SECTION THREE

» Macroeconomic Effects of Mitigation Options: REMI Model Analysis

I. Introduction

Since 2000, 34 U.S. states have completed or are developing Greenhouse Gas (GHG) reduction plans that evaluate and recommend specific policy options to achieve climate change stabilization targets and other important policy objectives including economic, energy and environmental security. The major focus has typically been on the direct, or on-site, impacts (such as cost-effectiveness or microeconomic analysis) of individual mitigation options and aggregate portfolios of actions (see section 2). However, the political needs of implementation also typically require assessment of indirect effects, including macroeconomic impacts, and in some cases detailed distributional impacts.

The importance of indirect and distributional impacts are clear to policy makers. For instance, some policy options can result in cost-savings directly to those who implement them as well as gains to their customers if the savings are passed on in the form of lower prices. However, these gains may come at the cost of others who provide investment outlays or suffer reduced sales of energy. Some policy options will incur additional costs to businesses, households, nonprofit institutions, and government operations, and the likely cutback in economic activity will also affect their suppliers. The 23 climate mitigation policy option results presented in Section 2 reflect the net direct costs or savings associated with their implementation, but they do not 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. 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 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 services 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.

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) Policy Insight Plus (PI+) modeling software to be discussed below (REMI, 2009) to evaluate the macroeconomic impacts to the U.S. of implementing the 23 GHG mitigation super options across the states. The REMI model is the most widely used economic modeling software package in the U.S. and has been heavily peer reviewed. The 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.

In order to perform macroeconomic impact analysis of climate action plans using REMI, information is needed on basic microeconomic considerations, such as the direct costs and direct savings of each GHG mitigation option, as well as on aspects that relate to macro linkages. The results reported in the state action plans include GHG reduction potentials, net cost/savings in Net Present Value (NPV), and cost-effectiveness (per ton cost/saving of GHG removed). The macro study needs more detailed and disaggregated information on both the costs and savings aspects. For example, program costs need to be disaggregated into capital cost, operation and maintenance (O&M) cost, and fuel cost; energy savings need to be specified in different types of energy and for specific economic sectors. In addition, all these data are needed for individual years in the study period (2010-2020).

This level of detailed information may not always be reported in the state action plans for each option. Therefore, it was necessary to obtain the calculation workbooks used to quantify the policy options, and to extract the data needed by the REMI analysis from the workbooks. Because of the time limitation of this study, our study focused our data collection for macroeconomic linkage variables on seven states (Colorado, Florida, Iowa, Michigan, North Carolina, Pennsylvania, and Washington) that we believe are representatives of national diversity, and used the weighted average costs and savings of each individual super option to get the scaled-up estimates at the national level. Please refer to the separate document Annex D* for a summary of the methodology used in the scale-up estimation.

This report is structured as follows: Subsection II describes the 3 modeling scenarios analyzed, Subsection III is an overview of the REMI model (see greater detail in Annex C*), Subsection IV reviews how the data from the climate plan was used in the REMI analysis, Subsection V reviews the setup of the REMI simulation, Subsection VI presents the REMI results for Scenario 1, Subsection VII summarizes the major features of the Kerry-Lieberman Senate bill, and Subsection VIII presents the analyses of two hybrid scenarios of the Kerry-Lieberman bill and the Stakeholder recommended policies and measures.

II. Three Modeling Scenarios

The purpose of this section is to estimate the macroeconomic impacts of three scenarios representing different applications of stakeholder recommended policies and measures, including recent climate change legislation in the form of the U.S. Senate bill sponsored by Senators Kerry and Lieberman. The impacts are expressed in terms of major macroeconomic indicators – output, employment, and income—for the economy as a whole and for each of 169 sectors of the economy, for all years in the study period under Scenario 1 (2010-2020) and the year 2020 under Scenarios 2 and 3.

For Scenarios 2 and 3 we identify the major features of the Senate bill relating to the emission cap, sectors covered by cap and trade and other major policy instruments, the allocation of allowances, and the potential to use offsets from domestic and international sources, and the government spending ("recycling") of allowance auction revenue.

Scenario 1. Stakeholder Scenario

This case assumes the full implementation of all 23 mitigation options described and presented in Section 2. It assumes that all measures described in Annex B* are implemented in all 50 states using the national scale-up methodology described in Annex A.*

Scenario 2. Stakeholder/Senate Scenario

This case assumes full implementation of the 23 measures in all 50 states, but it also includes the application of a limited federal cap-and-trade program as contemplated in the Kerry-Lieberman (K-L) bill and described in detail in Annex F.*

* The Annexes to this report are available at energypolicyreport.jhu.edu.

Scenario 3. Senate Scenario

In this simulation case we model the major features of the K-L bill, including cap-and-trade, using the 23 super option measures as in Scenario 2, except in this case we limit the GHG reduction benefits to precisely match the national reduction goal stated in the legislation.

III. REMI Model Analysis

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 (see, e.g., Rose and Miernyk, 1989; Partridge and Rickman, 1998).[1]

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 the REMI PI+ model. The REMI model is superior to the other reviewed in terms of its forecasting ability1 and is comparable to CGE models in terms of analytical power and accuracy. 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 software program, but is built with a combination of national and region-specific data. 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 detailed discussion of the major features of the REMI PI+ model is presented in Annex C.* We simply provide a summary for general readers here. 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 somewhat in that it includes some key relationships, such as exports, in a bottom-up approach. In fact, it makes use of the finely grained sectoring detail of an I-O model, i.e., in the version we used it divides the economy into 169 sectors, thereby allowing important differentials between them. This is especially important in a context of analyzing the impacts of GHG mitigation actions, where various options 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 PI+ 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 pooled time series and regional (panel) data across all states of the U.S. (the other candidate models use "calibration," based on a single year's data).[2] This gives the REMI PI+ model an additional capability of being better able to extrapolate[3] the future course of the economy, a capability the other models lack. The major limitation of the REMI PI+ 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,

1. Statistically estimated time series models are best suited to forecasting, but were not among the candidates considered here because our emphasis was on policy analysis.
2. REMI is the only one of the models reviewed that really addresses the fact that many impacts take time to materialize and that the size of impacts changes over time as prices and wages adjust. In short, it better incorporates the actual dynamics of the economy.
3. The model can be used alone for forecasting with some caveats, or used in conjunction with other forecast "drivers."

can more readily accommodate data changes in technology that might be inferred, for example from engineering data. However, our assessment of the REMI PI+ model is that these adjustments were not needed for the purpose at hand.

The use of the REMI PI+ 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 GHG mitigation options. Again, this includes the direct effects in the sectors in which the options 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 these policy options.

IV. Input Data

1. REMI PI+ Model Input Development

The quantification analysis of the costs/savings undertaken by the state stakeholder processes and the updates performed for this study by the sectoral analysts were limited to the direct effects of implementing the options. For example, the direct costs of an energy efficiency option include the ratepayers' payment for the program and the energy customers' expenditure on energy efficiency equipments and devices. The direct benefits of this option include the savings on energy bills of the customers.

As described in Section 2, these state level microeconomic analyses have been scaled up to the national level. To supplement the microeconomic analysis the REMI PI+ model was selected to evaluate macroeconomic impacts (such as gross domestic output, employment, and personal income) of every major option (the super options) that had been identified by various states. The U.S. two-region REMI PI+ model used in this study is based on panel data through 2007.[4] In addition, we chose the larger 169-sector U.S. 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 various GHG mitigation policy options because the former combines electricity, gas and water into a single Utilities sector, while the latter separates the three activities into individual sectors.

Before undertaking any economic simulations, the costs and savings for each policy option are translated to model inputs that can be utilized in the model. This step involves the selection of appropriate policy levers in the REMI PI+ model to simulate the policy's changes. The input data include sectoral spending and savings over the full time horizon (2010-2020) of the analysis. In Tables 2-5, we choose one example option from each of the Residential, Commercial and Industrial (RCI), Energy Supply (ES), Agriculture, Forestry and Waste Management (AFW), and Transportation and Land Use (TLU) sectors to illustrate how we translate, or map, the TWG results into REMI PI+ economic variable inputs.

Using RCI-1 Demand Side Management (DSM) as an example, the first set of inputs in Table 3-1 is the increased cost to the Commercial, Industrial, and Residential sectors due to the purchases of energy efficient equipment and appliances. For the Commercial and Industrial sectors, this is simulated in REMI by increasing the value of the "Capital Cost" variable of individual Commercial sectors and individual Industrial sectors under the "Compensation, Prices, and Costs Block." For the Residential sector, the program costs (which represent total incremental costs of new equipment over conventional equipment) are simulated by increasing the "Consumer Spending" on "Kitchen & Other Household Appliances" (and decreasing all the other consumptions correspondingly). The "Consumer Spending (amount)" and "Consumption Reallocation (amount)" variables can be found in the "Output and Demand Block" in the REMI model.

4. The REMI model construction methodology is typically applied at the regional level, with at least a two-region set-up (the target region and the rest of the U.S.). Even the national model must be constructed in this manner. In this study, the two regions are Esmeralda County, NV and the rest of U.S. Given the low population (less than 700) and small economy size (less than 14 million GDP) of Esmeralda County, there is negligible inaccuracy in treating the second region (the rest of U.S.) as the entire country. One difference in this "single entity" approximation is that there is no interregional migration effect.

The second set of inputs are the corresponding stimulus effect to the economy of the spending on efficient equipment and appliances, i.e., the increase in the final demand for goods and services from the industries that supply energy efficient equipment and appliances. This is simulated in REMI by increasing the "Exogenous Final Demand" (in the "Output and Demand Block") of the following sectors: Ventilation, Heating, Air-conditioning, and Commercial Refrigeration Equipment Manufacturing sector; Electric Lighting Equipment Manufacturing sector; Electrical Equipment Manufacturing sector; and Other Electrical Equipment and Component Manufacturing sector. The interest payment due to the financing of the capital investment is simulated as the "Exogenous Final Demand" increase of the Monetary Authorities, Credit Intermediation sector.[5] The administrative cost of the DSM program is simulated as the "Exogenous Final Demand" increase of the Management, Scientific, and Technical Consulting Services sector.

