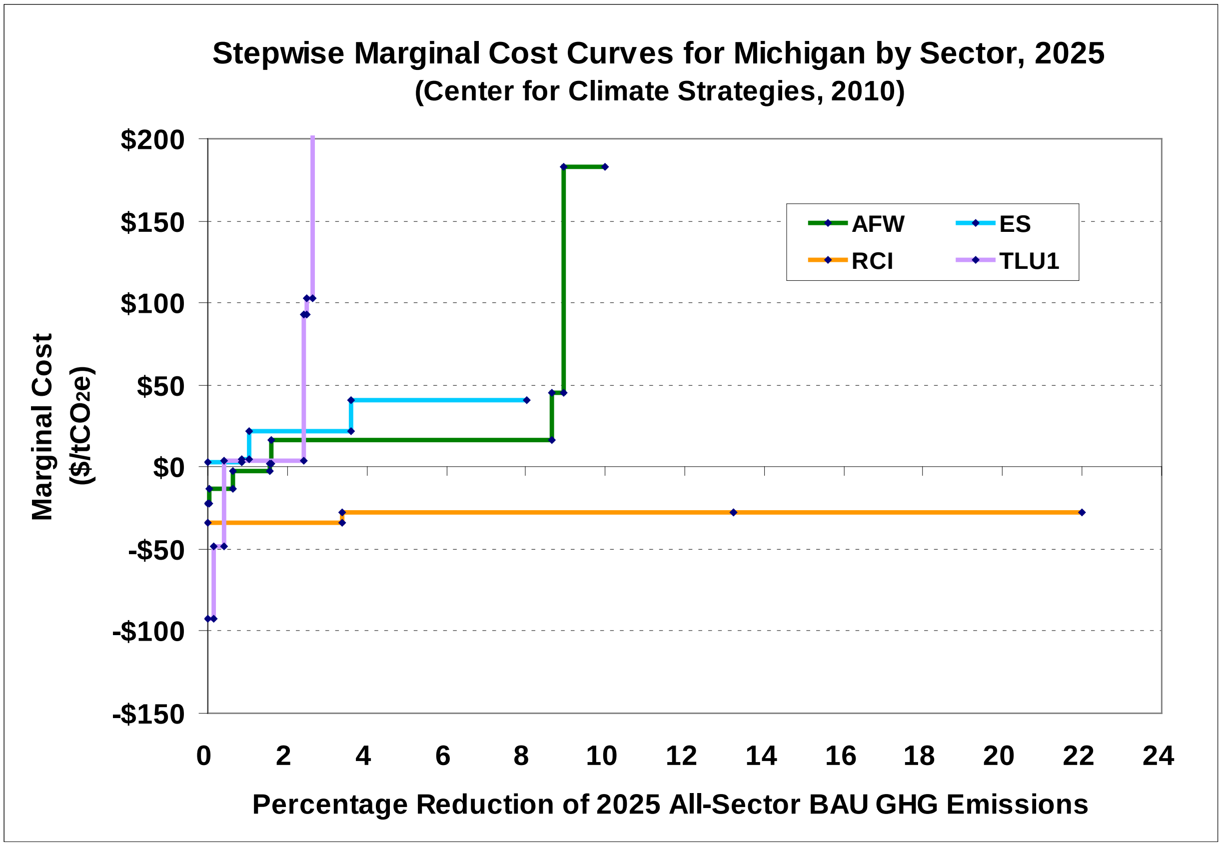

Figure 1. Marginal Cost Curves for Michigan by Sector, 2025

Table 1. Sectoral Employment Impacts, Michigan (thousand jobs)

Sector	2010	2015	2020	2025
ES	0.448	1.054	2.294	4.500
RCI	1.789	13.290	27.343	43.045
TLU	0.277	4.672	10.686	14.180
AFW	2.211	9.715	15.350	20.061

Source: Miller et al. (2010).

RCI options yield the highest job gains to the economy, while the ES options result in the lowest positive impacts. The overall job impacts of the AFW options and TLU options rank in between the other two categories.

Based on the REMI modeling results of the macroeconomic impacts of GHG mitigation policies recommended in the state climate action plans of Florida, Pennsylvania, Michigan, and New York, a reduced-form statistical model is developed to capture the relationship between macroeconomic impacts and various microeconomic costs, structural linkages and mitigation option characteristics (see Rose et al., 2011, for a description of a similar reduced form models we developed for Pennsylvania). Appendix A presents the details of the reduced-form regression equations. One of the major explanatory variables in the model is the annualized Net Present Value (NPV) of direct net cost of the 92 GHG mitigation options for the four states (i.e., the direct cost quantification results from the microeconomic analysis). Figure 2 shows the scatter plot of annualized NPV of GSP impact obtained from the REMI simulations and annualized NPV of direct net cost. These two sets of values have an overall high (negative) correlation (Rho = -0.49). That is, those policy options that are assessed to be cost-saving in the microeconomic analysis track positively with GSP impacts in the macroeconomic analysis, while cost-incurring options track negatively with GSP.

One should note that the cost savings effect can be influenced negatively or positively by other drivers and assumptions made in the micro quantification process. For example, assumptions on capital cost and avoided fuel cost would affect the cost/cost saving estimation results on the micro side. For example, in the PA climate action planning process, the ES Subcommittee assumed relatively low avoided electricity cost for the ES options, while the RCI Subcommittee assumed relatively high avoided fuel and electricity cost for RCI options. These, potentially, would lead to relatively higher cost saving estimation, and thus more preferable macroeconomic outcomes for the RCI options.

