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Analysis

Climate change and the economy in Baja California: Assessment of macroeconomic impacts of the State's Climate Action Plan

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ABSTRACT

Despite its developing country status, Mexico ranks 10th worldwide in total greenhouse gas (GHG) emissions. However, Mexico's vulnerability to climate change impacts is a major motivating factor behind its announced intended contributions at COP21 to cut its baseline emissions by at least 25% in 2030. We analyze the macroeconomic impacts of the Climate Action Plan (CAP) process undertaken in the Mexican border state of Baja California (BC). We adapt a state-of-the-art regional macroeconometric model to analyze the BC economy-wide impacts of 22 GHG mitigation policy options recommended in the Baja California CAP. The combined effects include an average annual increase of 1680 new jobs (or about 0.11% of the average annual employment in the baseline economic forecast) and a Gross State Product (GSP) increase of $9.85 billion pesos in NPV over the 2015–2030 planning horizon. Although the main objective of GHG mitigation is to reduce atmospheric concentrations, and hence future potential damages of these pollutants, the stimulus to the BC economy from the implementation of its CAP represents a valuable co-benefit. Moreover, it is a tangible one that will take place in the near-term, in contrast to the more long-term and more uncertain benefits associated with reducing climate change damages.

1. Introduction

In 2012, Mexico contributed approximately 1.6% of total global greenhouse gas (GHG) emissions, ranking 10th worldwide (WRI, 2015). Between 1990 and 2012, Mexico's total GHG emissions have increased from 477 million metric tons of CO_2 equivalent ($MMtCO_2e$) to 749 $MMtCO_2e$, or an increase of 57%, with an average annual increase of about 2.1% (WRI, 2015). Although Mexico only accounts for a small share of total global emissions, the country is an active participant in efforts to reduce its emissions. In March 2015, Mexico submitted its *Intended Nationally Determined Contribution* (*INDC*) to the UNFCCC announcing the country's unconditional and conditional GHG emission reduction targets. At the UN Conference of the Parties to the Framework Convention on Climate Change held in Paris in December 2016, COP21, the country volunteered to unconditionally cut 25% of its baseline emissions in 2030. Conditional on the progress of a global climate agreement that addresses issues such as international carbon pricing and availability of international support, including technology transfer and low-cost financial resources, the country could increase its reduction target to 40% (UNFCCC, 2015a; Averchenkova and Bassi, 2016). These goals will require structural transformation in national and regional development policy.

Mexico is ecologically vulnerable to climate change. Based on the projection by the Mexican Network of Climate Modeling, Mexico is likely to experience higher temperature increases than the global average increases in the future (Federal Government of Mexico, 2013). In the past decade, the country has suffered from an increasing number of climate change-related events, including floods, heatwaves, droughts, heavy rainfalls, landslides, etc. The economic damage caused by such extreme hydro-meteorological events increased from an average of about 700 million pesos yearly in the 1980s and 1990s to over 21 billion pesos in the past decade (Federal Government of Mexico, 2013).[1]

Given its developing country status, the Mexican government has recently begun to think strategically about economic development and poverty reduction. Legislation on social development in 2004 (Ley de Desarrollo Social, 2013) and the recent so-called structural reforms (Ramírez and Robles, 2013) attest to that effect. Although only less than 2% of people in Mexico live below the international poverty line set by

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[1] The annual average exchange rate between the Mexican peso and the U.S. dollar over the past five years was 14.052:1 (IRS, 2016).

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the World Bank, based on a more comprehensive assessment of poverty by the Mexican government that includes multiple dimensions such as social rights and living standards, 38% of the population (or 41.8 million people) lived in moderate poverty and 9.8% (or 11.5 million people) in extreme poverty in 2012 (Wilson and Silva, 2013). Evidence suggests that Mexico's vulnerability to climate change impacts, as well as its commitment to continued growth as an emerging economy, are the motivating factors behind a major institutional effort underway nationally.

Mexico is the only Non-Annex I nation to issue all of the five National Communications under the UNFCCC guidelines, including two National Climate Change Strategies, two special action plans, one national legislation, and several programs at the federal level (UNFCCC, 2015b). Although Mexico has significantly advanced its agenda on climate change, by the end of the last decade it became clear that actions and policy initiatives had focused only on the national level. Recognizing this, the National Institute of Ecology[2] (INE) determined that state climate change action plans would need to be implemented taking into account the economic, social, geographic and environmental specificities of each region in the country, with local stakeholders and policy makers involved in the regional plan development process. In turn, the INE began a process of capacity building and strengthening on issues of climate change at the subnational level. The most important accomplishment of this strategy was the development of the State Climate Action Plans (PEACC, the acronym in Spanish). By 2012, out of the 32 states, 29 PEACCs, 26 state inventory and forecasts (I&F), and 28 state climate change scenarios had been created, and 15 studies on the impact of climate change on water quality had been conducted.

In this paper, we examine the macroeconomic impacts of the Climate Action Plan (CAP) process undertaken in Mexico's state of Baja California. Baja California (BC) is one of the U.S.-Mexico border states where the binational Border Environment Cooperation Commission (BECC) is building partnerships with experts, academics and state government officials to adapt international CAP methodologies to local conditions. The international border region of Mexico is one of the most economically dynamic regions of the World and strategic not only to Mexico but to the North American Partnership as well. In order for the climate strategy to maintain momentum across changing administrations, those who design policies and implement them are placing greater emphasis on policy relevance, economic stimuli, and cost-effective measures that will create the necessary incentives for state and local government. The importance of this strategy is outlined in this paper through the refinement of an economic model to assess the macroeconomic impact of the Baja California Climate Action Plan in order to facilitate the formulation of useful policy recommendations.

We apply, in an innovative manner, the Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI^+) Model, to analyze the macroeconomic impacts of the Baja California Climate Action Plan. Although the REMI Model has been applied to analyze the economic impacts of climate action plans in several states and regions in the U.S., this is the initial effort at applying the REMI Model to evaluate a climate action plan outside the US; thus, a particular focus of this study is to design the policy analysis to apply to special considerations of the developing region. This paper also represents a contribution to the literature by invoking the "Custom Industry" feature of the Model for the first time to evaluate a climate action plan. Furthermore, the methods we developed using the "Custom Industry" function will prove useful for other users as they can adapt the REMI Model to other developing regions of the World, where greater likelihood exists that data shortcomings will necessitate this remedy as well. Finally, great efforts went into collecting and refining microeconomic data on individual mitigation options (unique to Baja California), and carefully translating these micro level data into the REMI Model inputs, which have significant bearing on the accuracy of the results.

The rest of this paper is structured as follows: In Section 2, we provide an introduction to the climate action planning process in Baja California, including a summary of the microeconomic analysis results of the mitigation policy options recommended in the BC climate action plan. In Section 3, we introduce the REMI Regional Macroeconometric Model, followed by a description of how we translate the micro level analysis results to REMI policy levers and related economic drivers. A list of major assumptions used in the REMI simulations is also presented. In Section 4, we present and discuss the simulation results, which include both aggregate and sectoral impacts, as well as the sensitivity analysis results. The paper concludes with a discussion of policy implications in Section 5.

2. Climate Action Planning in Baja California

2.1. Socioeconomic Conditions of Baja California

With a population of 3.43 million, Baja California accounts for 2.9% of the total population in Mexico in 2014 (CityPopulation, 2015). The Gross State Product (GSP) of Baja California exceeded 437 billion pesos (about $34 billion USD) in 2013, representing 2.8% of the national total. The primary industry (Agriculture and Forestry) only accounts for 3.2% of the state GSP. The secondary industry (including mining, utilities, construction and manufacturing) and tertiary industry (including various types of service activities) account for 35.5% and 61.3% of the state GSP in 2013, respectively (ProMexico, 2015). In 2014, the average salary payment per day in BC was $268.1 pesos, which was lower than the national average of $282.1 pesos. In addition, there is a large variation in the average salary payment across sectors, ranging from $165.6 pesos per day for the Ag, Forestry, Fishing and Hunting sector and $205 pesos for Construction sector to $727.7 pesos for Utility sector (ProMexico, 2015). Baja California used to be among the group of states that have high unemployment records in Mexico (Mngcornaglia, 2013). However, in the first quarter of 2015, the unemployment rate in BC has decreased to 4.1%, which was slightly lower than the national average of 4.2% (INEGI, 2015).