Table 3-1. Mapping the Direct Economic Impacts of RCI-1 Demand Side Management into REMI Variables

Direct Economic Impacts		Policy Variable Selection in REMI
Customer Outlay on Energy Efficiency (EE)	Businesses (Commercial and Industrial Sectors)	Compensation, Prices, and Costs Block →Capital Cost (amount) of individual commercial sectors → Increase
	Households (Residential Sector)	Output and Demand Block → Consumer Spending (amount) → Kitchen & other household appliances[a] → Increase Output and Demand Block → Consumer Spending (amount) → Bank Service Charges → Increase Output and Demand Block →Consumption Reallocation (amount) → All Consumption Sectors →Decrease
Investment in EE Technologies		Output and Demand Block → Exogenous Final Demand (amount) for Ventilation, Heating, Air-conditioning, and Commercial Refrigeration Equipment Manufacturing sector; Electric Lighting Equipment Manufacturing sector; Electrical Equipment Manufacturing sector; and Other Electrical Equipment and Component Manufacturing sector → Increase
Interest Payment of Financing Capital Investment		Output and Demand Block → Exogenous Final Demand (amount) for Monetary Authorities, Credit Intermediation sector→Increase
Administrative Outlays		Output and Demand Block → Exogenous Final Demand (amount) for Management, Scientific, and Technical Consulting Services sector → Increase
Energy Savings of the Customers	Businesses (Commercial and Industrial Sectors)	Compensation, Prices, and Costs Block → Electricity, Natural Gas, and Residual (Commercial Sectors) Fuel Cost (share) of All Commercial Sectors → Decrease Compensation, Prices, and Costs Block→ Electricity, Natural Gas, and Residual (Industrial Sectors) Fuel Cost (share) of All Industrial Sectors→ Decrease
	Households (Residential Sector)	Output and Demand Block → Consumer Spending (amount) → Electricity, Gas, and Fuel Oil → Decrease Output and Demand Block → Consumption Reallocation (amount) → All Consumption Sectors → Increase
Energy Demand Decrease from the Energy Supply Sectors[b]		Output and Demand Block → Exogenous Final Demand (amount) for Electric Power Generation, Transmission, and Distribution sector; Natural Gas Distribution sector; and Petroleum and Coal Products Manufacturing sector → Decrease

a. Since there is no specific consumer expenditure category for furnaces, it is included in the investment in EE technologies in the row below. Home insulation and sealing services and other associated measures are included in the simulations of RCI-2 High Performance Buildings and RCI-4 Building Codes policy options.
b. The final demand change here only reflects the energy consumption reductions from the Commercial and Industrial sectors; Residential sector reductions are entered in the model's "Consumer Spending" variable.

5. The opportunity cost of the interest payment is included in the increase of the "Capital Cost" variable for the Commercial and Industrial sectors (row 1 in Table 3-1). As for the Residential sector, it is reflected in the reduction in consumption of all other commodities (i.e., this is reflected in a decrease in the "Consumption Reallocation" variable shown in row 2 in Table 3-1).

Table 3-2. Mapping the Direct Economic Impacts of ES-1 Renewable Portfolio Standard into REMI Variables

Direct Economic Impacts	Policy Variable Selection in REMI
Incremental Capital Cost of Electricity Generation (Renewable minus Avoided Traditional)	Compensation, Prices, and Costs Block → Capital Cost (amount) of Electric Power Generation, Transmission, and Distribution sectors→Increase
Incremental O&M Cost of Electricity Generation (Renewable minus Avoided Traditional)	Compensation, Prices, and Costs Block → Production Cost (amount) of Electric Power Generation, Transmission, and Distribution sectors→Increase
Reduction on Fuel Cost of Electricity Generation	Compensation, Prices, and Costs Block → Production Cost (amount) of Electric Power Generation, Transmission, and Distribution sectors→Decrease
Incremental Investment in Generation Technologies (Renewable minus Avoided Traditional)	Output and Demand Block → Exogenous Final Demand (amount) for Construction sector → Increase Output and Demand Block → Exogenous Final Demand (amount) for Engine, Turbine, and Power Transmission Equipment Manufacturing sector → Increase
Interest Payment of Financing Capital Investment	Output and Demand Block → Exogenous Final Demand (amount) for Monetary Authorities, Credit Intermediation sector → Increase
Renewable (Biomass) Fuel Inputs	Output and Demand Block → Exogenous Final Demand (amount) for Waste Collection; Waste Treatment and Disposal and Waste Management Services sector and Forestry sector → Increase
Fossil Fuel Savings	Output and Demand Block → Exogenous Final Demand (amount) for Coal Mining sector, Oil and Gas Extraction sector, and Pipeline Transportation sector → Decrease[a]
Tax Credits to Renewable Electricity Generation	Output and Demand Block → State Government spending (amount) → Decrease

a Assume the displaced electricity generations are 50% coal-fired electricity and 50% NG-fired electricity.

Table 3-3. Mapping the Direct Economic Impacts of AFW-5 Urban Forestry into REMI Variables

Direct Economic Impacts		Policy Variable Selection in REMI
Spending Stimulation		Output and Demand Block → Exogenous Final Demand (amount) for Forestry; Fishing, Hunting and Trapping sector and Support Activities for Agriculture and Forestry sector → Increase
Cost of Urban Forestry		Output and Demand Block → Local Government spending (amount) → Decrease[a]
Energy Savings (reduction in electricity consumption)	Commercial Sectors	Compensation, Prices, and Costs Block → Electricity (Commercial Sectors) Fuel Cost (amount) of All Commercial Sectors → Decrease[b]
	Households (Residential Sector)	Output and Demand Block → Consumer Spending (amount) → Electricity → Decrease[b] Output and Demand Block → Consumption Reallocation (amount) →All Consumption Categories → Increase
	Government	Output and Demand Block → Local Government spending (amount) → Decrease[b]
Electricity Demand Decrease from the Utility Sector[c]		Output and Demand Block → Exogenous Final Demand (amount) for Electric Power Generation, Transmission, and Distribution sector → Decrease

a It is assumed that all the costs of urban forestry program will be borne by the local government. Accordingly, we assume the local government spending elsewhere will be reduced by the same amount of spending on the urban forestry program.
b It is assumed that energy savings resulted from shading of structures will be split between the Commercial sector, Residential sector, and Government by 40%, 40%, and 20%.
c The final demand change here only reflects the energy consumption reductions from the Commercial and Industrial sectors. The Residential sector energy consumption reductions will be entered into the model through the "Consumer Spending" variable.

Table 3-4. Mapping the Direct Economic Impacts of TLU-6 Mode Shift from Truck to Rail into REMI Variables

Direct Economic Impacts	Policy Variable Selection in REMI
Cost of Additional Terminal and Track Upgrades	Compensation, Prices, and Costs Block → Capital Cost of Rail Transportation sector → Increase
Investment to Improve Rail Transportation System	Output and Demand Block →Exogenous Final Demand (amount) for Construction sector → Increase
Interest Payment of Financing Capital Investment	Output and Demand Block → Exogenous Final Demand (amount) for Monetary Authorities, Credit Intermediation sector → Increase
Fuel Savings	Compensation, Prices, and Costs Block → Residual Fuel Cost[a] for Truck Transportation sector → Decrease Compensation, Prices, and Costs Block → Residual Fuel Cost (amount) of All Commercial and Industrial sectors →Decrease
Fuel Demand Decrease of Fuel	Output and Demand Block → Exogenous Final Demand (amount) for Petroleum and Coal Products Manufacturing sector →Decrease

a In the REMI model, residual fuel includes all energy fuels other than electricity and natural gas.

The third set of inputs to REMI presents the energy savings of the Commercial, Industrial, and Residential sectors resulting from the DSM program. For the Commercial and Industrial sectors, the energy savings are simulated in REMI by decreasing the value of the "Electricity/Natural Gas/ Residual Fuel Cost of All Commercial/Industrial Sectors" variables. These variables can be found in the "Compensation, Prices, and Costs Block." For the Residential sector, the energy savings are simulated by decreasing the "Consumer Spending" on "Electricity," "Gas" and "Fuel Oil" (and increasing all the other consumption categories correspondingly). Again, the "Consumer Spending (amount)" and "Consumption Reallocation (amount)" variables can be found in the "Output and Demand Block" in the REMI model.

The last set of inputs are the corresponding damping effects to the Energy Supply sector due to the decrease in the demand from the customer sectors. These effects are simulated by reducing the "Exogenous Final Demand" of the Electric Power Generation, Transmission, and Distribution sector, Natural Gas Distribution sector, and Petroleum and Coal Products Manufacturing sector in REMI.[6] In this step, the final demand change is only modeled for the non-residential sectors, i.e., only the decreased demand from the Commercial and Industrial sectors need to be manually entered into the model as final demand change for the energy supply sectors. For the Residential sector, the model will internally convert the change in the Consumer Spending (amount) policy variable into changes in final demand for the corresponding sectors.

2. Modeling Assumptions

The major data sources of the analysis are the scaled-up quantification results on costs and savings of various mitigation policy options. 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 options are not specified in the micro analysis or are not known with certainty. Below is the list of major assumptions we adopted in the analysis:

1. In the base case analysis, for all the policy options that involve capital investment, we simulated a stimulus from only 50% of the capital investment requirements. This is based on the assumption that 50% of the incremental investment in new equipment will simply displace other investment in the state.

6. The values of energy demand reductions are scaled up from the state level estimates of energy consumption changes in different customer sectors due to the implementation of various mitigation options. They are not derived from the REMI model runs, instead they are exogenously computed and fed into the REMI model as simulation inputs.

2. 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).

3. For the RCI options, the energy consumers' participant costs of energy efficiency programs are computed for the Residential, Commercial, and/or Industrial sectors by the state level technical working groups (TWGs). For the Commercial and Industrial sectors, the TWGs' analyses only provide the aggregated costs for the entire Commercial sector and the entire Industrial sector. Since in the REMI model capital cost and production cost variables can only be simulated for individual Commercial sectors or Industrial sectors, we distributed these costs among the 169 REMI sectors based on the national input-output data provided in the REMI model in relation to the delivery of utility services to individual sectors.