2. <u>Projections of Avoided Fuel Prices Affect Macroeconomic Assessment Results</u>

For most GHG mitigation policy options, direct economic benefits come from energy savings. In the macroeconomic impact analysis, both the stimulus and dampening effects of reduced energy consumption are estimated. The stimulus effects stem from the increase in disposable income of households because of the reduced energy bills and the decrease in production costs of the businesses because of reduced fuel inputs. The dampening effects are the reduced demand of goods and services from the fossil fuel supply sectors and the associated multiplier effects. The overall macroeconomic impacts are the net of the stimulus effects and the dampening effects. Thus projections of avoided fuel prices affect the macro simulation results in both the positive and negative ways. Our experiences in the REMI analyses of state climate action plans indicate that in general higher fuel price projections would lead to more positive overall macro impacts. This implies that in most states, the direct and indirect stimulus effects stemming from energy savings can more than offset the dampening effects on the fossil fuel sectors. In other words, if the prices of the avoided fuels are projected to be higher, the mitigation options would be more attractive to the state economy. The positive effect of higher fuel price projections is more prominent for states that have large amounts of fossil fuels imported from outside of the state. This is because if the projected fuel prices are higher, the households and businesses would save

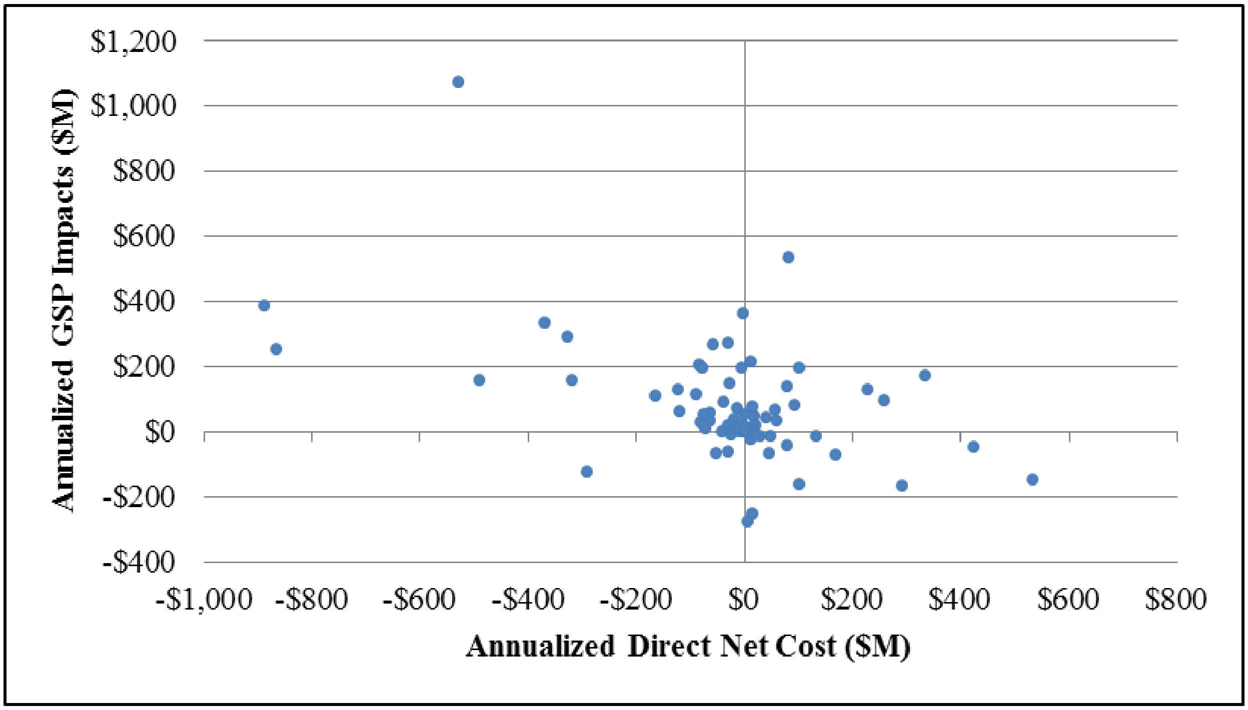

Figure 2. Scatter Plot of Annualized GSP Impacts (NPV) and Annualized Direct Net Cost (NPV) of 92 GHG Mitigation Policy Options for FL, PA, MI, and NY

more money from reduced fuel consumption through reduced fuel uses, but the dampening effects of reduced fuel production will take place mostly outside of the state.[1]

In the U.S. scale-up analysis of the macroeconomic impacts of 23 major GHG mitigation options, we have performed sensitivity analyses on the avoided energy prices for several key policy options (CCS, 2010). We assumed the avoided energy prices are 50% higher than those in the Base Case scenario. The macroeconomic performance of all the options improved in the higher avoided energy price scenario. In a few cases, such as the Combined Heat and Power option, higher price projections in avoided fossil fuels and electricity can turn the overall macro impacts of the options from negative to positive. Also note that different options will have a different degree of sensitivity to the price assumptions on avoided fuels. For example, higher price projections of petroleum fuels will mostly affect the macro impact results of the TLU options. Residential and commercial energy efficiency options will be less sensitive to petroleum fuel prices than industrial efficiency options, since petroleum fuels are comparatively used more in

[1] Note that other related effects of energy savings include investment in energy efficient technologies and equipment. The existence of adequate technologies in the local supply chain would affect the level of imports of technologies and outflows of investment from a given state. These effects could potentially lessen or enhance the energy saving effects. If the dampening effect associated with the increased capital cost of the businesses (or decreased disposable income of households) due to the purchase of energy efficient equipment can be offset by the stimulus effects stemming from the increased demand from local energy efficient equipment supply sectors, the benefit from energy saving will be enhanced; otherwise, the benefit from energy saving will be lessened.

industrial processes. Comparatively, major ES options, such as RPS and Low Carbon Portfolio Standards, are least sensitive to petroleum fuel prices, because, in the U.S., oil-fired electricity generation accounts for only a very small proportion of the mix of the displaced fossil fuel electricity generation.