Based on the most comprehensive assessment to date, the GHG emission inventory of Baja California conducted by the Border Environment Cooperation Commission (BECC) and the Center for Climate Strategies (CCS), Baja California generated approximately 15.8 $MMtCO_2$ emissions in 2005, which represents about 2.4% of Mexico's total GHG emissions (BECC and CCS, 2010). From 1990 to 2005, the state gross consumption-based GHG emissions increased by 112%, while the national emissions only increased by about 31%. The two primary drivers of Baja California's fast growing emissions were electricity consumption and transportation activities. It is projected that the state gross GHG emission will continue to grow to 26.5 MMt CO_2 by 2025, an increase of 294% over the 1990 level. The transportation sector is projected to be the largest contributor to future state emission growth, followed by electricity consumption. By 2025, these two sectors will account for 44% and 36% of the total state gross emissions, respectively (BECC and CCS, 2010).

2.2. The Two-Phase Climate Action Planning Process in Baja California

Baja California has undertaken various efforts to reduce GHGs. In 2012, the Law on Prevention, Mitigation and Adaptation of Climate Change for the State (LPMACC) was enacted and in 2014 a council to address climate change was established.

From 2008 to 2012, Baja California's State Environmental Protection Agency (SPA, Spanish acronym of Secretaria de Protección al Ambiente)

[2] On June 6, 2012, Mexico's General Law on Climate Change was enacted, which created the National Institute of Ecology and Climate Change (INECC). Shortly thereafter, the INE became the INECC.

led the first phase of the State's Climate Action Plan (CAP) development, with the support of three institutions of higher education,[3] three federal authorities,[4] and a binational environmental cooperation agency set up by both countries. Key achievement from the first phase of the program include: 1) an Inventory and Forecast (I&F) of GHG emissions; 2) an analysis of regional climate scenarios; 3) an assessment of possible impacts and vulnerability; 4) identification of more than 100 actions in mitigation and adaptation; and 5) several elements of cross-cutting policies. The first phase of the program was facilitated by the Center for Climate Strategies (CCS), a non-profit organization based in Washington D.C. that has facilitated more than twenty states in the U.S. in the development of state climate action plans.

The second phase of the Baja California CAP process commenced in 2013. A short list of 26 prioritized mitigation policies were selected from the first phase. The second phase starts with the comprehensive design of each selected mitigation policy. The main objective of the second phase is to develop a state CAP for BC that includes quantitative evaluations of the microeconomic and macroeconomic impacts of each policy. An additional goal is to enhance state capacity in climate planning and analysis through a capacity building process.[5]

2.3. Microeconomic Impacts of the Baja California CAP

Table 1 summarizes the microeconomic impacts (GHG mitigation potentials and costs/savings) of the GHG mitigation and sequestration options recommended and quantitatively analyzed in BC CAP, which are categorized into five sectors: Energy Supply (ES) Sector, Residential, Commercial, Institutional and Industrial (RCII) Sector, Transportation and Land Use (TLU) Sector, Agriculture, Forestry, and Other Land Uses (AFOLU) Sector, and Waste Management (WM) Sector. In total, the 26 quantified policy options are estimated to reduce 49 $MMtCO_2e$ GHG emissions and at the same time generate over $28 billion (in 2012 Mexican pesos; or about $2 billion USD) cost savings in net present value (NPV) terms during the 2015–2030 period. The weighted average cost-effectiveness of the options (calculated as the ratio of NPV of total net costs over total emission reductions over the planning period) is minus $575 pesos per $MMtCO_2e$ emissions removed. The minus sign indicates that the implementation of these GHG mitigation options on average would yield overall cost savings.

Fig. 1 shows the marginal mitigation cost curve for BC in Year 2030, developed based on the data presented in Table 1. In the figure, the horizontal axis represents the cumulative reduction potentials from various mitigation policy options in 2030 with respect to the baseline total GHG emissions. The vertical axis represents the per ton cost of GHG reduction. Each horizontal segment represents an individual policy option. To develop the marginal mitigation cost curve, policy options are first ordered from the lowest cost one to the most costly one. According to the marginal cost curve, if all of the mitigation policies presented in Table 1 are successfully implemented, they can help reduce over 15% of total baseline emissions in BC in 2030. More than an 8% reduction can be achieved from cost-saving mitigation options.

3. Methodology of Macroeconomic Impact Analysis on Baja California CAP

3.1. Introduction of Baja California REMI PI$^+$ Model

The microeconomic analysis of the BC's CAP only estimated the direct costs and savings incurred to the sectors that are directly involved in the implementation of these mitigation options. The indirect impacts that are generated through the interdependencies of the sectors and the interactions of supply and demand in various markets are the focus of the macroeconomic impact analysis. In this study, we adapt the Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI$^+$) Model to estimate the macroeconomic impacts of BC's State CAP.

We chose to use the REMI PI$^+$ Model for several reasons: 1) it has many preferable features compared to the other candidate models, such as input-output, computable general equilibrium (CGE), and mathematical programming models (see, e.g., Rose and Miernyk, 1989; Partridge and Rickman, 2010), especially in terms of its forecasting ability, which is important when we analyze the economic impacts of climate change policies over the 15-year planning horizon; 2) it is comparable to CGE models in terms of analytical power, accuracy, and transparency, which we considered to be the three overriding criteria; 3) the research team has successfully applied the REMI Model in similar analyses in many states of the U.S., including Florida, Michigan, Wisconsin, Pennsylvania, New York and California (Miller et al., 2010; Rose et al., 2011; Wei and Rose, 2011; Rose and Wei, 2012; Wei and Rose, 2014). The research team has also facilitated capacity building in China with the use of the REMI Model to analyze the macroeconomic impacts of sub-national low-carbon development plans.

The REMI PI$^+$ Model is a standardized modeling system of equations based on econometric estimation using both national and region-specific data. The Model has been widely used in the U.S. at the state and local levels for a variety of policy applications including fiscal, energy, transportation, and environmental initiatives. In recent years, REMI has developed its REMI PI$^+$ Model for many countries, including China, Korea, Brazil, Mexico, Italy, Spain, and others.

Most macroeconometric forecasting models are based on a “top-down” approach beginning with aggregate relationships such as production, consumption and investment. REMI is more balanced and also includes a “bottom-up” approach for key economic relationships such as input combinations in production, based on input-output (I-O) account data. At its core, the Baja California REMI Model uses a 32-industry I-O model developed based on the data found in the World Input-Output Database (WIOD).[6] With the I-O inter-industry relationships at its core, the Model is able to analyze the interactions between sectors (ordinary multiplier effects). However, REMI overcomes many of the limitations of the standard I-O model by capturing the effects of price changes and behavioral adjustment of businesses and households in response to changes in price and other market signals in product markets (REMI, 2016a; Rose and Wei, 2012). The REMI model also includes aspects of the workings of capital and labor (factor) markets, as well as competitiveness through changes in market shares in relation to trade

[3] The three institutions of higher education are: Centro de Investigación Científica y Educación Superior de Ensenada (Center for Scientific Research and Higher Education of Ensenada, or CICESE), the Autonomous University of Baja California (UABC), and El Colegio de la Frontera Norte (College of the Northern Border, COLEF).

[4] The three federal authorities are: Ministry of Environment and Natural Resources (SEMARNAT), the National Institute of Ecology and Climate Change (INECC) and the Border Environment Cooperation Commission (BECC).

[5] To achieve the objective of capacity development, SPA, BECC and WWF determined that El Colegio de la Frontera Norte (El Colef), a regional U.S./Mexico Border Public Research Center of the Mexican National Council of Science and Technology, rather than SPA, would be the entity to host the Panel of Experts (PE) and to receive the training for micro-economic and macro-economic analysis. The training was provided by the Center for Climate Strategies on the micro-economic analysis and by University of Southern California on the macro-economic impact modeling.

[6] The Mexico Input-Output matrices used to develop the BC REMI Model are obtained from the World Input-Output Database (WIOD). The WIOD project was originally funded by the European Commission as part of the 7th Framework Programme. The development of the World and national input-output tables was under Theme 8 of the Programme: Socio-Economic Science and Humanities. WIOD provides national Input-Output tables for the time period from 1995 to 2011 for 27 EU countries and 13 other major countries around the world (WIOD, 2014). The construction of the WIOD I-O tables is based on official national statistics and data obtained from National Accounts of each country. First, the national Supply and Use Tables (SUTs) are used as the core data of developing the I-O tables. Second, the National Accounts are used as the benchmark. Finally, time series data on industrial output and value added, imports and exports, as well as final demand by consumption category were obtained from the National Accounting Statistics to generate the time series of SUTs (Dietzenbacher et al., 2013).