4. The interest payment and the administrative cost are split out from the levelized cost using the following assumptions:
   a. For the RCI options, it is assumed that 50% of the RCI costs will be covered by private-sector financing and 50% will be covered by the utility expenditures, such as those supported by public benefit charges. The administrative costs are assumed to account for 10% of the 50% utility portion of the capital costs.
   b. For the ES, AFW, and TLU options that involve capital investment, we assume 100% of the total costs will be covered by financing.

5. For the Combined Heat and Power option, the total costs of installing the CHP systems are only available for the Commercial and Industrial sectors as a whole from the micro analysis. We used the energy consumption data by sector as the basis to distribute the costs among the REMI sectors.

6. For the Restoration/Afforestation option, it is assumed that the costs are borne by the private sector (farmers). The potential future cost savings from forest products (e.g., merchantable timber or bioenergy feedstocks) are not taken into account, since these cost savings would most likely not be realized during the period of this analysis.

7. For the Urban Forestry option, it is assumed that all the costs will be borne by the local government. It is also assumed that increasing the government spending in the urban forestry program will be offset by a decrease in the same amount of government spending on other goods and services. The energy savings breakout is 20% Government, 40% Commercial sector, and 40% Residential sector.

8. For the TLU options related to fuel cost changes for heavy duty trucks, we distribute 45% of the fuel savings (or cost increase) to the Truck Transportation sector based on the Vehicle Inventory and Use Survey data that about 45% of the miles accumulated by heavy trucks are for the "For-Hire" transportation and 55% are for the "Own Account Transportation" (U.S. Census Bureau, 2002). Further, the 55% of the fuel savings (or cost increase) are distributed across sectors other than the Truck Transportation sector in the economy in proportion to the petroleum inputs for each sector.

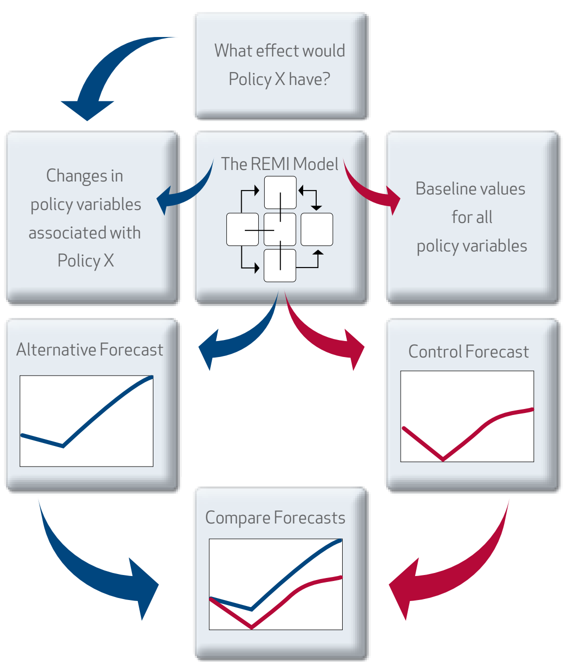
9. For the RPS option and the nuclear power option, we assume that the displaced electricity generation from fossil fuels is split half and half between coal-fired electricity and gas-fired electricity. This assumption is based on the fact that in Iowa and Pennsylvania, all displaced electricity is assumed to be coal, in Florida and Arkansas, it is assumed to be all gas, while in other CCS-facilitated states, the displacement is a mix of the two.

V. Simulation Set-up in REMI

Figure 3-1 shows how a policy simulation process is undertaken in the REMI PI+ model. First, a policy question is formulated (such as what would be the economic impacts of implementing the Demand Side Management Programs). Second, external policy variables that would embody the effects of the policy are identified (take DSM 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 electricity, natural gas, etc.). Third, baseline values for all the policy variables are used to generate the control forecast (baseline forecast). In REMI PI+, the baseline forecast uses the most recent data available (i.e., 2007 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 option, the costs to the Commercial and Residential sectors and the avoided consumption of energy were based on the scale-up of the technical assessment of implementing this mitigation option in the CCS facilitated states. 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 ran the REMI PI+ model for each of the 23 super options individually in a comparative static manner, i.e., one at a time, holding everything else constant. Next, we ran a simultaneous simulation in which we assume that all the super options are implemented together.

Figure 3-1. Process of Policy Simulation in REMI



REMI = Regional Economic Models, Inc.

Then the simple summation of the effects of individual options was 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 PI+ model.

Before performing the simulations in REMI PI+, overlaps between options within the same sector and across different sectors were eliminated.

VI. Presentation of the Results – Scenario 1- Stakeholder Recommendations

1. Basic Results

The results of the macroeconomic simulation of Scenario 1, the stakeholder recommendations without cap-and-trade or other features of proposed legislation are presented here. Following a discussion of the Kerry-Lieberman bill in Subsection VII, the results of the 2 scenarios involving provisions of the K-L bill are presented in Subsection VIII.

A summary of the basic results of the application of the REMI PI+ model to determine the macroeconomic impacts of the individual mitigation super options analyzed in this study is presented in Tables 3-5 and 3-6. Table 3-5 includes the GDP impacts for each super option for three selected years, as well as a net present value (NPV) calculation for the entire period of 2010 to 2020. Table 3-6 presents analogous results for employment impacts, though, for reasons noted below, an NPV calculation of employment impacts is not appropriate.

Table 3-5. Gross Domestic Product Impacts of the 23 GHG Mitigation Policy Options (billions of fixed 2007 dollars)

Policy Options	2010	2012	2015	2020	NPV
ES-1 Renewable Portfolio Standard	–$0.25	–$2.27	–$5.32	–$5.35	–$35.52
ES-2 Nuclear	$0.00	–$0.07	–$0.46	–$6.85	–$8.14
ES-3 Carbon Capture and Storage or Reuse (CCSR)	$0.00	$0.00	–$2.80	–$4.47	–$16.57
ES-4 Coal Plant Efficiency Improvements	$0.01	$0.02	$0.04	$0.48	$0.86
Subtotal – Energy Supply (ES)	**–$0.24**	**–$2.32**	**–$8.57**	**–$16.19**	**–$59.38**
RCI-1 Demand Side Management Programs	$4.82	$16.17	$36.19	$90.05	$305.05
RCI-2 High Performance Buildings	$0.84	$1.73	$4.72	$12.12	$40.14
RCI-3 Appliance standards	$0.02	–$0.04	–$0.12	$0.05	–$0.43
RCI-4 Building Codes	$0.89	$2.68	$6.06	$13.65	$49.05
RCI-5 Combined Heat and Power	–$3.79	–$8.57	–$14.08	–$21.17	–$104.38
Subtotal – Residential Commercial and Industrial (RCI)	**$2.79**	**$11.99**	**$32.77**	**$94.68**	**$289.44**
AFW-1 Crop Production Practices	$0.08	$1.05	$2.28	$4.55	$17.50
AFW-2 Livestock Manure	–$0.01	–$0.02	–$0.07	–$0.17	–$0.58
AFW-3 Forest Retention	$0.06	$0.31	$0.57	$0.48	$3.45
AFW-4 Reforestation/Afforestation	–$5.92	–$7.67	–$9.23	–$11.07	–$73.47
AFW-5 Urban Forestry	$1.32	$4.75	$5.95	$5.44	$40.12
AFW-6 Source Reduction	$0.04	$0.62	$1.45	$2.53	$10.37
AFW-7 Enhanced Recycling of MSW	$0.88	$3.49	$7.94	$10.38	$51.61
AFW-8 MSW Landfill Gas Management	$1.02	$1.57	$2.61	$10.44	$26.47
Subtotal – Agriculture, Forestry & Waste (AFW)	**–$2.52**	**$4.09**	**$11.51**	**$22.58**	**$75.46**
TLU-1 Vehicle Purchase Incentives	$0.02	$0.62	$3.78	$16.51	$39.64
TLU-2 Renewable Fuel Standard	–$0.02	–$0.27	–$2.38	–$4.78	–$17.08
TLU-3 Smart Growth	$0.18	$0.89	$2.32	$6.15	$19.54
TLU-4 Transit	–$0.05	$0.00	$0.23	$1.18	$2.46
TLU-5 Anti-Idling Technologies and Practices	–$0.08	$0.01	$0.18	$1.92	$2.96
TLU-6 Mode Shift from Truck to Rail	–$0.44	–$2.39	–$0.56	$6.69	$2.92
Subtotal – Transportation and Land Use (TLU)	**–$0.38**	**–$1.15**	**$3.56**	**$27.68**	**$50.45**
Summation Total	**–$0.34**	**$12.60**	**$39.28**	**$128.76**	**$355.97**
Simultaneous Total	**–$0.34**	**$12.68**	**$41.34**	**$159.60**	**$406.74**

GHG = greenhouse gas; MSW = municipal solid waste; NPV = net present value. Note: A positive number in this table means a positive stimulus to the economy, or an increase in the gross domestic product (GDP); a negative number in this table means a negative impact to the economy, or a decrease in the GDP.