A related concept to the avoided fuel price is the price differential effect. This effect measures the changes in economic activities attributable to the relative price changes due to the displacement of fossil fuels by clean/renewable energy. Studies in the literature show that the price-output elasticity of energy ranges between -0.01 to -0.05 (IEA, 2004; Huntington, 2005; EIA, 2006). This indicates that a 10% increase (or decrease) in energy costs would lead to 0.1% to 0.5% decrease (or increase) in state economic output. The assumption on avoided fuel price would affect the price differential effect calculation since it changes the relative price of new/renewable energy with respect to the displaced energy (e.g., higher projections on avoided fuel price would lead to relatively favorable price differential effects).

3. More Indigenous Resource Use Results in Higher Positive Macroeconomic Impacts

Policy options that encourage more utilization of in-state energy resources can help stimulate their economies, since the initial spending and the associated multiplier effects tend to stay within their borders. For example, the proportion of biofuel feedstock that can be provided by in-state sources would greatly affect the overall macroeconomic performance of options like Alternative Transportation Fuel. Promotion of in-state resources used in alternative (low-carbon) fuel production can stimulate investment and increase jobs and income in the local/regional agriculture, forestry, and waste sectors. In addition, additional jobs will be created in the downstream and upstream chains of sectors that provide inputs to and use outputs of these biofuel feedstock. Similar ripple effects will also take place from the increased ethanol and biodiesel production.

The overall stimulus effect of utilizing domestic resources to provide renewable and alternative energy will be even more prominent in those states that import large quantities of conventional energy from outside of the state. For example, the RPS option is more attractive to Florida than to Pennsylvania. In Florida, the projected GSP increase and job creation of the RPS option in the study terminal year (2025) are $4.5 billion and 36,710 jobs, respectively, representing 0.35% increase of GSP and 0.28% increase of employment from the baseline levels. In Pennsylvania, the Alternative Energy Portfolio Standards are projected to increase GSP and employment by $0.8 billion and 8,863 jobs, respectively, representing 0.12% and 0.14% increases from the baseline levels of the study terminal year (2020). The more prominent results for Florida stem from the fact that the dampening effects associated with the displacement of conventional fossil fuel-fired electricity by renewable electricity generation is not significant, since coal and most natural gas are not produced in the state, but rather are imported.

4. Investment in Sectors with High Regional Purchase Coefficients Can Generate Stronger Stimulus to the State Economy

The previous section focuses on the stimulating effects stemming from the promotion of indigenous energy utilization. This fits in the general consideration of the Regional Purchase Coefficient (RPC) of the economic sectors in a region/state. The RPC represents the proportion of total regional demand (by all users) for a good or service that is supplied by the producers that are located within the study region. RPC is a number between zero and one. A higher RPC in a given sector indicates that an increase in its final demand will largely stimulate the in-state producers of this sector. Conversely, a final demand increase for a sector with a lower RPC will be fulfilled mostly by out-of-state imports, and thus will have a limited effect in stimulating the state local economy.

The examples in Section 3 emphasize the importance of increasing RPCs in certain sectors (e.g., by increasing in-state supply of bio-energy feedstock, or by attracting new renewable equipment manufacturers to the state). The concept of the RPC can also help us understand how investment impacts can differ between sectors with different RPCs. In many states the magnitude of macroeconomic benefits of two RCI sector options, Appliance Standard and Building Codes, may differ to a great extent. For the former option, a large portion of investment goes to energy efficient equipment and appliance manufacturing sectors. However, in most states, sectors such as Household Appliance Mfg; Electrical Equipment Mfg; Ventilation, Heating, Air-conditioning; etc., have relatively low RPCs. As for the Building Codes option, a large amount of investment goes to the Construction sector, which in most states has a high RPC. In New York State, for example, the RPCs for the Equipment and Appliances Mfg sectors are less than 0.15, while the RPC for the Construction sector is 0.77. This indicates that capital investments in Construction are more stimulating to the state economy than investment in Equipment Mfg, whose demand is satisfied with greater proportions of imports.

Table 2 presents the RPCs of selected sectors in New York State. These sectors are those that would most likely be affected by climate action policies. Except for the Construction sector, Electricity Generation sector and Technical Services and Scientific Research sectors in NY have relatively high RPCs. Manufacturing sectors, Forestry, and fossil fuel production sectors have low RPCs.

Table 2. RPCs of Selected Sectors in New York, 2008

Sector	**RPC**
Forestry; Fishing, hunting, trapping	0.015
Support activities for agriculture and forestry	0.273
Oil and gas extraction	0.011
Coal mining	0.001
Electric power generation, transmission, and distribution	0.849
Natural gas distribution	0.385
Construction	0.766
Petroleum and coal products manufacturing	0.068

Sector	RPC
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing	0.113
Engine, turbine, power transmission equipment manufacturing	0.087
Electric lighting equipment manufacturing	0.142
Household appliance manufacturing	0.021
Electrical equipment manufacturing	0.090
Other electrical equipment and component manufacturing	0.100
Motor vehicle manufacturing	0.016
Motor vehicle body and trailer manufacturing	0.126
Motor vehicle parts manufacturing	0.156
Truck transportation	0.184
Transit and ground passenger transportation	0.742
Monetary authorities, credit intermediation	0.754
Management, scientific, and technical consulting services	0.751
Scientific research and development services; Other professional, scientific, and technical services	0.582
Waste collection; Waste treatment and disposal and waste management services	0.491

Source: REMI, 2010.

5. **Attraction of Out-State Investment and Funds Can Lead to Higher Positive Impacts on a State Economy**

Policy options that have the potential to attract out-of-state investment or federal government funds would be more beneficial to the state or regional economy than those that purely depend on in-state private and public investment. In the macroeconomic impact analysis, both the positive and negative influences of capital investment to the economy should be simulated. On the stimulus side, the capital investment stimulates the equipment manufacturing sectors, construction sectors, and other private and public service sectors. On the dampening side, the increased capital investment reduces the disposable income of households and increases the capital costs of businesses. However, if the investment comes from sources outside of the state, such as in cases where part of the investment is supported by federal government funds, the associated dampening effect of the capital investment (i.e., reduced federal government investment in other general areas) will not affect (or only partially affect) the state economy.