Table 1
Summary of microeconomic impacts of Baja California's CAP.

Policy ID	Policy name	2020 Annual reductions ($TgCO_2e$)	2030 Annual reductions ($TgCO_2e$)	Cumulative 2015–2030 ($TgCO_2e$)	NPV costs/savings 2015–2030 (millions of 2012 pesos)	Cost-effectiveness ($2012 pesos/$tCO_2e$)
ES-1	Micro-hydro renewable energy	0.047	0.065	0.78	$231	$294
ES-2	Energy supply diversification	0.94	1.3	16.0	$6814	$425
ES-3	Distributed energy supply for building	0.013	0.019	0.22	$6.9	$31
ES-4	Photovoltaic panel electricity generation	0.018	0.025	0.30	$150	$505
Energy supply (ES) sector totals		**1.0**	**1.5**	**17**	**$7201**	**$415**
RCII-1	Energy efficiency: residential shell improvement	0.019	0.019	0.26	−$309	−$1172
RCII-2	Energy efficiency: new housing appliances	0.016	0.016	0.43	−$290	−$675
RCII-3	Energy efficiency: existing buildings	0.58	0.58	8.2	−$10,952	−$1342
RCII-4	Finance incentives for machinery energy efficiency in industrial sector	0.27	0.73	6.1	−$11,771	−$1915
RCII-5	Solar water heaters on housing	0.44	0.44	6.1	−$8800	−$1435
RCII-6	Flow water heaters for residential sector	0.14	0.14	2.0	−$3095	−$1559
Residential, commercial, institutional and industrial (RCII) sector totals		**1.5**	**1.9**	**23**	**−$35,217**	**−$1523**
TLU-1	Black carbon control measures	0.046	0.000	0.30	$60	$196
TLU-2	Alternative fuels	0.03	0.08	0.77	−$188	−$242
TLU-3	On-road fleet efficiency	0.00	0.01	0.07	−$81	−$1150
TLU-5	Smart growth planning	0.011	0.036	0.28	−$480	−$1716
TLU-6	Energy efficient government fleet	0.000084	0.00011	0.0015	$2.3	$1609
Transportation and land use (TLU) sector totals		**0.10**	**0.12**	**1.4**	**−$686**	**−$480**
AFOLU-1	Manure management: non-dairy livestock	0.00037	0.00037	0.0048	$3.4	$714
AFOLU-2	Manure management: dairies	0.020	0.021	0.27	$31	$117
AFOLU-3	Utilization of wheat straw	GHG reductions and costs are reported with the ES-2 policy totals.				
AFOLU-4	Bioethanol production from Sorghum	GHG reductions and costs are reported with the TLU-2 policy totals.				
AFOLU-5	Livestock grazing management	0.07	0.12	1.31	$1117	$855
AFOLU-6	Urban forestry	0.00005	0.0006	0.0034	$17	$5514
Agriculture, forestry, and other land uses (AFOLU) sector totals		**0.090**	**0.14**	**1.58**	**$1169**	**$739**
WM-1	Landfill gas management	0.27	0.32	3.9	$258	$67
WM-2	Indirect potable water *re*-use	0.025	0.035	0.43	−$226	−$532
WM-3	Water reclamation	0.041	0.071	0.76	−$415	−$545
WM-4	Biodiesel production	GHG reductions and costs are reported with the TLU-2 policy totals.				
Waste management (WM) sector totals		**0.34**	**0.43**	**5.1**	**−$383**	**−$76**
Total integrated plan results		**3.0**	**4.1**	**49**	**−$27,916**	**−$575**

Source: CCS (2014).

with other Mexican states and other countries (Treyz, 1993; REMI, 2016b). The spatial dimension of the model is further enhanced by the introduction of New Economic Geography elements. Accessibility to labor and intermediate production inputs are important economic factors that affect the productivity and competitiveness of local industry. The economic geography equations in REMI can analyze the changes in labor productivity, labor access and commodity access and their implications for changes in economic activity across regions.

As a regional macroeconometric model, advanced statistical techniques are used to estimate the key parameters of the equations and the model responses to external shocks in REMI. The econometric features of the REMI Model provides them better capability in extrapolating into the future course of the regional economy (Treyz, 1993).

A more detailed description of the major features of the REMI Model is presented in Appendix A. The readers are referred to REMI (2016b) for the full list of model equations.

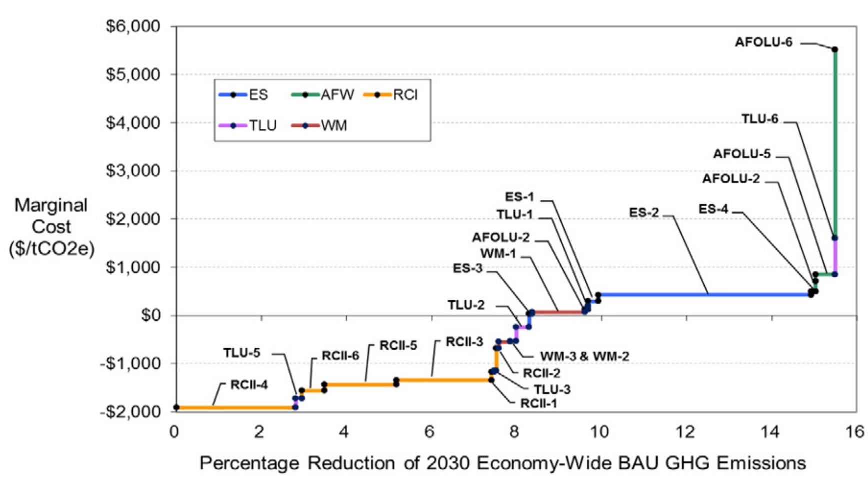


Fig. 1. Marginal GHG mitigation cost curve for Baja California, 2030.

3.2. Disaggregation of the Utility Sector in the Baja California REMI Model

A major refinement we made to the BC REMI Model is to disaggregate the utility sector into three sub-sectors using the Custom Industry (CI) Function provided in the REMI Model. In the WIOD input-output table, electric power generation, natural gas distribution, and water treatment and supply are aggregated into one single utility sector. It is very essential to have the three sectors separated since many GHG mitigation policy options incur direct impacts to one specific utility sub-sector or to more utility sub-sectors in different ways. For example, the Energy Supply Diversification policy results in impacts on the capital, O&M, and fuel costs of the power generation sector, and can also impact the natural gas supply sector if natural gas is used as the fuel of the displaced generation technology.

The CI Function in the REMI Model allows the user to begin from a base sector in the existing I-O table in the Model and to completely customize the relevant column I-O vector, productivity, and compensation rate to create sectors at a finer level of the base sector. In our case, we start from the utility sector and created three sub-sectors of electric power generation, natural gas distribution, and water treatment and supply. We obtained the relevant information of each disaggregated utility sector from the 170-sector detailed I-O table constructed by Mexico National Institute of Statistics, Geography and Informatics (INEGI). After the establishment of the CI sectors, we can introduce shocks on these CI sectors to the model. This helps address the concern with having an aggregate sector when we need to consider the operation of one or more of its subsectors. The enhanced model is able to trace the impact of the CI on the remainder of the economy being modeled, including feedback effects. With the incorporation of the detailed technical coefficient vector of the custom industry, shocks to this new industry create the first round of effects for output, employment, compensation, and intermediate demand. Then successive rounds of backward (demand-side) impacts are calculated based on the normal I-O approach.

3.3. Preparation of the Input Data

The major inputs we used in the REMI macroeconomic impact analysis are the micro-level quantification results of each individual policy option (including, for instance, the changes in capital cost, O&M cost, administrative cost, fuel expenditures of the sectors that are directly involved in the implementation of the mitigation policy options). We then carefully map these micro-level effects to proper economic variables in the REMI Model to simulate the indirect and total impacts of the policy options. In Table 2, Policy Option RCII-3 Energy Efficiency Expansion in Existing Buildings is used as an example to illustrate how the microeconomic quantification results of the mitigation options are translated into REMI economic variable inputs. Similar mapping tables are provided for one example policy option from each sector in Appendix B.