Table 3-6. Employment Impacts of the 23 GHG Mitigation Policy Options (thousands of full-time-equivalent jobs)

Policy Options	2010	2012	2015	2020
ES-1 Renewable Portfolio Standard	0.4	–21.4	–52.7	–58.6
ES-2 Nuclear	0.0	–0.7	–5.1	–73.3
ES-3 Carbon Capture and Storage or Reuse (CCSR)	0.0	0.0	–35.8	–35.4
ES-4 Coal Plant Efficiency Improvements	0.3	0.6	0.1	1.1
Subtotal – Agriculture, Forestry & Waste (AFW)	**0.7**	**-21.5**	**-93.5**	**-166.3**
RCI-1 Demand Side Management Programs	72.5	217.9	431.7	886.2
RCI-2 High Performance Buildings	22.5	52.6	112.1	183.3
RCI-3 Appliance standards	2.3	7.6	15.7	25.1
RCI-4 Building Codes	17.8	49.7	100.0	181.1
RCI-5 Combined Heat and Power	–37.0	–78.9	–114.0	–127.9
Subtotal - Residential Commercial and Industrial (RCI)	**77.9**	**248.9**	**545.5**	**1,147.8**
AFW-1 Crop Production Practices	8.4	31.2	53.0	87.7
AFW-2 Livestock Manure	–0.1	–0.2	–0.5	–0.9
AFW-3 Forest Retention	7.4	32.5	54.7	71.2
AFW-4 Reforestation/Afforestation	–40.8	–67.0	–90.6	–117.8
AFW-5 Urban Forestry	71.9	271.2	377.8	505.3
AFW-6 Source Reduction	–0.6	6.5	15.8	25.7
AFW-7 Enhanced Recycling of MSW	7.9	34.2	81.0	114.4
AFW-8 MSW Landfill Gas Management	12.4	17.8	26.4	94.0
Subtotal - Agriculture, Forestry & Waste (AFW)	**66.5**	**326.2**	**517.4**	**779.5**
TLU-1 Vehicle Purchase Incentives	–0.3	5.3	41.2	179.5
TLU-2 Renewable Fuel Standard	–0.2	–2.5	–15.8	–25.2
TLU-3 Smart Growth	12.7	40.7	85.5	165.7
TLU-4 Transit	3.7	12.2	26.2	52.2
TLU-5 Anti-Idling Technologies and Practices	–1.3	0.0	1.4	16.7
TLU-6 Mode Shift from Truck to Rail	–11.4	–37.8	–20.7	40.9
Subtotal - Transportation and Land Use (TLU)	**3.2**	**17.9**	**117.8**	**429.8**
Summation Total	**148.3**	**571.5**	**1,087.2**	**2,190.8**
Simultaneous Total	**147.8**	**572.8**	**1,118.0**	**2,524.0**

GHG = greenhouse gas; MSW = municipal solid waste.
Note: A positive number in this table means job creations; a negative number means a reduction in the total employment.

The reader is referred to Annex E* for detailed results for each year, as well as the impacts on other economic indicators, such as output, personal disposable income, for the simultaneous run. Individual sectoral results are presented in Annex E.* Please note that contrary to the qualitative nature of the results presented in the microeconomic analysis tables, where, for example, a negative number represented a savings, a negative number in the macroeconomic result tables has a dampening effect, in this case a blow to the economy (i.e., a decrease in GDP or jobs). A positive number, by contrast, means a stimulus to the economy (i.e., an increase in GDP or a creation of jobs).

The last row of Table 3-5 and Table 3-6 present the simulation results of the GDP and employment impacts for the simultaneous run, in which we assume that all the 23 super options are implemented concurrently across the country. When we implement the simultaneous run in the REMI model, we "shock" the model by including all the variable changes of the individual runs together.

* The Annexes to this report are available at energypolicyreport.jhu.edu.

For the simple summation results, the NPV of the total GDP impact for the period 2010-2020 is about $356 billion (constant 2007 dollars), with the impacts being slightly negative in 2010 and increasing steadily over the years to an annual high of $129 billion in 2020. In that year, the impacts represent an increase of 0.75% in GDP. For the simultaneous simulation case, the 2010-2020 NPV of the GDP impacts is about $407 billion, or an increase of 0.93%.

Table 3-5 highlights several important points:

- The macroeconomic impacts of 15 of the 23 options are positive, which means implementing these policy options will bring about a positive stimulus to the nation's economy by increasing the GDP and creating more jobs.
- Super option RCI-1 (Demand Side Management) yields the highest positive impacts on the economy—an NPV of $305.05 billion; Super option RCI-5 (Combined Heat and Power) results in the highest negative impacts to the economy—a net present value (NPV) of −$104.38 billion.
- From a sectoral perspective, super options from the Residential, Commercial, and Industrial sector would yield the highest positive impacts on the economy, followed by the super options from the Agriculture and Waste Management sector, and the Transportation and Land Use sector.

Most of the policy options 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 the country, 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 policy options 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.[7]

Note that several of these gains would not be forthcoming through market forces alone. Several market failures (e.g., split incentives, myopia) exist that inhibit the optimal spending on energy efficiency improvements (see National Commission on Energy Policy, 2004). State climate action plans specifically address such barriers by recommending appropriate barrier removal policies and tools. Note that such direct economic stimulus considerations reflect the input data and not the internal workings of the REMI model. The model, does, however, calculate their indirect, or macroeconomic effects.

The employment impacts, which represent impacts on full-time-equivalent jobs, are summarized in Table 3-6 and are qualitatively similar to those in Table 3-5. In this case, 16 of 23 options yield positive employment impacts. By the year 2020, for the simple summation results, these new jobs accumulate to the level of about 2.19 million full-time-equivalent jobs generated directly and indirectly in the U.S. economy. This represents an increase over baseline projections of 1.19%. For the simultaneous simulation case, the job gains are projected to be 2.52 million full-time-equivalent jobs, or an increase of 1.37%.

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 2010 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 2010, 2011, 2012, etc. Every year it is the same 100 jobs that persist over time, not an additional 100 jobs. The simulation results indicate that options in the Residential, Commercial, and Industrial sector would create the largest number of new jobs, followed by the options from the Agriculture, Forestry, and Waste Management sector and then from the Transportation and Land Use sector.

7. The results for RCI-5 (Combined Heat and Power), for example, can be decomposed into negative and positive stimuli, with the net effects being negative. The negative economic stimuli of this option include the increased cost (including annualized capital costs, operation 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 heaters/water heaters). The positive stimuli include various fuel cost savings (e.g., electricity, 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 Natural Gas Distribution sectors due to the increased demand of fuels to supply the CHP facilities.

These GHG mitigation options also have the ability to lower the nation's Price Index by 0.77% from baseline by the Year 2020. This price decrease, of course, has a positive stimulus on GDP and employment.

A comparison between the simultaneous simulation and the summation of simulations of individual option shows that the former yields higher positive impacts to the economy—the GDP NPV is 14.3% higher and the job increase in 2020 is 15.2% higher. The overlaps between super options 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 options together, the increased magnitude of the total stimulus to the economy causes wage, price, cost, and population adjustments to occur differently than if each option is run by itself.

Table E-2 and Table E-3 in the Annex E* present the impacts on GDP and employment of each individual economic sector for the simultaneous simulation. The impacts of the various mitigation options vary significantly by sector of the 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 GDP are, in descending order, Monetary Authorities, Credit Intermediation,[8] Real Estate, Transit and Ground Passenger Transportation, Offices of Health Practitioners,[9] and Securities, Commodity Contracts, and Other Financial Investments and Related Activities.

One would expect Electric Utilities related to fossil fuels, including coal mining and 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 — $238 billion (NPV). Other negatively affected sectors in descending order of impacts are Oil and Gas Extraction, Coal Mining, Natural Gas Distribution, Construction, and Pipeline Transportation. However, none of these sectors is expected to have a decline of more than $35 billion.

Overall, employment increases by a higher percentage than GDP for several reasons. Increased capital costs shift production processes toward relatively greater labor intensity. Also, results from spending shifts to sectors with greater labor intensities such as retail trade and away from capital-intensive sectors such as energy production.

Finally, we have simulated the impacts of all the major mitigation options. Clearly, the impacts would be even more positive had we selectively included only those options that would yield only a positive stimulus to either GDP or employment. Moreover, the reader should keep in mind that this strategy would also lead to a relatively lower level of GHG mitigation than that provided by implementing all options.[10]

8. The increased activity in this sector reflects the demand increases of financing to fund the investment on energy efficiency technologies, new power plants construction, enhancement of transit systems, etc.

9. The increased activity in this sector stems not from any increase in healthcare needs per se but rather from the fact that consumer disposable income has increased.

10. Our results are similar to several other studies that have found positive stimulus effects of climate mitigation plans (see, e.g., Granade et al., 2009; Roland-Holst and Karhl, 2009), and differ from others that find negative impacts (e.g., Ross et al., 2008; Montgomery et al., 2009). Even within the category of studies that yield positive impacts there are some significant differences, however. For example, Laitner (2009) identified relatively larger direct cost-savings than are presented here, but lower stimulus effects. One reason is the difference in the macroeconomic models used (IMPLAN vs. REMI). Another is the difference in mitigation options considered. For example, we have evaluated a more comprehensive set of AFW options than the Laitner ACEEE study (the GHG reduction potentials of the CCS AFW options are more than 3 times of those yield by similar types of

* The Annexes to this report are available at energypolicyreport.jhu.edu.

2. Sensitivity Tests

a. Outcome Sensitivity to Key Input Variables

We performed sensitivity tests on two parameters of the analysis for some options with large economic impacts. The two variables are capital cost and avoided energy cost.

1. Capital Cost: 50% lower or 50% higher capital cost than the levels used in the base case analysis. This would change the values of two relevant policy levers in the REMI model. One is the capital cost of direct sectors that implement the GHG mitigation options. The other is the demand for production of the Construction sector and Equipment and Machinery Manufacturing sectors. Note also that this sensitivity test can implicitly also refer to how much the investment funds would displace other investment that would take place without the GHG mitigation actions.
2. Avoided Energy Cost: 50% lower or 50% higher avoided energy costs than the levels used in the base case analysis. This again would affect the values of two policy levers in the REMI model. One is the energy bill savings of the customer sectors. The second is the final demand change of the Energy Supply sector.

Table 3-7 and Table 3-8 show the results of sensitivity analysis on capital cost and avoided energy cost for RCI-1 (DSM) and RCI-5 (CHP), respectively. These two options yield the largest positive and negative economic impacts among the 23 super options analyzed in this study. It is not surprising to see that with the assumptions of lower capital cost or higher value of avoided electricity, the simulations yield more favorable impacts to the economy. The sensitivity tests show that the macroeconomic impact results of these two RCI options are more sensitive to the avoided electricity cost than to the capital cost.