The discussion of the source of capital investment also relates to the issue as to what extent the incremental capital investment of the climate policy options would simply displace the investment that would have taken place in the absence of these options. In a more refined analysis, only the proportion of capital investment under the climate action plan that is additive to the economy should be taken into consideration. In other words, the forgone net benefits of the ordinary investment (e.g., investment in modernization) displaced by the climate investment should be subtracted from the net stimulus effects in the analysis. However, if the climate policy actions can attract funds from out-of-state sources, the investment can be considered as 100% additive to the state or regional economy.

When a policy option is evaluated at the national level, the situation differs in terms of the effect of federal government funding. This is because at the national level, the increased federal spending in one area will lead to the decreased spending in other government spending areas, or it will be offset by increased taxes. One exception would be if the federal funding stems from an existing government budget allocation, in which case no offsetting effect needs to be considered from the macroeconomic point of view.

6. Job Gains Are Higher with Investment in Labor-Intensive Sectors

Many studies on the economic and employment impacts of GHG mitigation options indicate that investment in energy efficiency and clean/renewable energy would lead to a net positive impact on employment (Kammen et al., 2004; Global Insight, 2008; Bezdek, 2007; Pollin et al. 2009a). The reason of these net employment gains is that the energy efficiency and renewable energy related sectors (such as building refurbishment, wind and solar electricity generation, clean and renewable energy R&D, etc.) are more labor-intensive than the conventional fossil fuel-based energy sectors.[2]

In our macroeconomic assessment of the U.S. state climate action plans, the results often indicate greater job gains than the GSP gains in percentage terms. This is evidence that the sectors benefitting directly and indirectly from the implementation of GHG mitigation option are relatively more labor-intensive than those adversely affected. One good example is the mitigation policy option of urban forestry. Table 3 presents the GSP/GDP and employment impact of this option for Pennsylvania and Michigan, and in the scale-up macroeconomic impact analysis for the U.S. Compared with the GSP/GDP impacts, which are marginally positive or slightly negative, the positive employment impacts are significant. The implementation of this option generates considerable demand of goods and services from forestry planting, maintenance, and other related activities supporting sectors. The dampening effects of this option are concentrated in the electricity generation sector due to the reduced electricity demand in residential and commercial buildings because of the increased shading of trees. The forestry and the related activities supporting sectors are very labor-intensive compared with the electricity generation sector. For the U.S. as a whole, the employment per unit output of the former is more than 10 times of the latter.

[2] One again, we need to note the price differential effects. Excessive price differentials between conventional and new energy sources (or technologies) can lead to significant depressing effects on the economy by increasing the cost of goods and services, and can even offset the direct spending and higher multiplier effects from new/renewable energy-related economic activities.

Table 3. GSP and Employment Impacts of Urban Forestry Option for PA, MI, and U.S.*

	GSP Impact	Employment Impact
PA	-0.01%	0.21%
MI	-0.09%	0.33%
U.S.	0.03%	0.28%

*The impacts are for Year 2020 for PA and U.S., and Year 2025 for MI.
Source: Rose et al., 2011; Miller et al., 2010; CCS, 2010.

III. Other Considerations

Based on our REMI modeling results of the macroeconomic impacts of GHG mitigation options in FL, PA, MI, and NY, we developed a reduced form multivariate statistical model to examine the relationship between the microeconomic analysis results and the macroeconomic impacts yielded by the REMI model (see the details in Appendix A). In the regression models, the dependent variable is the annualized NPV of GSP impacts or annualized employment impacts of individual mitigation options. The explanatory variables include the annualized NPV of direct net cost of a mitigation option, a set of categorical ("dummy" or "binary") variables indicating the sectoral category of the option, and some additional dummy variables describing other characteristics of the options (e.g., whether or not an option involves capital investment in Construction or Equipment Mfg; receives a state government subsidy; results in consumer expenditure reallocation).

The results of the regression analysis demonstrate some points we have summarized in the above sections. For example, we found strong negative correlation between the macroeconomic impact (GSP and employment) and the direct net cost of an option, meaning that cost-saving options (which result in overall negative net costs or positive savings) are likely to lead to positive impacts on GSP and employment.

The coefficients of the capital investment in the construction sector and the equipment manufacturing sectors are both positive and significant in the regression models. This indicates that holding all the other variables constant, those mitigation options that involve capital investment expenditures in the construction sector or in the equipment manufacturing sectors are expected to result in higher positive impacts to the economy. The regression models also indicate that dollar for dollar, capital investments in the construction sector are more stimulating to the economy in terms of job creation than are investments in equipment manufacturing. This is largely due to the fact that the construction sector has a higher Regional Purchase Coefficient (RPC) and is more labor-intensive than the equipment manufacturing sector. Therefore, a higher proportion of the investment in the construction sector will stay within the state to create in-state jobs, rather than flow to outside of the state.

Those options that include subsidies from a state government have an overall positive but insignificant effect on both GSP and employment. In our macroeconomic modeling, the state government subsidy is simulated in two aspects: 1) the stimulus effects coming from the increased household income or increased investment in sectors that receive the government subsidy; 2) the dampening effects stemming from the decrease of the same amount of government spending elsewhere. The positive sign of this variable indicates that the stimulus effects of directing government subsidies to mitigation options is expected to more than offset the dampening effects associated with the decreased government spending in other areas.