In Table 2, the first column shows the micro analysis results for different types of direct impacts (or “shocks”) of this mitigation option according to their applicability to business (commercial and industrial) sectors and the household (residential) sector. The direct impacts are also categorized in terms of whether they are expected to generate positive or negative impacts to the economy. The second column presents the corresponding economic variables in the REMI PI$^+$ Model and indicates their position within the Model (i.e., in which one of the five model blocks in REMI, as presented in Appendix A, the policy variables can be found). Table 2 shows that there can be cases in which different categories of direct costs or savings are simulated using the same economic variable for one specific sector in REMI, and the effects can be in different directions. When we perform the economic impact analysis for each individual policy option in the REMI Model, we enter all the shocks to the policy variables (as listed in the second column of Table 2) simultaneously in one single simulation. If one economic variable (such as the Sales of the Electric Power Generation, Transmission, and Distribution Sector in the example in Table 2) is being shocked more than once in the simulation, the model will first calculate the simple sum of

Table 2
Mapping RCII-3 energy efficiency expansion in existing buildings into REMI inputs.

Direct (microeconomic) impacts	Economic variables in REMI
1. Capital investment on energy efficiency	
1a. Positive effects:	
Increased demand of energy efficient equipment/appliances	Output and demand block → exogenous final demand (amount) for construction, machinery, and electrical and optical equipment sectors → increase
Increased demand of financing services	Output and demand block → exogenous final demand (amount) for financial intermediation sector → increase
1b. Negative effects:	
Increased levelized capital cost to business sectors	Compensation, prices, and costs block → capital cost (amount) of individual commercial sectors → increase
Increased levelized capital cost to households	Output and demand block → consumption reallocation (amount) → all consumption sectors → decrease
2. Administrative cost	
2a. Positive effects:	
Increased demand of program administrative services	Custom industry → sale for electric power generation, transmission, and distribution sector → increase
2b. Negative effects:	
Increased administrative cost of businesses	Compensation, prices, and costs block → capital cost (amount) of individual commercial sectors → increase
Increased expenditure on utility administrative service by households	Output and demand block → consumption reallocation (amount) → all consumption sectors → decrease
3. Reduction in consumption of electricity and fuels	
3a. Positive effects:	
Electricity and fuel savings for businesses	Compensation, prices, and costs block → production cost of individual commercial sectors → decrease
Electricity and fuel savings for households	Output and demand Block → consumption reallocation (amount) → all consumption sectors → increase
3b. Negative effects:	
Reduced demand of electricity	Custom industry → sale for electric power generation, transmission, and distribution sector → decrease
Reduced demand of other fuels	Output and demand block → exogenous final demand (amount) for coke, refined petroleum and nuclear fuel sector → decrease

the positive and/or negative changes to the variable entered into the model, and then use the net change of value as the shock to the variable.

3.4. Major Modeling Assumptions

In addition to the micro-level analysis results that are used as the basis of inputs to the macroeconomic modeling, we also obtain additional data and make supplementary assumptions in the REMI simulations where there is a lack of information or there are uncertainties about the key variables from the micro analysis. The major assumptions we adopted are listed below, many of which are general assumptions that have been used in similar studies (e.g., Miller et al., 2010; Rose et al., 2011; Wei and Rose, 2011; Rose and Wei, 2012; Wei and Rose, 2014). Appendix Table C1 presents those assumptions that are tailored to individual GHG mitigation/sequestration options of Baja California.

1. We assume that none of the in-region private capital investment in GHG mitigation will displace (reduce) ordinary private investment in plant and equipment. In other words, 100% of the GHG mitigation investment is additive to the State's economy. This stems from the fact that many of the options pay for themselves, as shown by the segment of the abatement cost curve below the zero cost line (See Fig. 1), have incentives provided by government programs already underway (including the Federal Expenditure Budget created for GHG mitigation and adaptation to climate change and the National Climate Change Fund), involve zero debt financing for government, or receive international financial support. For example, in 2014, Mexico received $686.15 million dollars in international climate change financing, second only to Brazil. In addition, 85% of the amount went to GHG mitigation policies (CEMDA, 2015).
2. We assume capital investment in electricity generation splits between construction and purchases of generating equipment. A split of 40/60 is used for large power plants such as liquefied natural gas (LNG)-fired power plants, and 20/80 is used for smaller installations (such as most of renewable electricity generation).
3. In the Base Case analysis, we assume that the percentage of in-state supply of renewable electricity generation equipment and energy-efficient equipment and appliances equals the default Regional Purchase Coefficients (RPCs) for the relevant equipment manufacturing sectors in BC provided in the REMI Model.
4. Based on the baseline forecast conducted by the micro analysis team, on average, about 8.5% of the electricity consumed in Baja California will be imported during the planning period. This indicates that the RPC of the electricity generation sector of BC is about 91.5%. However, the power company in BC is a federal agency. Therefore, part of the direct impacts from the reduction of output and labor income in the electricity generation sector (due to electricity savings from the GHG mitigation options) will leak to outside of the state (shouldered by México City for example). To reflect this, we used an RPC of 80% for the electricity generation sector in BC.
5. For some of the RCII options, we distributed the costs and savings of the aggregated commercial and industrial sectors from the micro analysis among the 32 REMI sectors using baseline sectoral gross output as weights.
6. Other assumptions for individual policy options, especially for funding sources, are presented in Appendix Table C1. When we examine the funding sources for the mitigation policy options, we take into consideration the following possibilities: 1) whether the mitigation investment comes from in-state vs. out-of-state sources; 2) for in-state investment, whether it is covered by government funding or private investment; 3) for in-state private investment, whether it is covered by debt financing or equity; 4) for in-state government funding, whether it comes from existing programs and ongoing funding or it will be raised through tax increases or the displacement of other general government expenditures. Mitigation policy options that depend on different funding sources or different financing mechanisms are simulated differently in the REMI Model. For example, policy options that receive out-of-state funding or in-state government funding from existing programs will only generate stimulus impacts to the state economy through the mitigation investment. The sectors that implement the mitigation projects will not incur any increased capital cost because of the mitigation investment. However, for policy options that require debt financing to cover the initial investment, the sectors that invest in the mitigation projects will incur increased capital cost. For mitigation options that receive state funding not included in existing programs or budget, we simulate a corresponding reduction in other government general expenditures in the REMI Model. The detailed assumptions on funding sources for each individual policy option presented in Appendix Table C1 are largely based on the judgments of the Panel of Experts.

4. Macroeconomic Impact Analysis Results

4.1. Basic Aggregate Results

4.1.1. Macroeconomic Impacts of Individual Policy Options/Policy Bundles

Table 3 presents the results of the GSP impacts and employment impact analysis for the 22 policy options or policy bundles. The numbers in the left section of Table 3 represent the difference between the GSP computed under the Climate Action Plan and the GSP in the baseline (the level of economic activity that is projected to be forthcoming in the absence of the implementation of the recommended policies). The GSP impacts are presented for both key years (in terms of impact in those years) and the net present value (NPV) over the entire planning period. The employment impacts are presented in the right section of Table 3. The results are also presented for the key years and for an average job impact over the planning period in the last column. In terms of employment impacts of average jobs per year, 10 out of the 22 policies/policy bundles are estimated to yield positive impacts. In terms of the NPV of GSP impacts, 9 out of the 22 policies/policy bundles are estimated to results in positive impacts.

Finance Incentives for Machinery Energy Efficiency in Industrial Sector (Policy Option RCII-4 in Table 1) results in the highest positive impacts on the economy—an NPV of $10.4 billion pesos gains in GSP and an average annual increase of about 2394 jobs. In 2030, the GSP increase resulted from this policy option is estimated to be $2.6 billion pesos, or an increase of 0.23% from the baseline level. The employment is estimated to increase by 5.4 thousand jobs, or an increase of 0.31% from the baseline level. This is a highly relevant policy for the state, as the share of the manufacturing sector in the gross output for the state's economy is 57.6%, compared to 48.2% nationally, as reported in the 2014 Economic Census, by the National Institute of Statistics, Geography and Informatics (INEGI). There are two major causes of the positive economic impacts of this option. First, the investment in energy-efficient industrial equipment and machinery, amounting to about $400 million pesos each year, generates considerable stimulus effects to the relevant manufacturing sectors in the state. Second, electricity savings resulting from energy efficiency improvement will steadily increase over the years as higher proportion of the old and high energy-intensive machinery is replaced by more efficient ones. By the end of the project period (i.e., 2030), electricity savings of more than $3.4 billion pesos can be achieved each year through this policy option. The positive economic impacts generated from these two factors more than offset the negative impacts from increased capital costs of the industrial sectors investing in the project and the reduced demand and thus production level of the power generation sector.