Since the ES sector is the only sector that yields overall negative impacts to the economy, sensitivity tests on capital cost and fossil fuel cost are performed for each of the four individual ES options. The results are presented in Tables 3-10 through 3-13. For all the four ES options, lower capital cost would improve the macroeconomic impacts of implementing these options. In fact, with the 50% lower capital cost assumption, the overall economic impacts of RPS and nuclear will turn to positive in terms of NPV of GDP, and the employment impacts of RPS in 2020 will also turn to be positive. For RPS, nuclear, and coal-plant efficiency improvements policy options, assuming higher value of avoided energy cost would also improve the macroeconomic impacts of the options. However, for carbon capture and storage or reuse (CCSR), since more coal would be needed in new integrated gasification combined cycle (IGCC) plant with CCSR in order to capture and sequester CO_2, higher projected cost of coal would slightly increase the negative impacts of this option. Comparatively speaking, the macroeconomic impact results of RPS, nuclear, and CCSR are more sensitive to the capital cost, while the impacts of coal-plant efficiency improvements are more sensitive to the avoided coal price.

b. Sensitivity Tests on Discount Rate

When we evaluate the impacts on gross domestic product, it is important to consider the time value of money. People would value more the cash flows happening today than those happening in the future. In this study, we discount the cash flows between 2010 and 2020 to present values. The discount rate used in the base case analysis is 5%. Table 3-13 shows the comparison of GDP impacts using alternative discount rates. The middle numerical column of Table 3-13 replicates the net present values shown in Table 3-5, while the first numerical column shows the net present value calculation based on a 2% discount rate, and the third numerical column shows the calculation using an 8% discount rate. In general, the total net present value decreases when the discount rate increases and vice versa. This sensitivity test shows that the net present value of GDP impacts ranges between around $320 billion to $520 billion in the simultaneous simulation when the discount rate changes between 8% and 2%.

options included in the ACEEE study). The CCS AFW options incur direct net cost (or negative net savings) of about $7.2 billion. However, the REMI analysis shows that these options can create more than 500,000 jobs in 2020, because these options generate stimulus effects in sectors that have high output-based employment multipliers (such as the Agriculture and Forestry Supporting Activities sector).

For Tables 3-7 through 3-13, a positive dollar number means a positive stimulus to the economy—a cost saving or an increase in the GDP; a negative dollar number in the tables means a negative impact to the economy—a capital cost or a decrease in the GDP.

Table 3-7. Sensitivity Analysis on Capital Cost of RCI-1 Demand Side Management (billions of fixed 2007 dollars)

Scenarios	2010	2012	2015	2020	NPV
Base Case					
Gross Domestic Product (GDP) (Billions of Fixed 2007$)	$4.82	$16.17	$36.19	$90.05	$305.05
Employment (Thousands)	72.48	217.91	431.67	886.17	n.a.
50% Higher Capital Cost					
GDP (Billions of Fixed 2007$)	$4.29	$14.17	$30.63	$75.93	$258.68
Employment (Thousands)	66.25	193.72	371.08	753.88	n.a.
50% Lower Capital Cost					
GDP (Billions of Fixed 2007$)	$5.30	$18.16	$41.76	$104.27	$351.66
Employment (Thousands)	78.69	242.09	492.52	1,019.34	n.a.
50% Higher Avoided Energy (Electricity) Cost					
GDP (Billions of Fixed 2007$)	$5.52	$18.72	$43.78	$113.09	$373.55
Employment (Thousands)	86.95	263.67	544.05	1,152.30	n.a.
50% Lower Avoided Energy (Electricity) Cost					
GDP (Billions of Fixed 2007$)	$4.16	$13.73	$29.25	$70.70	$244.60
Employment (Thousands)	58.16	173.36	326.30	654.64	n.a.

Table 3-8. Sensitivity Analysis on Capital Cost of RCI-5 Combined Heat and Power (billions of fixed 2007 dollars)

Scenarios	2010	2012	2015	2020	NPV
Base Case					
Gross Domestic Product (GDP) (Billions of Fixed 2007$)	−$3.79	−$8.57	−$14.08	−$21.17	−$104.38
Employment (Thousands)	−37.05	−78.88	−113.98	−127.91	n.a.
50% Higher Capital Cost					
GDP (Billions of Fixed 2007$)	−$4.04	−$9.43	−$16.07	−$25.47	−$120.29
Employment (Thousands)	−40.22	−88.92	−134.77	−165.09	n.a.
50% Lower Capital Cost					
GDP (Billions of Fixed 2007$)	−$3.55	−$7.71	−$12.06	−$16.85	−$88.45
Employment (Thousands)	−33.95	−68.78	−93.20	−90.52	n.a.
50% Higher Avoided Energy (Electricity) Cost					
GDP (Billions of Fixed 2007$)	−$2.39	−$5.24	−$4.98	$1.07	−$26.60
Employment (Thousands)	−13.75	−24.81	−7.31	84.38	n.a.
50% Lower Avoided Energy (Electricity) Cost					
GDP (Billions of Fixed 2007$)	−$4.69	−$10.76	−$18.62	−$32.40	−$144.29
Employment (Thousands)	−53.70	−113.58	−173.61	−244.16	n.a.

Table 3-9. Sensitivity Analysis on Capital Cost of ES-1 Renewable Portfolio Standard (billions of fixed 2007 dollars)

Scenarios	2010	2012	2015	2020	NPV
Base Case					
Gross Domestic Product (GDP) (Billions of Fixed 2007$)	–$0.25	–$2.27	–$5.32	–$5.35	–$35.52
Employment (Thousands)	0.44	–21.42	–52.73	–58.61	n.a.
50% Higher Capital Cost					
GDP (Billions of Fixed 2007$)	–$0.69	–$4.23	–$9.93	–$16.61	–$73.69
Employment (Thousands)	–5.59	–44.33	–99.56	–153.20	n.a.
50% Lower Capital Cost					
GDP (Billions of Fixed 2007$)	$0.19	–$0.31	–$0.62	$6.33	$3.75
Employment (Thousands)	6.39	1.39	–5.00	39.31	n.a.
50% Higher Avoided Energy (Coal and Natural Gas) Cost					
GDP (Billions of Fixed 2007$)	$0.04	–$1.50	–$2.93	$6.31	–$8.91
Employment (Thousands)	4.63	–13.63	–34.50	22.27	n.a.
50% Lower Avoided Energy (Coal and Natural Gas) Cost					
GDP (Billions of Fixed 2007$)	–$1.25	–$3.80	–$7.00	–$12.05	–$53.56
Employment (Thousands)	–14.39	–42.41	–73.45	–112.22	n.a.

Table 3–10. Sensitivity Analysis on Capital Cost of ES–2 Nuclear (billions of fixed 2007 dollars)

Scenarios	2010	2012	2015	2020	NPV
Base Case					
Gross Domestic Product (GDP) (Billions of Fixed 2007$)	$0.00	–$0.07	–$0.46	–$6.85	–$8.14
Employment (Thousands)	0.00	–0.69	–5.08	–73.34	n.a.
50% Higher Capital Cost					
GDP (Billions of Fixed 2007$)	$0.00	–$0.20	–$1.01	–$12.75	–$17.36
Employment (Thousands)	0.00	–2.06	–10.48	–123.41	n.a.
50% Lower Capital Cost					
GDP (Billions of Fixed 2007$)	$0.00	$0.06	$0.08	–$0.83	$1.10
Employment (Thousands)	0.00	0.66	0.31	–22.20	n.a.
50% Higher Avoided Energy (Coal and Natural Gas) Cost					
GDP (Billions of Fixed 2007$)	$0.00	$0.05	–$0.10	–$2.35	–$1.24
Employment (Thousands)	0.00	0.53	–1.64	–35.67	n.a.
50% Lower Avoided Energy (Coal and Natural Gas) Cost					
GDP (Billions of Fixed 2007$)	$0.00	–$0.18	–$0.82	–$11.20	–$14.91
Employment (Thousands)	0.00	–1.94	–8.45	–109.75	n.a.

Table 3-11. Sensitivity Analysis on Capital Cost of ES-3 Carbon Capture and Storage or Reuse (billions of fixed 2007 dollars)

Scenarios	2010	2012	2015	2020	NPV
Base Case					
Gross Domestic Product (GDP) (Billions of Fixed 2007$)	$0.00	$0.00	–$2.80	–$4.47	–$16.57
Employment (Thousands)	0.00	0.00	–35.75	–35.44	n.a.
50% Higher Capital Cost					
GDP (Billions of Fixed 2007$)	$0.00	$0.00	–$3.93	–$6.45	–$23.19
Employment (Thousands)	0.00	0.00	–46.44	–49.59	n.a.
50% Lower Capital Cost					
GDP (Billions of Fixed 2007$)	$0.00	$0.00	–$1.68	–$2.46	–$9.93
Employment (Thousands)	0.00	0.00	–25.00	–21.09	n.a.
50% Higher Energy (Coal) Cost					
GDP (Billions of Fixed 2007$)	$0.00	$0.00	–$2.84	–$4.56	–$16.88
Employment (Thousands)	0.00	0.00	–36.13	–36.09	n.a.
50% Lower Energy (Coal) Cost					
GDP (Billions of Fixed 2007$)	$0.00	$0.00	–$2.77	–$4.40	–$16.28
Employment (Thousands)	0.00	0.00	–35.28	–35.02	n.a.

Table 3-12. Sensitivity Analysis on Capital Cost of ES-4 (Coal Plant Efficiency Improvements and Repowering) (billions of fixed 2007 dollars)

Scenarios	2010	2012	2015	2020	NPV
Base Case					
Gross Domestic Product (GDP) (Billions of Fixed 2007$)	$0.01	$0.02	$0.04	$0.48	$0.86
Employment (Thousands)	0.27	0.64	0.06	1.11	n.a.
50% Higher Capital Cost					
GDP (Billions of Fixed 2007$)	$0.01	–$0.07	–$0.43	–$0.65	–$2.78
Employment (Thousands)	0.31	–0.41	–4.45	–7.97	n.a.
50% Lower Capital Cost					
GDP (Billions of Fixed 2007$)	$0.01	$0.12	$0.49	$1.65	$4.44
Employment (Thousands)	0.20	1.67	4.58	10.70	n.a.
50% Higher Avoided Energy (Coal) Cost					
GDP (Billions of Fixed 2007$)	$0.04	$0.15	$0.58	$2.01	$5.24
Employment (Thousands)	0.58	2.25	5.59	12.63	n.a.
50% Lower Avoided Energy (Coal) Cost					
GDP (Billions of Fixed 2007$)	–$0.01	–$0.10	–$0.46	–$1.01	–$3.45
Employment (Thousands)	–0.05	–0.92	–4.97	–10.05	n.a.