The coefficient of the consumer consumption reallocation dummy variable is positive in both the regression models for the GSP impacts and the models for the employment impacts, though it is not statistically significant. The positive sign of the coefficient of the consumption reallocation dummy variable indicates that holding all the other variables constant, a mitigation option that includes a consumption reallocation is expected to results in a greater positive effect on the state economy. Major consumption reallocations resulted from GHG mitigation options involve increased spending on more energy-efficient appliances and vehicles, and reduced spending on fossil fuels. In most cases, such consumption reallocations result in an overall increase in purchasing powers of the consumers, and thus generating net stimulus effects to the economy stemming from the re-spending effect.
Finally, there are some caveats regarding the macroeconomic key driving factors summarized in this report:

1. The macroeconomic impacts of a given policy option are highly dependent on how the option is designed and implemented, as well as the assumptions on key parameters used in quantifying the costs and savings of the options. Option design elements can make a difference in, for example, how much in-state resources can be mobilized, as well as how much outside-state funding can be attracted. The assumptions made on key parameters can also greatly affect the estimates on costs and savings of the options. For example, whether the renewable electricity generation would displace base-load or peak-load power generation, and thus whether average delivered electricity cost or peak power cost is used as the avoided electricity cost, would make distinct difference in the cost-effectiveness of a renewable electricity project.

2. We have made the efforts to explain how key factors can affect the macroeconomic impact analysis results separately. However, due to the interdependency between economic sectors and the interaction of the multiple factors, the overall macroeconomic impact of a policy option is difficult to predict. Both the magnitude of the impacts of individual factors and the way they interact with each other would affect the overall macro impact of an option. For example, investment in most renewable energy can result in higher employment multiplier effects compared with the conventional fossil fuel technologies being replaced. However, excessive energy price differential effects in favor of fossil

fuel technologies can more than offset the expansionary effects stemming from the investment in green technologies. Therefore, the effects of the key factors should be considered jointly, to the extent possible, in the catalog review and option prioritization process. However, this also accentuates the importance of performing formal macro impact analysis in a well-structured macroeconomic model to get a comprehensive and thorough evaluation of the aggregate impacts of the policy options.

3. Uncertainty in the macroeconomic modeling results can stem from the uncertainty of the basic data of the contributing economic factors, especially given the constantly changing nature of those factors as the economy grows and develops.

4. One should also note the relative size of an individual option's contribution to GSP and employment with respect to the overall levels of GSP and employment. In most states, only a few major options can result in macroeconomic impacts higher than 0.1% of the baseline levels; most mitigation options only result in very slight and sometimes undetectable impacts to the economy, which sometimes can be buried in the measurement errors of GSP and employment.

References:

Bezdek, R. 2007. *Renewable Energy and Energy Efficiency: Economic Drivers for the 21st Century*. Report for American Solar Energy Society. http://www.greenforall.org/resources/renewable-energy-and-energy-efficiency-economic.

Center for Climate Strategies. 2010. *Impacts of Comprehensive Climate and Energy Policy Options on the U.S. Economy*. Johns Hopkins University, Baltimore. http://advanced.jhu.edu/academic/government/energy-policy-report/.

EIA. 2006. "Energy and Economic Impacts of H.R.5049, the Keep America Competitive Global Warming Policy Act." Available at: http://www.eia.doe.gov/oiaf/servicerpt/economicimpacts/execsummary.html

Huntington, H.G. 2005. "The Economic Consequences of Higher Crude Oil Prices." Report for the U.S. Department of Energy.

Global Insight. 2008. U.*S. Metro Economies: Current and Potential Green Jobs in the U.S. Economy*. Prepared for The Unitied States Conference of Mayors and the Mayors Climate Protection Center. http://www.usmayors.org/pressreleases/uploads/greenjobsreport.pdf.

IEA. 2004. Analysis of the Impact of High Oil Prices on the Global Economy. Available at: http://www.iea.org/textbase/papers/2004/high_oil_prices.pdf#search=%22electricity%20price%20increase%20economic%20output%20impact%22.

Kammen D., K. Kapadia, and M. Fripp. 2004. "Putting Renewables to Work: How many Jobs can the Clean Energy Industry Generate?" Energy Resources Group, Goldman School of Public Policy, University of California, Berkley.

Miller, S., Wei, D., and Rose, A. 2010. *The Macroeconomic Impact of the Michigan Climate Action Council Climate Action Plan on the State's Economy*. Report to Michigan Department of Environmental Quality. http://www.climatestrategies.us/ewebeditpro/items/O25F22416.pdf.

Montgomery, D.C., Peck, E.A., and Vining, G.G. 2005. *Introduction to Linear Regression Analysis*, NJ: Wiley.

Pollin, R. Heintz, J., and Garrett-Peltier, H. 2009. *The Economic Benefits of Investing in Clean Energy*. Report by Department of Economics and Political Economy Research Institute (PERI),University of Massachusetts-Amherst. http://www.peri.umass.edu/economic_benefits/.

Regional Economic Models, Inc. (REMI). 2010. New York State REMI Model.

Rose, A. and Wei, D. 2011. "Macroeconomic Impacts of the Florida Energy and Climate Change Action Plan," *Climate Policy*, forthcoming.

Rose, A., Wei, D., and Dormady, N. 2011. "Regional Macroeconomic Assessment of the Pennsylvania Climate Action Plan", *Regional Science Policy and Practice* 3(4): 357-79.

Wei, D. and Rose, A. 2011. *The Macroeconomic Impact of the New York Climate Action Plan: A Screening Analysis*. Report to New York State Energy Research and Development Authority, forthcoming.

Appendix A. Regression Analysis of the Macroeconomic Impacts of Climate Mitigation Options

The objective of this study is to develop a reduced form statistical model that can be used to quickly predict the macroeconomic impacts of various climate mitigation options. It is based on multivariate analyses of the relationship between macroeconomic impacts and various microeconomic costs, structural linkages and mitigation option characteristics. In this appendix, Section 1 introduces the basic data we used in the regression analysis. The regression models for production and employment impacts are developed in Section 2 and Section 3, respectively.