The policy bundle of Energy Supply Diversification and Utilization of Wheat Straw (the combination of policy options ES-2 and AFOLU-3 in Table 1) yields the highest negative impacts on the economy—an NPV of $3.0 billion pesos decrease in GSP and a loss of 773 jobs per year. In 2030, the decreases in GSP and employment stemming from the

Table 3
Gross state product and employment impacts (Difference from baseline levels).

	GSP impacts (millions of 2012 Pesos)					Employment impacts (number of jobs)				
Policy option	2015	2020	2025	2030	NPV	2015	2020	2025	2030	Jobs/Year
ES-1	$0	−$11	−$219	−$201	−$751	0	−31	−338	−251	−134
ES-2/AFOLU-3	$0	$908	−$2669	−$2446	−$3034	0	1683	−4451	−3228	−773
ES-3	$0	$31	−$54	−$53	−$25	0	56	−67	−55	−2
ES-4	$0	$47	−$62	−$59	$38	0	79	−80	−64	3
Subtotal - ES	***$0***	***$975***	***−$3004***	***−$2760***	***−$3772***	***0***	***1787***	***−4936***	***−3598***	***−905***
RCII-1	$3	−$10	−$21	−$25	−$122	14	1	−20	−19	−7
RCII-2	$2	−$4	−$12	−$15	−$59	6	5	−5	−7	0
RCII-3	$142	$67	−$141	−$242	−$92	354	379	20	−54	165
RCII-4	$0	$627	$1605	$2591	$10,401	0	1397	3474	5423	2394
RCII-5	$208	$346	$131	$104	$2238	302	439	110	62	216
RCII-6	$120	$256	$147	$119	$1797	187	379	197	138	225
Subtotal - RCII	***$475***	***$1282***	***$1710***	***$2534***	***$14,163***	***863***	***2600***	***3776***	***5543***	***2994***
AFOLU-1	$0	$0	$0	−$1	−$5	0	−1	−1	−1	−1
AFOLU-2	$0	$22	−$10	−$7	$6	0	33	−2	6	6
AFOLU-5	$0	−$83	−$15	$58	−$298	0	−464	−290	−46	−247
AFOLU-6	$0	$0	−$1	−$1	−$6	0	0	−1	−2	−1
Subtotal - AFOLU	***$0***	***−$61***	***−$26***	***$48***	***−$303***	***0***	***−432***	***−294***	***−43***	***−242***
WM-1	$0	−$63	−$102	−$71	−$456	0	−116	−176	−94	−84
WM-2	$0	−$2	$10	$19	$40	0	0	14	24	8
WM-3	$0	$43	$53	$96	$496	0	41	44	82	45
Subtotal - WM	***$0***	***−$22***	***−$39***	***$44***	***$79***	***0***	***−75***	***−118***	***12***	***−31***
TLU-1	$0	−$1	$0	$0	−$4	0	−3	−3	1	−1
TLU-2/AFOLU-4/WM-4	$0	−$76	−$154	−$204	−$662	0	−157	−333	−412	−166
TLU-3	$0	$14	$17	$19	$134	0	22	25	25	20
TLU-5	$11	$28	$44	$58	$330	32	55	71	83	58
TLU-6	−$1	$0	$0	$0	$0	−1	0	1	0	0
Subtotal - TLU	***$10***	***−$35***	***−$92***	***−$127***	***−$202***	***31***	***−83***	***−240***	***−303***	***−90***
Summation total	**$486**	**$2140**	**−$1451**	**−$261**	**$9967**	**894**	**3797**	**−1812**	**1611**	**1726**
Simultaneous total	**$486**	**$2141**	**−$1475**	**−$311**	**$9853**	**894**	**3794**	**−1881**	**1470**	**1680**

implementation of this policy bundle are estimated to be $2.4 billion pesos and 3.2 thousand jobs, respectively, which represent reductions of 0.22% and 0.18% from the respective baseline levels. The large negative economic impacts of this policy option mainly stem from the high capital investment cost that is required for the construction of the renewable (including bioenergy, solar, wind, etc.) electricity generation plants compared to the avoided costs of operating the fossil fuel power plants they displace.

From a sectoral standpoint, the Residential, Commercial, Institutional, and Industrial (RCII) options are estimated to result in the highest aggregate positive impacts on the Baja California economy, with Machinery Energy Efficiency in Industrial Sector (RCII-4) contributing for 73% of the GSP gains and nearly 80% of the employment gains. Energy Supply (ES) options are expected to result in the highest negative macro impacts on the Baja California economy, with Energy Supply Diversification and Utilization of Wheat Straw (policy bundle ES-2 and AFOLU-3) accounting for 80% and 85% of the GSP and employment losses. The Waste Management (WM) options aggregately are estimated to generate slight positive economic impacts, while the Agriculture, Forestry, and Other Land Uses (AFOLU) and Transportation policies/policy options are estimated to generate slight negative economic impacts, respectively. The major reason for the negative impacts of the energy supply options is the high capital cost of renewable alternatives compared with the displaced technologies. The major option that leads to the overall negative impact from the Transportation sector is the policy bundle of Alternative Transportation Fuels Use and Production (which is the combination of policy options TLU-2, AFOLU-4, and WM-4). This is largely because of the high capital and operating costs associated with the bioethanol production from sweet sorghum.

Macroeconomic impacts of the GHG mitigation and sequestration policy options in the BC CAP are in general similar to those found in our previous studies focusing on the economic impacts of CAPs developed in U.S. states (Miller et al., 2010; Rose et al., 2011; Wei and Rose, 2011; Rose and Wei, 2012; Wei and Rose, 2014). Energy efficiency and industrial process improvements generate net positive impacts on the economy because the savings from reduced energy expenditures help lower the production cost of businesses and increase the purchasing power of households, and those savings more than pay back the increased capital investment needed for the energy efficiency improvements. In our previous studies, we found that renewable and alternative energy supply is likely to generate positive economic impacts in some of the U.S. states, such as Florida and even in Michigan (Rose and Wei, 2012; Miller et al., 2010), but this was under conditions of relatively high gas prices prevailing in 2009–10 and projections into the future on that basis. In our recent study for Southern California, as well as this study for Baja California, we found negative impacts from the RPS (or the ES-2 Energy Supply Diversification policy option in BC CAP). Another important factor explaining the less attractive macroeconomic performance of the renewable and alternative energy supply options is that projections of capital and operating costs of renewable electricity generation are not expected to decline as much as in previous forecasts (Wei and Rose, 2014).[7]

4.1.2. Integrated Analysis of all Policy Options/Policy Bundles

The last row in Table 3 presents the integrated macroeconomic impacts of the 22 policy options/policy bundles. Table 4 presents the more detailed results of this simultaneous simulation in terms of both the value and percentage impacts. Fig. 2 presents the yearly GSP and employment impacts. The simultaneous simulation is conducted as a

[7] Note that the estimates of economic impacts of the mitigation options do not include the ecological efficiency of these options (such as the avoided negative environmental and social impacts resulting from continued GHG emissions and the associated emissions of ordinary pollutants from combustions of fossil fuels). In a policy evaluation to determine the prioritization of the mitigation policy options, the ecological benefits of the options should also be considered, such that, in an optimal policy mix, policy options with high costs would still likely be attractive if they contribute significant ecological benefits.

Table 4
Integrated macroeconomic impacts of all policy options/policy bundles.