Table 3-13. Comparing Net Present Values with Alternative Discount Rates (billions of fixed 2007 dollars)

Policy Options	Discount Rate (NPV)		
	2%	5%	8%
ES–1 Renewable Portfolio Standard	–$43.88	–$35.52	–$29.07
ES–2 Nuclear	–$10.75	–$8.14	–$6.23
ES=3 Carbon Capture and Storage or Reuse (CCSR)	–$20.86	–$16.57	–$13.31
ES–4 Coal Plant Efficiency Improvements	$1.10	$0.86	$0.67
Subtotal – ES	**–$74.40**	**–$59.38**	**–$47.94**
RCI–1 Demand Side Management Programs	$382.64	$305.05	$246.18
RCI–2 High Performance Buildings	$50.43	$40.14	$32.35
RCI–3 Appliance Standards	–$0.51	–$0.43	–$0.36
RCI–4 Building Codes	$61.34	$49.05	$39.71
RCI–5 Combined Heat and Power	–$127.76	–$104.38	–$86.36
Subtotal – RCI	**$366.14**	**$289.44**	**$231.52**
AFW–1 Crop Production Practices	$21.84	$17.50	$14.18
AFW–2 Livestock Manure	–$0.74	–$0.58	–$0.48
AFW–3 Forest Retention	$4.18	$3.45	$2.87
AFW–4 Reforestation/Afforestation	–$88.10	–$73.47	–$62.05
AFW–5 Urban Forestry	$48.07	$40.12	$33.87
AFW–6 Source Reduction	$12.94	$10.37	$8.41
AFW–7 Enhanced Recycling of MSW	$63.57	$51.61	$42.40
AFW–8 MSW Landfill Gas Management	$33.17	$26.47	$21.41
Subtotal – AFW	**$94.93**	**$75.46**	**$60.62**
TLU–1 Vehicle Purchase Incentives	$51.12	$39.64	$31.08
TLU–2 Renewable Fuel Standard	–$21.68	–$17.08	–$13.59
TLU–3 Smart Growth	$24.64	$19.54	$15.68
TLU–4 Transit	$3.22	$2.46	$1.90
TLU–5 Anti–Idling Technologies and Practices	$3.93	$2.96	$2.26
TLU–6 Mode Shift from Truck to Rail	$5.62	$2.92	$1.06
Subtotal –TLU	**$66.85**	**$50.45**	**$38.38**
Summation Total	**$453.53**	**$355.97**	**$282.59**
Simultaneous Total	**$520.74**	**$406.74**	**$321.29**

MSW = municipal solid waste; NPV = net present value; ES = Energy Supply; RCI = Residential, Commercial, and Industrial; AFW = Agriculture, Forestry, and Waste Management; TLU = Transportation and Land Use.
Note: A positive dollar number in the tables above means a positive stimulus to the economy – a cost saving or an increase in the GDP; a negative dollar number means a negative impact to the economy – a capital cost or a decrease in the GDP.

VII. Current Legislation

The Kerry-Lieberman bill (K-L, 2010) has the following major features:

1. Emission Caps: The emission caps for the covered sources are specified as 95.25% of the 2005 level in 2013; 83% of the 2005 level in 2020; 58% of the 2005 level in 2030; and 17% of the 2005 level in 2050 (i.e., 4.75%, 17%, 42%, and 83% below the 2005 level in 2013, 2020, 2030, and 2050, respectively).

2. Covered Sectors and Phase-in Schedule: Starting in 2013, the Electric Power sector and Refined Petroleum Products Manufacturing sector will be covered by the cap. Starting in 2016, the Industrial sector (for entities that emit > 25,000 tons of CO_2 equivalent from either fuel combustion or industrial processes) and the Natural Gas Distribution sector will be covered by the cap. Entities covered by the cap after year 2016 collectively contribute about 85% of gross GHG emissions in the U.S. (Doniger, 2010).

3. Allowance Price: The reserve price of an allowance at auction will be set at $12 per ton (2009$) starting in 2013, and this price will increase at the rate of inflation (as measured by the CPI) plus 3% for each year afterwards. The allowance price of the cost containment reserve will be set at $25 per ton (2009$) starting in 2013 and will increase at the rate of inflation (as measured by the CPI) plus 5% for each year afterwards. In our simulation cases, we will determine the allowance price internally based on the U.S. marginal mitigation cost curve developed in Section 2. Where this approach will not yield a reasonable allowance price (such as in the Stakeholder Full Implementation scenario), we will use the reserve price to compute the auction payments/revenues.

4. Banking and Borrowing: The bill allows unlimited banking. The bill will also establish a two-year rolling compliance period that allows the covered entities to borrow an unlimited number of allowances from one year into the future. However, they need to pay back the borrowed allowances in the second year to avoid any penalty. Covered entities can also use future five years' allowances for up to 15% of current year compliance with an 8% penalty.

5. Offsets: Offset credits can be used to achieve compliance for up to a maximum of 2 billion tons of GHG emissions annually. In general, the limit on the use of international offset credits is 0.5 billion tons. However, if the use of domestic offsets is less than 1.5 billion tons, the limit on the international offset credits can be increased to a maximum of 1 billion tons. In addition, covered entities can use 1 domestic offset credit or 1.25 international offset credits to demonstrate compliance. In our analysis, the domestic offset price is determined endogenously based on the cost curve of the methane and forestry mitigation options from the Agricultural, Forestry, and Waste sector.

6. Disposition of Allowances and Auction Percentage: Table 1 summarizes the use of auction revenues and is based on the provisions specified in Sec. 2101 of the K-L bill. The disposition of the allowances to different sectors and objectives are summarized for three key years within the study period of our analysis (years 2013, 2015, and 2020). The table is divided into two sections. The first section lists the direct (free) allocation of the allowances. The second section lists the allowances distribution through the spending of auction proceeds.

7. Auction Revenue Recycling: According to Table 1, the auction proceeds will be devoted to "Consumer Relief," "Universal Trust Fund," "Highway Trust Fund," and "Deficit Reduction Fund." The consumer relief program includes the working families refundable credit program and the energy refund program. For the working families refundable credit program, an eligible taxpayer is defined as an individual whose household income is less than 150% of the poverty line minus $1,000. For the energy refund program, there are many criteria to define an eligible household, such as a household that has income less than 150% of the poverty line, that is participating in the Supplemental Nutrition Assistant Program, Food Distribution Program, etc. In our simulation, we will use the 150 percent federal poverty level to define the household income group that will be covered by consumer relief programs. In addition, all households are likely eligible for the "Universal Trust Fund." However, this fund will not be established until 2026, and, therefore, it will not be simulated in our analysis.

Table 3-14. Allowance Allocation Scheme of the K-L Bill (based on Section 2101)

Allowance Allocation Schemes	2013	2015	2020	CCS Sectors
Direct Allocation of Allowances				
Electricity Consumers (first distributed to local distribution companies)	51.0%	51.0%	35.0%	ES
Natural Gas Consumers (first distributed to local distribution companies)	0.0%	0.0%	9.0%	Res, Com, Ind-EIS, and Ind-Other
Home Heating Oil and Propane Consumers (first distributed to states)	1.9%	1.9%	1.5%	Res
Trade-exposed Industries	2.0%	2.0%	15.0%	Ind-EIS
Industrial Energy Efficiency	0.5%	0.5%	0.0%	Ind-EIS and Ind-Other
Refiners	4.3%	4.3%	3.8%	Ind-Other
Deployment of Carbon Capture and Sequestration Technology	0.0%	0.0%	4.5%	ES
Clean Vehicle Technology	1.0%	1.0%	1.0%	TLU
Low-carbon Industrial Technologies Research and Development	1.0%	1.0%	1.0%	Com (R&D sector)
Clean Energy Technology Research and Development	2.0%	2.0%	2.0%	Com (R&D sector)
Investment in Energy Efficiency and Renewable Energy	2.5%	2.5%	1.0%	Split between ES, Ind-EIS, Ind-Other, and Com sectors
Early Action	1.0%	1.0%	0.0%	Split between ES, Ind-EIS, Ind-Other, and Com sectors
National Surface Transportation System	4.0%	4.0%	2.0%	TLU
Investment in Transportation GHG Emission Reduction Programs	4.0%	4.0%	2.0%	Ind-Other (auto manufacturing and refiner sectors)
Total Free Allocation Percentage	**75.2%**	**75.2%**	**78.8%**	
Adaptation (1/2 to domestic adaptation and 1/2 to international adaptation)[a]	0.0%	0.0%	1.5%	
Distribution of Spending of Allowance Auction Proceeds				
Consumer Relief	12.3%	12.3%	10.6%	
Universal Trust Fund	0.0%	0.0%	0.0%	
Highway Trust Fund	4.0%	4.0%	2.0%	
Deficit Reduction Fund	8.5%	8.5%	8.1%	
Total Auction Percentage	**24.8%**	**24.8%**	**20.8%**	

Notes: ES = Electricity Supply sector; Res = Residential sector; Com = Commercial sector; Ind-EIS = Energy-Intensive Industrial sector; Ind-Other = Other Industrial sector; R&D = research and development; TLU = Transportation sector.
a Allowances to adaptation will not be simulated as allowance distribution to any capped sectors; instead, we will simulate it as a lump-sum payment to state and local government for domestic adaptation and as a foreign transfer for international adaptation.

VIII. Analysis of the Senate Bill

1. Scenario 1. Stakeholder Recommendation Case

This is the implementation of all mitigation options presented in Table 3-15 as described in Subsection VI above. This scenario excludes consideration of major features of the K-L bill.