1. Basic Data

The basic data utilized for this analysis are obtained from a set of macroeconomic analyses sponsored by the Center for Climate Strategies for the states of Florida, Pennsylvania, Michigan, and New York, on a comprehensive set of mitigation options and their critical features, specified in each respective state's Climate Action Plan (Rose and Wei, 2011; Rose et al., 2011; Miller et al., 2010; Wei and Rose, 2011). The data analyzed here are a pooled cross-section of mitigation options and macroeconomic variables. The mitigation options were identified and analyzed by various technical working groups comprised of a broad set of stakeholders in each state. The dependent variable to be explained by the statistical analysis is the Net Present Value (NPV) of Gross State Product (GSP) impacts (in million 2005$) and employment impacts (in thousand person-years) of each individual mitigation option. These impacts are outputs generated by the Regional Economic Model, Inc. Policy Insight Plus (REMI PI$^+$) macroeconometric model, and are shaped by all of the relevant independent variables and their interactions in the macroeconomic modeling (see, e.g., Rose et al., 2011).

Given the diversity of these four states, there is also a great deal of variation in the macroeconomic impacts across the states. For this reason, the data analyzed here are "noisy", and some adjustments must be made in order for the analysis to attain the required inferential asymptotic qualities. The planning horizon for Florida and Michigan is 17 years (from 2009 to 2025). For New York and Pennsylvania, the planning horizons are 20 (from 2011 to 2030) and 12 (from 2009 to 2020) years, respectively. Given the differences in planning horizons, and non-linearities present in the macroeconomic impacts across years (e.g., some policy options may have more long-run benefits, whereas others may have more immediate-term benefits). In the regression model for GSP impacts, our dependent variable considers the GSP impacts on an annualized basis; that is, the NPV of GSP impacts across a planning horizon is divided by the number of years of its planning horizon. In the regression model for employment impacts, annualized employment impact are used. We first compute the total employment impact in terms of person-years of a policy option as the simple sum of each year's employment impacts over the planning horizon. The average employment impact is then computed by dividing the total employment impact by the number of years in each state's planning horizon.

The main explanatory variable is the NPV of the direct net cost of a GHG mitigation option over the entire planning horizon, which is obtained from the respective state climate action plans. Analogous to the dependent variable, the annualized direct net cost is calculated by dividing the NPV of the direct net cost by the number of years in the planning horizon. A positive value indicates that the option has been estimated in a climate action plan to result in a direct net cost, and a negative value indicates that the direct effect of the option will be cost-saving.

The regression model also includes eight binary ("dummy", or "categorical") variables to help explain the option-specific characteristics. The variables "RCI", "AFW", "TLU" and "ES" indicate the sector in which the mitigation policy is implemented Residential, Commercial and Industrial Sector, the Agriculture, Forestry and Waste Management Sector, the Transportation and Land Use Sector, and the Electricity Supply Sector, respectively). "Construction" is a binary variable that indicates whether or not the mitigation option involves a capital investment in construction (e.g., building a new power plant). "Manufacturing" is a binary variable that indicates that the option represents a capital investment in equipment or appliance manufacturing. "Government Subsidy" is a binary variable indicating whether or not the mitigation option receives state government aid. And finally, "Consumption Reallocation" indicates that the mitigation option results in a shift in the composition of consumer expenditures, such as reducing spending on electricity, gas, and other fuels, and increasing consumption in energy-efficient appliances and other consumption categories.

Appendix Table 1 provides the descriptive statistics of all the independent variables in our regression model.

2. Regression Model for GSP Impacts

The functional form of the regression model for the GSP impacts is given by equation 1:

$$y = \beta_1 x * ES + \beta_2 x * RCI + \beta_3 x * TLU + \beta_4 x * AFW + \beta_5 ES + \beta_6 RCI + \beta_7 TLU$$

$$+\beta_8 AFW + \beta_9 CONST + \beta_{10} MFG + \beta_{11} GS + \beta_{12} CR$$

(1)

where

y:	Annualized NPV of the GSP impacts of a policy option
x:	Annualized NPV of the direct net cost of a policy option
ES:	Energy Supply policy option
RCI:	Residential, Commercial, Industrial policy option
TLU:	Transportation and Land Use policy option
AFW:	Agriculture, Forestry, and Waste Management policy option
CONST:	Capital investment on building constructions, which has stimulus impacts to the local construction sector

MFG: Capital investment on equipment, which has stimulus impacts to the machinery and equipment manufacturing sectors

GS: Policy option that receives state government subsidy (assuming government spending decreases by the same amount elsewhere)

CR: Policy option that results in consumer consumption reallocation and increased purchasing power of the consumers

We suppress the intercept term in our model. This is warranted on theoretical grounds, due to the fact that the absence of a policy change would represent no additional change in the Gross State Product of a state or regional economy. This also enables us to explicitly display the effects of our four binary sectoral variables (inclusion of the intercept would force us to exclude a sectoral reference categories. Our analysis assumes the extant economy is in equilibrium. To account for potential heteroskedasticity, we used the robust Huber-White standard error in the inference.