Differences from baseline level						
Variable	Units	2015	2020	2025	2030	Jobs/Yr/NPV
Total employment	Jobs	894	3794	−1881	1470	1680
Gross domestic product	Millions of fixed (2012) pesos	486	2141	−1475	−311	9853
Output	Millions of fixed (2012) pesos	930	4262	−2613	46	21,004
Disposable personal income	Millions of fixed (2012) pesos	274	1701	94	1040	11,367
PCE-price index	2009 = 100 (Nation)	−8	−73	−209	−266	N/A
Baseline plus addition of the policy						
Variable	Units	2015	2020	2025	2030	
Total employment	Jobs	1,382,763	1,506,728	1,620,484	1,765,949	
Gross domestic product	Millions of fixed (2012) pesos	733,967	869,858	1,032,077	1,233,786	
Output	Millions of fixed (2012) pesos	1,493,397	1,791,123	2,152,880	2,605,516	
Disposable personal income	Millions of fixed (2012) pesos	414,410	498,166	602,587	736,114	
PCE-price index	2009 = 100 (Nation)	125	144	162	183	
Percent change from baseline level						
Variable	Units	2015	2020	2025	2030	
Total employment	Jobs	0.0647%	0.2525%	−0.1159%	0.0833%	
Gross domestic product	Millions of Fixed (2012) pesos	0.0663%	0.2467%	−0.1428%	−0.0252%	
Output	Millions of fixed (2012) pesos	0.0623%	0.2385%	−0.1212%	0.0017%	
Disposable personal income	Millions of fixed (2012) pesos	0.0661%	0.3427%	0.0156%	0.1416%	
PCE-price index	2009 = 100 (Nation)	−0.0056%	−0.0459%	−0.1163%	−0.1305%	

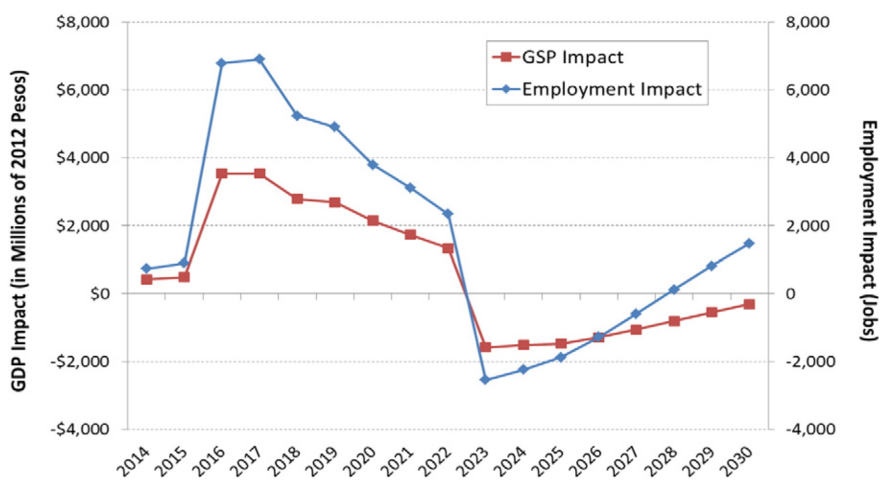
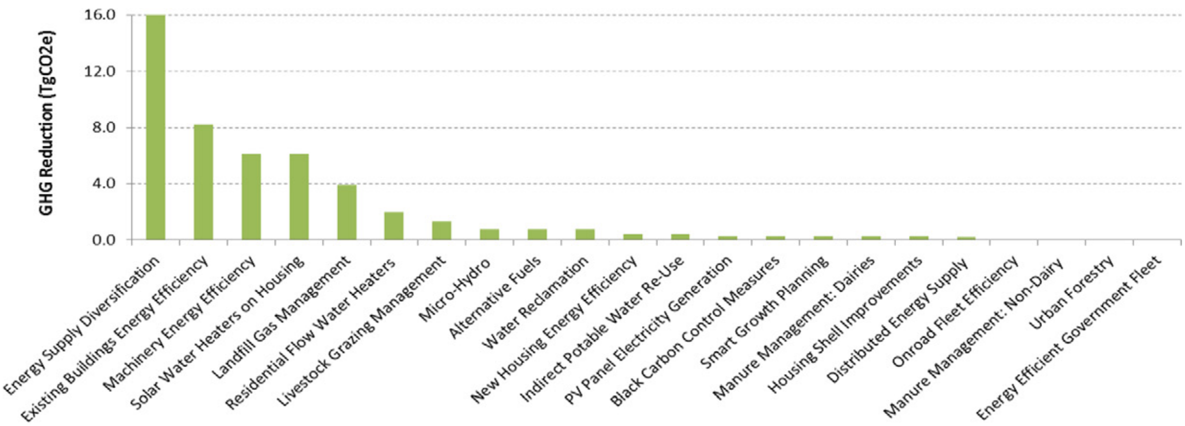


Fig. 2. Integrated yearly GSP and employment impacts of the 22 policy options/policy bundles.

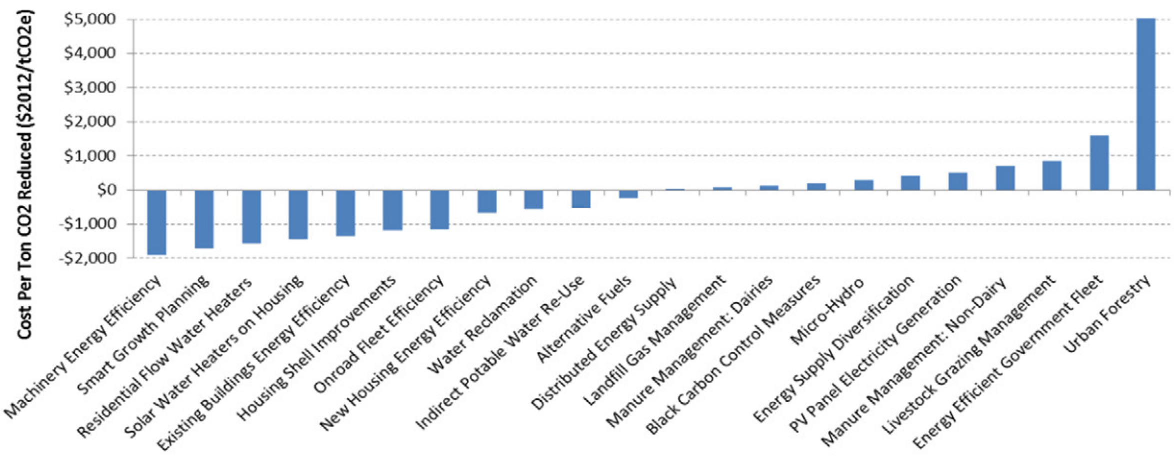
single run in the REMI Model with all of the 22 policy options/policy bundles combined, with any potential double-counting of costs or savings between policy options being addressed at the micro analysis stage. The simultaneous run provides insights on the potential macro impacts for the case that all of the policy options are implemented together. The results highlight the following impacts of the GHG mitigation options on the Baja California economy:

- The investment in GHG mitigation policies is estimated to generate significant positive impacts on the Baja California state economy during the upfront investment period of the various projects (primarily between 2015 and 2022, though different options have different starting years and initial investment periods);
- Both the GSP and employment impacts become negative starting from 2023 when the initial investment of the various options is completed and the production of capital equipment has peaked. That means the stimulus effects to the state economy stemming from the increased demand of the mitigation equipment manufacturing and construction of new plants and facilities will cease by 2023. On the other hand, the increased capital cost due to the financing of the mitigation investment is amortized over the entire payback period of the mitigation project. After the stimulus effects from the initial investment cease, the negative impacts to the economy caused by the increased amortized capital costs will start to dominate the overall impact (although it is partially offset by the savings on fuel expenditures discussed below)[8];
- The savings resulting from the implementation of energy efficiency related options increase overtime, and, by 2028, the net employment impact is projected to become positive again, while the net GSP impact approaches zero by the target year 2030 (in general employment impacts are more positive than GSP impacts in percentage terms because of the relative labor intensity of the mitigation options);
- The employment gain is projected to be 1680 jobs per year (or about 0.11% of the average annual number of jobs in the baseline) over the entire planning period;

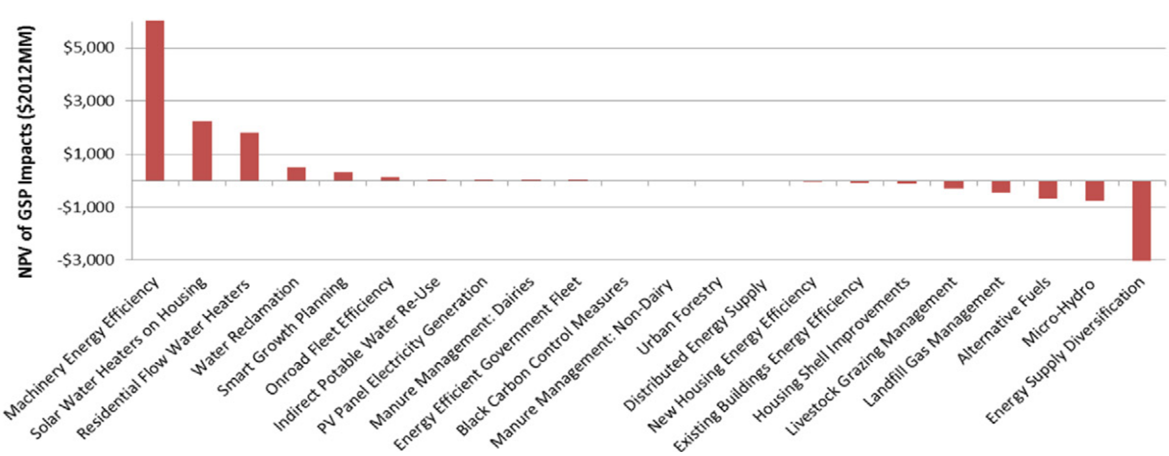
[8] Taking policy option ES-2 Energy Supply Diversification as an example, during its initial investment period from 2016 to 2022, an average annual investment of $6 billion pesos will generate significant stimulus effects to the Power Generation Equipment Manufacturing and Construction sectors. However, after 2023, the stimulus effect of this policy option will cease, while the negative impacts to the economy due to the over $2 billion pesos annualized capital cost (including the interest payment to debt financing) will dominate the net impact of this policy option.