Table 3-15. 2020 GHG Reduction Potentials and Cost-Effectiveness of 23 GHG Mitigation "Super Options" for the U.S., 2020

Sector	Climate Mitigation Actions	Estimated 2020 Annual GHG Reduction Potential ($MMtCO_2e$)	Estimated Cost or Cost Savings per Ton GHG Removed ($)	GHG Reduction Potential as Percentage of 2020 Baseline Emissions	Cumulative GHG Reduction Potentials	Price-Responsive Options
TLU-6	Mode Shift from Truck to Rail	36.85	–$91.56	0.48%	0.48%	No
TLU-1	Vehicle Purchase Incentives, Including Rebates	103.07	–$66.37	1.34%	1.82%	Yes
TLU-5	Anti-Idling Technologies and Practices	33.82	–$65.19	0.44%	2.26%	No
RCI-3	Appliance Standards	80.86	–$53.21	1.05%	3.31%	No
RCI-1	Demand Side Management Programs	424.80	–$40.71	5.52%	8.83%	30% of the emission reductions are price-responsive
RCI-2	High Performance Buildings (Private and Public Sector)	193.88	–$24.99	2.52%	11.35%	30% of the emission reductions are price-responsive
RCI-4	Building Codes	161.08	–$22.86	2.09%	13.44%	No
AFW-1	Crop Production Practices to Achieve GHG Benefits	65.01	–$15.69	0.84%	14.29%	50% of the emission reductions are price-responsive
RCI-5	Combined Heat and Power	136.37	–$13.18	1.77%	16.06%	30% of the emission reductions are price-responsive
AFW-6	MSW Source Reduction	147.09	–$3.20	1.91%	17.97%	No
TLU-3	Smart Growth/Land Use	71.04	–$1.11	0.92%	18.89%	No
AFW-8	MSW Landfill Gas Management	48.38	$0.34	0.63%	19.52%	Yes
AFW-2	Livestock Manure – Anaerobic Digestion and Methane Utilization	19.25	$11.27	0.25%	19.77%	Yes
ES-4	Coal Plant Efficiency Improvements and Repowering	151.05	$12.95	1.96%	21.74%	Yes
AFW-7	Enhanced Recycling of Municipal Solid Waste	249.27	$13.39	3.24%	24.97%	No
AFW-5	Urban Forestry	39.96	$15.35	0.52%	25.49%	Yes
TLU-4	Transit	27.05	$16.72	0.35%	25.85%	No
ES-1	Renewable Portfolio Standard	508.39	$17.84	6.61%	32.45%	No

Table 3-15, continued from previous page

Sector	Climate Mitigation Actions	Estimated 2020 Annual GHG Reduction Potential ($MMtCO_2e$)	Estimated Cost or Cost Savings per Ton GHG Removed ($)	GHG Reduction Potential as Percentage of 2020 Baseline Emissions	Cumulative GHG Reduction Potentials	Price-Responsive Options
ES-2	Nuclear	300.77	$26.98	3.91%	36.36%	Yes
ES-3	CCSR	130.23	$32.92	1.69%	38.05%	Yes
AFW-4	Reforestation/Afforestation	178.77	$33.18	2.32%	40.38%	Yes
AFW-3	Forest Retention	39.21	$39.38	0.51%	40.89%	Yes
TLU-2	Renewable Fuel Standard (Biofuels Goals)	92.34	$57.14	1.20%	42.09%	Yes

Note: In order to develop the step-wide marginal cost curve, the options are ordered in an ascending sequence in terms of their cost-effectiveness (per ton cost). The cost here is the net of the direct cost and direct savings of the policy option implementation. Any indirect costs or cost of allowances are not included here. The details of the methodology for estimating the reduction potentials and cost-effectiveness of these options are presented in Section 2.

2. Scenario 2. Stakeholder/Senate Scenario

We first assume that all the 23 super options summarized in Table 3-15 will be implemented regardless of the cost. The cost is ascertained from application of the average cost and feasibility estimates in the Table.

Over 77% of the total allowances are distributed freely among sectors based on the allowance disposition scheme specified in the K-L bill (see Table 3-14). About 21% of the total allowances will be sold in the auction market. In our analysis, we assume that a sector will first purchase allowances from the auction market before turning to the inter-sectoral trading market or offset market if the sector cannot achieve sufficient GHG reductions from autarkic mitigation activities. The auction payments are then added to the production cost of each purchasing sector.

Auction revenues collected by government are to be "recycled" back into the economy. According to Table 3-14, more than half of the auction revenues will be returned back to low-income households through the Working Families Refundable Credit Program and the Energy Refund Program. Over 10% of the total auction proceeds will be used to increase the Highway Trust Fund. The remaining auction revenues will be used to reduce deficit. The discussion of how the revenue recycling is entered into the REMI model is presented in Annex F.*

Table 3-16 presents the calculation steps of this simulation scenario:

1. The first two rows of Table 3-16 present the 2005 gross emissions and the 2020 projected baseline gross emissions, respectively. The cap covered sectors are assumed to be all economic sectors excluding the Agriculture, Forestry, and Waste sectors. The same emissions cap, which is 17% below 2005 level in year 2020, is applied to each of these cap-and-trade covered sectors. In row 3, the 2020 emission caps of the Electricity Supply sector (ES), Residential sector (Res), Commercial sector (Com), Energy-Intensive Industrial sector (Ind-EIS), Other Industrial sector (Ind-Other), and TLU sectors are computed by multiplying the sectors' respective 2020 projected baseline emissions by 83%.
2. Row 4 presents the free-granted allowances distributed to each individual sector. The numbers in this row are computed by multiplying the allowance allocation percentage to relevant sectors (specified in "CCS Sectors" column in Table 3-14) by the quantity of total allowances (which equals the 2020 emissions cap). Row 5 computes the emission reductions or allowances a capped sector needs to obtain from either autarkic mitigation or from allowance sources (such as auction

* The Annexes to this report are available at energypolicyreport.jhu.edu.

market, inter-sectoral trading market, or offset market). This is computed as the difference between the 2020 baseline emission of a sector (row 2) and the free allocated allowances to this sector (row 4). Please note the numbers for the Commercial sector and the Energy-Intensive Industrial sector in this row are negative. This means according to our calculation, these two sectors will receive more free allowances than their projected baseline emissions.

3. Row 6 presents the reductions that can be achieved from the full implementation of the CCS options in the respective sectors. The total efforts of the 23 super options can help reduce the 2020 baseline emissions by 42.09%.
4. Row 7 computes the allowances each sector purchases from auction. The values are zero for the ES sector and Residential sector because their respective reductions from mitigation (row 6) are greater than the emissions reductions or allowances they need to obtain as indicated in row 5. The values are zero for the Commercial sector and the Energy-Intensive Industrial sector because they even get free allowances above their baseline emissions. Ind-Other and TLU are the only two sectors that need to purchase allowances after their own-source mitigation. The number for the Ind-Other sector is computed as the difference between the reductions and allowances this sector needs (row 5) and the mitigation this sector can achieve from implementing sectoral mitigation options (row 6). The allowances the TLU sector will buy from the auction market is computed as the residual of the total allowances available in the auction market and the allowances purchased by the Ind-Other sector from the auction market. Comparing the numbers in rows 5 to 7 in the TLU column, we can see that the TLU sector cannot acquire enough reductions from TLU mitigation and the auction market (row 6 + row 7 < row 5).
5. In row 8, we compute the allowances transactions in the inter-sectoral trading market. Since Scenario 2 assumes that the 23 super options will be fully implemented under regulations, even though many sectors will achieve over-compliance, they cannot sell the excess reductions to the other sectors. Therefore, we assume in this step that only the free-allocated allowances that exceed the baseline emissions of a sector will be sold to the other sectors. Thus, the TLU sector can buy 11 million tons of allowances from the Commercial sector and 368 million tons from the Ind-EIS sector.
6. Domestic offsets will not be available in this scenario since all sectors are "covered" by either cap and trade or other policies and measures. Therefore, the numbers in row 9 are all zero.
7. The remaining need for allowances of the TLU sector is then assumed to be achieved from purchasing allowances from the international offset market. Since 1.25 tons of international offset credits are needed for 1 ton of emissions, a factor of 1.25 is applied to get the total international offsets purchased in tons in row 10. The offset price is assumed to be same as the allowance price.
8. Row 11 computes the allowances banking by sector. Based on all the above assumptions, no allowances are available for banking in this scenario.

The macroeconomic impacts and its decomposition of the Stakeholder/Senate scenario 2 are presented in Table 3-17. The overall impacts of this simulation case are projected to be a $116.9 billion increase in GDP (or a 0.68% increase from the baseline level) and a 2.13 million increase in employment (or a 1.15% increase from the baseline level) in 2020. The decomposition of the results is as follows:

» Implementation of the 23 super options will increase GDP by $159.5 billion and create 2.5 million more jobs in 2020. These reflect the total impacts of the 23 super options implemented simultaneously.

» Production cost increase of the Ind-Other and TLU sectors due to the purchases of allowances in the auction market will cause a decrease in GDP of $43.0 billion and a decrease in employment of 432,000.

» Recycling of the auction revenue would generate an increase in GDP of $19.0 billion and an increase in employment of 240,000.

- Production cost increase of the TLU sectors resulted from the purchases of allowances from other capped sectors will result in a decrease in GDP of $13.1 billion and a decrease in employment of 132,000.
- Sales of allowances by the Com and Ind-EIS sectors will yield a $17.9 billion GDP increase and 171,000 more jobs.
- Purchases of international offsets by the TLU sector will cause a decrease in GDP of $23.5 billion and a decrease in employment of 238,000.

3. Scenario 3. Senate Scenario

In this simulation case, we first scale back the reduction potentials of the 23 super options presented in Table 3-15 to the level that in aggregate the cap-and-trade sector can achieve the K-L reduction target exactly and the non-cap-and-trade sector can also achieve the same reduction goal specified in the K-L bill through policies and measures other than cap-and-trade. The stakeholder target simulated in Scenario 2 can reduce 2020 baseline emissions by 42%. The Senate (K-L bill) 2020 target simulation in this scenario is 17% below 2005 levels in 2020 (or 22.3% below the 2020 baseline emissions level).

The free allocation of the allowances, the allowances auction, and government revenues recycling are simulated in similar manners as in Scenario 2. Because the free allowances are not equally distributed among the capped sectors and the reduction potentials of the mitigation options vary across sectors, some capped sectors would have excess allowances. In this scenario, we assume that those capped sectors with excess allowances can sell those allowances to the other capped sectors that still fall short of emissions reductions or allowances after own-sector mitigation and allowances purchase from the auction market. The outcome is that through inter-sectoral trading, the scaled-back reductions of the super options from the capped sectors can help the cap-and-trade sector achieve the K-L bill target exactly.