Appendix Table 1. Descriptive Statistics

	Mean	**Standard Deviation**	**Minimum Value**	**Maximum Value**
D.V.: Annual Gross State Product Impact (y)(in Models 1 and 2)	-23.30	194.39	-886.00	532.74
D.V.: Annual Employment Impact (y)(in Models 3 and 4)	2.20	4.81	-5.57	22.59
Direct Net Cost (x)	60.13	165.53	-279.12	1,075.39
$x \times TLU$	-15.06	150.40	-886.00	532.74
$x \times ES$	-0.21	65.55	-528.23	259.59
$x \times RCI$	-22.41	81.99	-488.34	79.46
$x \times AFW$	14.39	61.23	-30.39	423.38
TLU	0.24	0.43	0	1
ES	0.17	0.38	0	1
RCI	0.24	0.43	0	1
AFW	0.35	0.48	0	1
CONST	0.38	0.49	0	1
MFG	0.57	0.50	0	1
GS	0.22	0.41	0	1
CR	0.35	0.48	0	1

Appendix Tables 2 and 3 provide the results of our multivariate statistical analysis. We ran both a reduced form model (Model 1) and an extended model (Model 2), which includes interaction terms to evaluate the individual sectoral impacts of the direct net costs associated with GHG mitigation work plans. Our assumption that the regression coefficient for each sector is statistically distinct from the aggregate is affirmed in the results below.

Appendix Table 2. Regression with Robust Standard Error -- Results of Model 1

	Estimate	Robust Std. Error	t value	Pr(>|t|)
Direct Net Cost (x)	-0.4460	0.1565	-2.850	0.006***
TLU	-34.6979	31.1626	-1.113	0.269
ES	4.4071	41.9376	0.105	0.917
RCI	15.0399	41.6208	0.361	0.719
AFW	1.9431	19.5526	0.099	0.921
CONST	45.2208	31.6471	1.429	0.157
MFG	47.5961	24.1839	1.968	0.052**
GS	37.5745	37.5379	1.001	0.320
CR	2.0831	34.4348	0.060	0.952

*p<0.1, ** p<0.05, *** p<0.01
N=92; R^2 (0.3771); F-statistic (5.584); Overall Model P-value: 0.0000

Appendix Table 3. Robust Standard Error Regression Results of Model 2

	Estimate	Robust Std. Error	t value	Pr(>|t|)
$x \times TLU$	-0.2701	0.0713	-3.789	0.000***
$x \times ES$	-1.4735	0.3489	-4.223	0.000***
$x \times RCI$	-0.4212	0.1839	-2.291	0.025**
$x \times AFW$	-0.3154	0.1995	-1.581	0.118
TLU	-42.8740	27.1733	-1.578	0.119
ES	-9.7424	33.9657	-0.287	0.775
RCI	1.3397	42.0114	0.032	0.975
AFW	-18.8966	23.1223	-0.817	0.416
CONST	49.2232	26.7376	1.841	0.069*
MFG	57.0694	26.2910	2.171	0.033**
GS	60.7348	45.3140	1.340	0.184
CR	13.9717	31.0767	0.450	0.654

*p<0.1, ** p<0.05, *** p<0.01
N=92; R^2 (0.5438); F-statistic (7.946); Overall Model P-value: 0.000

Comparatively speaking, Model 2 has a more robust summary measure, as indicated by a multiple correlation coefficient (R-squared) value of about 0.54. This indicates that Model 2 explain about 54 percent of the variance in macroeconomic impact in terms of GSP across our pooled sample. In addition, both models have relatively robust fitness measures, as indicated by the F-statistic, reflecting that our models have included a proper set of explanatory variables.

Model 1 indicates that the direct cost assessments provide a significant determinant of the overall macroeconomic impacts on GSP. According to the results of Model 1, holding the other variables constant at their means, when the annualized direct net cost of an average mitigation option is decreased by one million dollars, the annualized GSP impact is expected to increase by about $0.45 million.

In terms of a sectoral decomposition of the direct cost effects, the coefficients of the interaction terms of direct net cost with the four sector dummies are all negative, which indicate that options with higher direct net cost are expected to result in less favorable GSP impacts. All of the interaction terms are statistically significant in Model 2, except for x*AFW. According to Model 2, holding the non-sectoral binary variables constant at their means, one million dollars decrease in direct net cost of an average mitigation option in the TLU, ES, and RCI sector is expected to increase the annualized GSP impact by $0.27, $1.47, and $0.42 million, respectively.

The sectoral binary variables lack statistical significance across the board in both Model 1 and Model 2, however. It is important to control for differences in each sector's mitigation option, but our models show there to be no statistically significant difference between sectors throughout our pooled sample. That is, one sector may include greater or fewer numbers of cost-incurring or cost-saving options than another, but, across the larger sample, their impact has no statistically discernable difference.

The coefficient estimate of the variable pertaining to the capital investment to the construction sector is positive and significant. This means those mitigation options that involve a capital investment expenditure in the construction sector (e.g., investment in building plants or highways) have an overall positive impact on a state's macroeconomy. According to Model 2, holding all the other variables fixed at their mean values, if a mitigation option involves capital investment in construction, the overall impact on the annualized GSP is expected to be an increase of $49 million. Simulating construction capital investment increase in REMI involves two aspects: 1) an increase of the capital cost of the sectors that take the mitigation actions, and 2) an increase of the final demand of the construction sector. In general, the former yields negative impacts to the economy, and the latter yields positive impacts. The positive sign of the construction investment binary variable indicates that the positive effects are expected to exceed the negative effects in the three states.

The coefficient estimate of the variable pertaining to the capital investment to the equipment manufacturing sector is positive and significant as well. This means those mitigation options that involve investments in manufactured equipment also have a strong positive influence on a state's overall macroeconomy. According to Model 2, holding all the other variables fixed, if a mitigation option involves capital investment in equipment and machinery (e.g., energy-efficient appliances, vehicles, equipment, and etc.), the overall impact on the annualized GSP is expected to be an increase of $57 million.

Those options that include subsidies from a state government have an overall positive, but insignificant effect on GSP. In REMI, the state government subsidy is simulated in two aspects. The stimulus effects come from the increased spending of households or increased investment in sectors that receive the government subsidy, while the dampening effects stem from the decrease of the same amount of government spending elsewhere. The positive sign of this variable indicates that, in the four states, it is expected that the stimulus effects of directing government subsidies to mitigation options in general can more than offset the dampening effects associated with the decreased government spending in other areas.