(a) Cumulative GHG Reduction Potential by Policy



(b) Cost-Effectiveness by Policy



(c) Net Changes to Baja California GSP by Policy (2015-2035 NPV)

Fig. 3. GHG reduction, cost-effectiveness, GSP impacts.

- The net GSP gain is projected to be about $9.85 billion (2012 pesos, or $0.72 billion USD) in NPV by 2030. Although the yearly GSP impacts are projected to be negative between 2023 and 2030, the substantial GSP gains in the earlier years more than offset the negative impacts in later years, and thus lead to the overall positive GSP impacts in NPV over the entire planning period;
- The net disposable personal income gain is projected to be about $11.37 billion (2012 pesos, or $0.87 billion USD) in NPV over the planning period.

A comparison of the macroeconomic impacts presented in the last two rows of Table 3 shows only marginal difference between the simple summation of impacts from individual policy options and impact results from the simultaneous simulation. In general, the former yields slightly higher positive impacts to the economy in terms of the NPV of GSP increases and the average annual employment gains. However, the differences are only 1% and 3%, respectively.

Fig. 3 presents a comparison of the recommended policies in terms of their cumulative GHG reduction potentials (from highest to lowest), cost-effectiveness (from cheapest to most costly) and GSP impacts (from most positive to most negative). A comparison of these results indicates that in general the cost-effectiveness of a policy is closely correlated with the GSP impact. In other words, the cost-effective (cost-saving) policies are more likely to result in positive GSP impact. RCII-4 Machinery Energy Efficiency in Industrial Sector is estimated to be the most cost-effective policy option, and results in the highest GSP gains. Moreover, this policy option also has large GHG reduction potential (ranking 3rd). Other options that result in high GHG reduction, low per ton cost of GHG reduction, and high GSP impact include Solar Water Heaters on Housing and Residential Flow Water Heaters. Energy Supply Diversification is projected to result in the highest GHG reduction. However, this policy is estimated to lead to the highest negative GSP impact, mainly due to the high capital costs of the renewable electricity generation (see further discussions of this policy option in the Sensitivity Tests Section below).

4.2. Sectoral Impacts

Different sectors would be impacted differently under the implementation of the CAP in BC.

In terms of the GSP impacts, sectors that are related to household spending (such as Real Estate Activities and Wholesale and Retail) are projected to be mostly stimulated by the GHG mitigation policies. The positive impacts on these sectors mainly come through the increased purchasing power of the households with reduced overall expenditures on electricity and other fuels.[9] Other positively impacted sectors include manufacturing sectors that produce energy efficiency equipment and appliances, as well as renewable generation equipment. The Electricity, Gas, and Water Supply sector is projected to be mostly negatively affected. The vast majority of the negative impacts are for the Electricity Generation and Distribution due to the reduction of electricity consumption resulting from the energy savings and improvement in energy efficiency. The Construction sector ranks second to experience overall negative impacts. One major reason is that the reduced demand for electricity from energy efficiency improvement in the Residential, Commercial, Institutional, and Industrial sectors would reduce the need to build new power plants, which will in turn reduce the demand for the Construction. In addition, compared with conventional electricity generation, renewable electricity generation has a relatively lower percentage investment demand for Construction.

4.3. Sensitivity Tests

Our modeling results indicate that the policy bundle ES-2/AFOLU-3 Energy Supply Diversification yields the largest negative macroeconomic impact among the 22 GHG mitigation policy options/bundles analyzed. In this section, we perform several sensitivity analyses to examine how the macroeconomic impact results for this policy bundle change with different assumptions on the value of some key variables.

4.3.1. Renewable Electricity Generation Equipment Produced within Baja California

The default Regional Purchase Coefficients (RPCs) used in the REMI Model represent the proportion of local demand for any given good or service in Baja California that is supplied by in-state producers. In order to perform sensitivity analyses to examine the firms' decisions in the new regulatory environment, including the choices of purchasing goods and services from in-state vs. out-of-state producers, and business development strategies to expand their manufacturing facilities in BC vs. relocating their existing facilities to other states, one approach is to adjust the default value of the sectoral RPCs in the REMI Model. With a higher RPC, the assumption is that new businesses will be attracted into BC if there are incentive or industrial targeting programs in place to catalyze the growth of green industry. Oppositely, a lower RPC indicates that more firms will be moving out of the state due to the potential risks and uncertainties they perceive about the new regulations.

The default RPCs for the Manufacturing sector used in the REMI Model for the forecasting years are estimated based on historical data. Over the planning period, the default average RPC of the Manufacturing sector is about 57%. This indicates that 57% of local demand for manufactured goods is supplied by in-state producers, and the other 43% is met by imports. In the sensitivity analyses, we increase or decrease the RPCs of the Manufacturing sector by 50% to examine how changes in the proportion of in-state supply of renewable electricity generation equipment will affect the simulation results.

Table 5 presents a comparison between the various sensitivity analyses results and the impact results in the Base Case. The results for the RPC analyses are presented in columns 4 and 5. We see that when the in-state supply of renewable generation equipment increases by 50%, the negative average annual employment impact of this option is decreased by about 35% (changing from −773 to −515 jobs per year). The negative GSP impact is decreased from about −$3 billion to less than $0.2 billion Pesos. With a 50% lower RPC, the negative employment and GSP impacts will increase by about 35% and 96% (changing from −773 to −1042 jobs and from −$3.0 to −$5.97 billion pesos), respectively.

4.3.2. Capital Cost of Renewable Electricity Generation

In this sub-section, we perform sensitivity tests to analyze the impacts of variations in the capital cost of renewable electricity generation in the policy bundle ES-2/AFOLU-3 (Energy Supply Diversification). Many studies analyze how learning by doing (LBD) and research and development (R&D) can help reduce the costs of GHG abatement over time. LBD, as discussed in Manne and Richels (2004), refers to the process that the accumulated experience with a certain technology helps reduce the cost of the technology over time, which is reflected in a downward shift of the marginal cost curve of mitigation. However, there is considerable uncertainty with respect to the timing and level that LBD and R&D can affect the capital cost of mitigation. Grubb (1997) describes the LBD process as a virtuous cycle, while Sue Wing (2001) argued that more empirical evidence is needed to prove this theoretical assumption. Some recent studies found that the projections of capital costs of mitigation, such as renewable electricity generation technologies, are not expected to decline as much as in previous forecasts (Wei and Rose, 2014).

Given the uncertainty of the capital cost of mitigation in the future course of the planning period of our study, we perform a 50% higher and a 50% lower capital cost sensitivity test for ES-2/AFOLU-3 (Energy Supply Diversification). Columns 6 and 7 of Table 5 present the results

[9] Note that there are multiple factors that affect the purchasing power of households. On the one hand, households pay for the more energy-efficient appliances and vehicles. On the other hand, over the lifetime of these appliances and vehicles, savings on the expenditure of fuels are projected to more than offset the increased capital investment of the households. The impacts of the CAP on the prices of goods and services also vary. Although the aggregate price of fuels (including electricity, gas, and other fuels) is projected to slightly increase by about 0.64% by 2030 (which reflects the net effect of more expensive renewable electricity generation technologies and the decreased demand of electricity due to energy efficiency improvement), prices of other goods and services are projected to decrease, which results in a decrease in PCE-Price Index of −0.13% by 2030. This also increases the purchasing power of the households.

Table 5
Sensitivity analysis results for ES-2/AFOLU-3.