Table 3-18 presents the calculation steps for the Senate Scenario:

1. The first two rows of Table 3-18 present the 2005 gross emissions and the 2020 projected baseline gross emissions, respectively. The Senate bill target is to reduce emissions 17% below the 2005 levels by 2020, which requires a reducing the 2020 baseline emissions by 22.3%. In row 3, the Senate bill reduction target is applied equally to the baseline emissions of the capped sectors.
2. Similar to the Stakeholder/Senate Scenario analysis, row 4 shows the allowances that are freely allocated to each capped sectors based on the allowance disposition specified in the K-L bill. Row 5 computes the emissions reductions or allowances needed by the capped sectors as the difference between the 2020 baseline emission of a sector (row 2) and the free allocated allowances to this sector (row 4).
3. The Stakeholder Target is 42.1% below the 2020 baseline emissions level (which equals the maximum reduction potentials shown in the U.S. marginal cost curve in Figure 2-4). In this scenario, the reduction potential of each option from the cap-and-trade sector is multiplied by a scale-back factor of 62% so that aggregately implementing these options can help the capped sector achieve the K-L bill target (17% below 2005 levels in year 2020). Similar adjustment is also applied to the options from the non-cap-and-trade sector. A factor of 27% is applied to each non-cap-and-trade sector option so that they aggregately can help the non-cap-and-trade sector achieve the K-L bill reduction goal. The scaled-back reductions from autarkic mitigation activities for each sector are presented in row 6.
4. Row 7 computes the allowances each sector purchases from auction. Similar to Scenario 2, the ES, Residential, Commercial, and Ind-EIS sectors do not need to purchase any allowances from auction. Ind-Other and TLU are the only two sectors that need to purchase allowances after their autarkic mitigation with a scaled-back level. The number for the Ind-Other sector is computed as the difference between the allowances this sector needs (row 5) and the mitigation this sector can achieve from implementing sectoral mitigation options at a scaled-back level (row 6). The

allowances the TLU sector will buy from the auction market is computed as the residual of the total allowances available in the auction market and the allowances purchased by the Ind-Other sector from the auction market. Comparing the numbers in rows 5 to 7 in the TLU column, we can see that the TLU sector cannot acquire enough reductions or allowances from its own mitigation and the auction market (row 6 + row 7 < row 5).

5. Row 8 computes the allowance transactions in the inter-sectoral trading market. Since the objective of this Scenario is that the proportional scaled-back reductions of the cap-and-trade sector mitigation options will enable the cap-and-trade sector to achieve the Senate bill target exactly, we assume that the capped sectors with excess emission reductions can sell the allowances to the TLU sector. The negative numbers in this row represent allowance selling and positive numbers represent allowance purchasing.
6. Domestic and international offsets will not be needed in this scenario since the proportional scaled-back reductions of the cap-and-trade sector mitigation options will enable the cap-and-trade sector achieve the Senate bill target exactly.
7. Finally, no allowances can be banked since there are no excess allowances.

The macroeconomic impact and its decomposition of the Senate Scenario are presented in Table 3-19. The overall impacts of this simulation case are projected to be a $50.7 billion increase in GDP (or a 0.30% increase from the baseline level) and a 0.92 million increase in employment (or a 0.50% increase from the baseline level) in 2020. The decomposition of the results is as follows:

» The scaled-back implementation of the 23 super options will increase GDP by $76.9 billion and create 1.15 million more jobs in 2020. These impacts are computed by applying the scale-back factor of 62% and 27% to the simultaneous impacts of the cap-and-trade sector options and the simultaneous impacts of the non-cap-and-trade sector options, respectively.

» The production cost increase of the Ind-Other and TLU sectors due to the purchases of allowances in the auction market will cause a decrease in GDP of $43.6 billion and a decrease in employment of 438,000.

» Recycling of the auction revenue would generate an increase in GDP of $19.0 billion and an increase in employment of 240,000.

» The production cost increase of the TLU sectors resulted from the purchases of allowances from other capped sectors will result in a decrease in GDP of $33.7 billion and a decrease in employment of 341,000.

» The sales of allowances by the Com and Ind-EIS sectors will yield a $32.1 billion GDP increase and 314,000 more jobs.

Several findings are summarized for a comparison of the Stakeholder/Senate Scenario results and the Senate Scenario results:

» The Senate Scenario yields less positive impacts to the economy compared with the Stakeholder/Senate Scenario.

» The major positive impacts in both scenarios come from the implementation of the 23 super options. As expected, with scaled-back efforts of the 23 super options in the Senate Scenarios, the stimulus is lower.

» In the Stakeholder/Senate Scenario, since the 23 super options will be implemented in full under regulations, we assume that a sector cannot sell its excess reductions achieved from mitigation to other sectors. In the Senate Scenario, we assume that the excess reductions can be traded among the capped sectors. Therefore, compared with the Stakeholder/Senate Scenario, there will be more allowances transactions among the capped sectors and no allowance purchases from the international offset market in the Senate Scenario. Since the inter-sectoral trading will generate stimulus effects to the allowances selling sectors, while the international offset purchases will be a pure out-flow of money to outside of the country, the Senate Scenario results in higher stimulus effects in the inter-sectoral trading aspect.

» However, since the dominant economic impacts still come from the implementation of the 23 super options, the Senate Scenario results in an overall smaller stimulus impact to the economy than the Stakeholder/Senate Scenario. This is consistent with the findings associated with modeling regional and single-state cap-and-trade programs under state climate action plans. These analyses have found that price mechanisms alone do not access the lowest-cost mitigation options. Lowest-cost (or highest-savings) outcomes invariably require a blend of price and non-price measures, since price measures alone cannot resolve regulatory barriers and market failures, such as split incentives.

Table 3-16. Calculation Table of Stakeholder/Senate Scenario (Full Stakeholder Implementation Plus Cap-and-Trade), 2020 (all numbers are in $MMtCO_2e$)

Stakeholder/Senate Scenario		ES	Res	Com	Ind-Other	Ind-EIS	TLU	Total
1	2005 emissions	2,420	374	228	782	537	2,192	6,534
2	2020 baseline emission	2,633	363	255	800	549	2,331	6,932
3	2020 emissions caps: 83% of 2005 emissions level (row 2 × 83%)	2,009	310	189	649	445	1,820	5,423
4	Free-granted allowances	2,137	235	261	456	904	160	4,153
5	Emissions reductions or allowances needed to be acquired from either autarkic mitigation or allowance sources (e.g., auction market, offset market)[a] (row 2 – row 4)	497	129	–7	344	–354	2,171	2,779
6	Reductions from autarkic mitigation activities	1,090	368	387	144	99	364	2,452
7	Allowances bought from auction (=0 if row 6 > row 5)	0	0	0	200 (= row 5 – row 6)	0	925[b]	1,125
8	Allowance trading among sectors[c]	0	0	–7	0	–354	361	0
9	Domestic offsets	0	0	0	0	0	0	0
10	International offsets	0	0	0	0	0	615 (= row 5 – row 6 – row 7 – row 8)	615
11	Banked allowances	0	0	0	0	0	0	0

a Negative numbers in this row mean that the sector receives more free-granted allowances than its cap.
b Computed as the residual of all allowances available in the auction market and the allowances purchased by the Ind-Other sector.
c Negative numbers represent allowance sales; positive numbers represent allowance purchases.

Table 3-17. 2020 GDP and Employment Impacts of the Stakeholder/Senate Scenario

Mitigation Activities (23 super options)	Allowance Purchases from Auction	Allowance Auction Revenue Recycling	Sectoral Trading — Allowance Purchases	Sectoral Trading — Allowance Sales	International Offset Purchases	Total
2020 GDP Impacts (billions 2007$)						
$159.55	–$43.01	$19.01	–$13.07	$17.94	–$23.52	$116.90
2020 Employment Impacts (thousands)						
2,524	–432	240	–132	171	–238	2,132

Table 3-18. Calculation Table of Senate Scenario (Scaled-Back Stakeholder Implementation Plus Cap-and-Trade), 2020 (all numbers are in $MMtCO_2e$)

Senate Scenario		ES	Res	Com	Ind-Other	Ind-EIS	TLU	Total
1	2005 emissions	2,420	374	228	782	537	2,192	6,534
2	2020 baseline emission	2,633	363	255	800	549	2,331	6,932
3	2020 emissions caps: 83% of 2005 emissions level (row 2 × 83%)	2,009	310	189	649	445	1,820	5,423
4	Free-granted allowances	2,137	235	261	456	904	160	4,153
5	Emissions reductions or allowances needed to be acquired from either autarkic mitigation or allowance sources (e.g., auction market, offset market)[a] (row 2 – row 4)	497	129	–7	344	–354	2,171	2,779
6	Reductions from autarkic mitigation activities	671	227	238	88	61	224	1,509
7	Allowances bought from auction (=0 if row 6 > row 5)	0	0	0	256 (= row 5 – row 6)	0	870[b]	1,125
8	Allowance trading among sectors[c]	–175	–98	–245	0	–415	932	0
9	Domestic offsets	0	0	0	0	0	0	0
10	International offsets	0	0	0	0	0	0	0
11	Banked allowances	0	0	0	0	0	0	0

$MMtCO_2e$ = million metric tons carbon dioxide equivalent; ES = Electricity Supply sector; Res = Residential sector; Com = Commercial sector; Ind-EIS = Energy-Intensive Industrial sector; Ind-Other = Other Industrial sector; TLU = Transportation sector.
a Negative numbers in this row mean that the sector receives more free-granted allowances than its cap.
b Computed as the residual of all allowances available in the auction market and the allowances purchased by the Ind-Other sector.
c Negative numbers represent allowance sales; positive numbers represent allowance purchases.

Table 3-19. 2020 GDP and Employment Impacts of the Senate Scenario

Mitigation Activities (scaled-back implementation of the 23 super options)	Allowance Purchases from Auction	Allowance Auction Revenue Recycling	Sectoral Trading—Allowance Purchases	Sectoral Trading—Allowance Sales	Total
2020 GDP Impacts (billion 2007$)					
$76.86	–$43.60	$19.01	–$33.74	$32.08	$50.73
2020 Employment Impacts (thousands)					
1,147	–438	240	–341	314	922