Mitigation options that include consumption reallocation have only a minimal influence on a state's GSP, on the average. Whereas some mitigation options that include a consumption reallocation have overall positive effects on a state's GSP and others have overall negative effects, according to Model 2, the average mitigation option that includes a consumption reallocation has a $14 million greater positive effect on GSP. However, again, this relationship is not statistically significant.

3. Regression Model for Employment Impacts

We also developed similar regression models as shown in equation 1 for employment impacts. The dependent variable in this case is the annualized employment impact over the entire planning horizon in terms of person-years. All the independent variables we included in the employment impact regression models are the same as the corresponding GSP impact regression models.

Appendix Tables 4 and 5 provide the results of the regression analysis for the employment impacts. Similar to the GSP impact, we ran both a reduced form model (Model 3) and an extended model (Model 4). The former model includes one independent variable pertaining to the direct net costs associated with the implementation of the GHG mitigation options, while in the latter model we include interaction terms to evaluate the individual sectoral impacts of the direct net costs associated with the options implemented in the respective sector. Comparatively speaking, Model 4 has a relatively more robust summary measure, as indicated by a multiple correlation coefficient (R-squared) value of about 0.35.

Appendix Table 4. Robust Standard Error Regression Results of Model 3

	Estimate	Robust Std. Error	t value	Pr(>|t|)
Direct Net Cost (x)	-0.0054	0.0023	-2.315	0.023 **
TLU	-1.9905	0.7516	-2.648	0.010 **
ES	0.5842	1.5109	0.387	0.700
RCI	-0.3866	1.0207	-0.379	0.706
AFW	0.0201	0.6118	0.033	0.974

	Estimate	Robust Std. Error	t value	Pr(>|t|)
CONST	1.9655	0.7757	2.534	0.013 **
MFG	1.4389	0.5828	2.469	0.016 **
GS	2.2271	1.2771	1.744	0.085 *
CR	1.3983	0.9538	1.466	0.146

*p<0.1, ** p<0.05, *** p<0.01
N=92; R^2 (0.2884); F-statistic (3.738); p-value: 0.0006

Appendix Table 5. Robust Standard Error Regression Results of Model 4

	Estimate	Robust Std. Error	t value	Pr(>|t|)
$x \times TLU$	-0.0046	0.0020	-2.287	0.025 **
$x \times ES$	-0.0140	0.0088	-1.584	0.117
$x \times RCI$	-0.0138	0.0052	-2.660	0.009 ***
$x \times AFW$	0.0116	0.0049	2.378	0.020 **
TLU	-1.0923	0.7427	-1.471	0.145
ES	1.1357	1.6030	0.708	0.481
RCI	-0.3506	1.0832	-0.324	0.747
AFW	-0.0797	0.5657	-0.141	0.888
CONST	1.8631	0.7631	2.441	0.017 **
MFG	0.9485	0.6073	1.562	0.122
GS	1.5274	1.1260	1.356	0.179
CR	0.7092	0.9308	0.762	0.448

*p<0.1, ** p<0.05, *** p<0.01
N=92; R^2 (0.3417); F-statistic (3.461); p-value: 0.0004

The direct net cost of an option provides a significant determinant of the overall employment impact of this option. According to the results of Model 3, holding all the other variables constant at their means, when the annualized direct net cost of an average mitigation option is decreased by one million dollars, the annualized employment impact increases by about 5.4 person-years.

Model 4, which includes the interaction terms of direct net cost and sectoral dummies, provides a sectoral decomposition of the effects stemming from the change in direct net cost. The coefficient estimates show that the most statistically-significant variation across the direct cost variable is driven by the TLU, RCI and AFW sectors. In contrast to the coefficients of the interaction terms for the other sectors, the sign of the coefficient of x*AFW (the interaction terms of the direct net cost and AFW) is positive. This means that an increase in the direct net cost of an AFW option is expected to result in increased employment gains. This can be explained by the fact that the investment of many AFW options, especially the Forestry options, stimulates economic activities in relatively labor-intensive sectors, such as Forestry, Farm, Support Activities for Agriculture and Forestry. For example, according to the baseline forecast in the National Standard Control module in the REMI Model, the labor intensity of the Support Activities for Agriculture and Forestry sector is 53.3 jobs per $1 million of output, compared with the economy-wide employment intensity of 5.86.

The sectoral binary variables again lack statistical significance in both models. That means, across our sample, the sectoral impact has no statistically discernable difference.

The coefficient estimate of the variable pertaining to the capital investment to the construction sector is positive and significant in both models. This means holding all the other variables constant at their means, those mitigation options that involve a capital investment expenditure in the construction sector are expected to result in more employment gains. The coefficient of the binary variable pertaining to the capital investment in equipment is also positive (but is only significant in Model 3), which means those mitigation options that involve investments in equipment are also expected to lead to a stronger positive effect on job creations. The higher value of the coefficient of CONST (the construction sector investment binary variable) than the coefficient of MFG (the equipment manufacturing sector investment binary variable) stems from two reasons. First, in most states, the construction sector has a higher Regional Purchase Coefficient (RPC) than the equipment manufacturing sector. This indicates that dollar for dollar, capital investments in the construction sector are more stimulating to the in-state job market than investments in equipment manufacturing, whose demand is satisfied by a greater proportion of imports. Second, compared with the equipment manufacturing sectors, the construction sector is relatively more labor-intensive.

The coefficient of the binary variable pertaining to the state government subsidy is positive. However, this variable is not statistically significant. The positive sign means that those options that include subsidies from a state government have an overall positive, but insignificant, effect on employment.

The coefficient of the binary variable pertaining to consumption reallocation is positive, which indicates that mitigation options that include consumption reallocation are likely to have a positive impact on a state's employment. However, this variable is again not statistically significant.