Category	Units	Base case[a]	50% Higher RPC	50% Lower RPC	50% Higher capital costs	50% Lower capital costs	50% Higher NG fuel cost	50% Lower NG fuel cost
Differences from baseline[b] level (2015–2030)								
Average annual employment	Jobs per year	−773	−515	−1042	−1806	328	−232	−1446
Gross state product (NPV)	Millions of fixed (2012) pesos	−3034	−197	−5967	−11,881	3628	1335	−8475
Output (NPV)	Millions of fixed (2012) pesos	−6381	−498	−12,453	−24,212	7292	2468	−17,407
Disposable personal income (NPV)	Millions of fixed (2012) pesos	−536	1030	−2121	−5719	3392	2496	−4320
Percent change from baseline level (2030)								
Total employment	Jobs	−0.183%	−0.188%	−0.177%	−0.339%	−0.025%	−0.133%	−0.245%
Gross state product	Millions of fixed (2012) pesos	−0.198%	−0.200%	−0.195%	−0.389%	−0.006%	−0.128%	−0.286%
Output	Millions of fixed (2012) pesos	−0.186%	−0.188%	−0.184%	−0.368%	−0.003%	−0.118%	−0.272%
Disposable personal income	Millions of fixed (2012) pesos	−0.150%	−0.153%	−0.146%	−0.321%	0.023%	−0.076%	−0.241%

[a] Base Case refers to a simulation in the presence of the Climate Action Plan. In the Base Case simulation, we use the default value from the REMI Model or best estimate from the micro analysis for the key variables. The respective sensitivity analyses are then performed to determine how the deviation of the values of the key variables from the Base Case would affect the simulation results.

[b] Baseline levels refer to the future forecasts of economic and population growth, and other macro-level development in the absence of any new climate policy (like the climate action plan modeled in this study).

of the sensitivity analyses. The results indicate that the macroeconomic performance of this option bundle is very sensitive to the capital cost variable. When the capital cost of renewable electricity generation is 50% lower than the Base Case level, the policy bundle can result in positive macro impacts of about a \$3.6 billion pesos increase in GSP and 328 average annual job gains. However, if the capital cost is 50% higher than the Base Case level, the negative impact will be more than doubled for employment impact (changing from −773 to −1806 jobs per year) and more than tripled for GSP impact (changing from −\$3.0 to −\$11.9 billion pesos).

4.3.3. Projected Price of Natural Gas

For ES-2, the fuel used in the displaced electricity generation is LNG. Therefore, the projected price of natural gas will affect the cost of the displaced NGCC generation. A higher projected NG price will make renewable electricity generation alternatives more cost-competitive compared with the displaced technology. Again, we increase or decrease the projected NG price in the Base Case by 50% in the sensitivity analyses to examine how changes in NG price forecast will affect the macro impacts of the ES-2/AFOLU-3 policy bundle. The last two columns of Table 5 present the sensitivity analyses results on NG price. When the projected NG price is 50% higher, the macroeconomic performance of the policy bundle improves by about 70% in terms of employment impact (changing from −773 to −232 jobs per year). The GSP impact becomes positive, amounting to about \$1.3 billion pesos in NPV. However, if the projected NG price is 50% lower, the renewable generation alternatives will become less cost-competitive, and the negative macro impact of the policy bundle would increase by about 87% for employment impact (changing from −773 to −1446 jobs per year) and more than doubled for GSP impact (changing from −\$3.0 to −\$8.5 billion pesos).[10]

If we compare the simulation results across the sensitivity analyses for the various key factors, we find that the macroeconomic impact of the policy bundle ES-2/AFOLU-3 is most sensitive to the changes in capital costs and least sensitive to the proportion of in-state supply of renewable electricity generation equipment.

[10] Since for the sensitivity analyses, we only focus on the policy bundle ES-2/AFOLU-3 (Energy Supply Diversification), which mainly involves replacing NGCC generation with alternative renewable power generation technologies, the fuel price sensitivity analysis was only performed for natural gas. Similar approach used in this sensitivity analysis can also be applied to other types of fuels, such as oil, that is subject to high price volatility. In general, with higher projected oil price, transportation mitigation options, such as alternative transportation fuels and vehicles, will become more attractive, and the macroeconomic performance of such options will improve. On the contrary, with lower projected oil price, the alternative fuels and vehicles will become less competitive, which will dampen the macroeconomic performance of the options.

4.3.4. Discount Rate

We also evaluated how changes in discount rate would affect the GSP impacts of the mitigation policies. In the Base Case analysis, a 5% discount rate is used to calculate the present value of GSP impacts between 2015 and 2030. The GSP impacts increases from \$10.4 billion to \$10.7 billion pesos when the discount rate decreases from 5% to 2%, and decreases to \$9.7 billion pesos when an 8% discount rate is used. Thus, the overall GSP impact of the CAP on Baja economy is not very sensitive to changes in the discount rate used.

4.3.5. Discussion of Other Sensitivity Analyses

We have assumed that none of the in-region private capital investment in GHG mitigation will displace (reduce) ordinary private investment in plant and equipment, based on the fact that many of the options receive incentives and funding support through state government programs already underway, involve zero debt financing for government, or receive international financial support. Sensitivity analyses can be performed on this assumption. If we assume a certain percentage of the in-state private capital investment on the mitigation projects will displace ordinary investment in plant and equipment (especially for productivity improvement purposes), several additional shocks need to be added in the REMI analysis, which include: 1) the foregone stimulus effect (to, for example, the manufacturing and construction sectors) of ordinary business investment; 2) the avoided annual capital cost of ordinary business investment that would otherwise be borne by the business making the investment; and 3) the foregone productivity improvement that would have been achieved through the ordinary investment. Previous studies indicate that in general investment displacement will reduce the positive economic outcomes of the mitigation policy options. Wei and Rose (2014) estimated that when the level of investment displacement increases by 50%, the positive economic impacts of the mitigation options will roughly reduce by about 50%.

5. Conclusion

This paper summarizes the analysis of the macroeconomic impacts of the 22 GHG mitigation/sequestration policy options/

policy bundles on the Baja Mexico state economy. A state-of-the-art regional macroeconometric model, the Regional Economic Models, Inc. Policy Insight Plus (REMI PI$^+$) Model is refined and applied for this study. The major data inputs to the Model are estimates of microeconomic impacts (such as costs and savings) associated with the implementation of the GHG mitigation policy options. In the macroeconomic impact modeling, additional data and assumptions are used to supplement the micro-level estimates.

Macroeconomic analyses of climate action plans are increasingly being conducted in industrialized countries using various modeling approaches, including, macroeconometric, input-output and computable general equilibrium. More recently, similar analyses have been performed for developing counties. It is, of course, necessary to adapt these models for the special circumstances in the developing world. In this study, we have taken advantage of the REMI "Custom Industry" feature, which facilitates necessary modifications.

Our macroeconomic modeling results indicate that, in aggregate, the 22 GHG mitigation policy options/policy bundles recommended in the Baja California CAP can result in positive impacts on the state economy. The combined effects are an increase in employment of an average of 1680 new jobs per year during the planning period from 2015 to 2030 and an increase in GSP of about $9.85 billion pesos in NPV over the planning horizon.

In addition, our results indicate a great disparity in the impacts across individual mitigation options. RCII-4 Finance Incentives for Machinery Energy Efficiency in Industrial Sector is estimated to contribute the highest economic gains. This stems primarily from their ability to improve energy efficiency and thus reduce production costs of the industrial sectors. The results also stem from the stimulus of increased investment in energy-efficient equipment and machinery. ES-2/AFOLU-3 Energy Supply Diversification is estimated to result in the highest negative impacts on the Baja economy. The negative impacts from this policy bundle mainly stem from the high capital cost of renewable electricity generation compared with the avoided fossil fuel electricity generation. Several analyses were performed to determine the sensitivity of the results of this policy bundle to major changes in key variables and assumptions. The results indicate that this policy bundle is most sensitive to capital costs of renewable electricity generation, followed by the price of fossil fuel of the displaced generation technology. The sensitivity analyses not only help determine the robustness of the analysis, but also provide insights to policy designs. For example, policies and incentives that encourage R&D and attract foreign support to help lower down the capital cost of renewable electricity generation are important strategies to improve the macroeconomic performance and thus promote the adoption of these renewable technologies.

Note that the estimates of economic benefits of the Baja California CAP do not include the economic value of other benefits associated with implementing the GHG mitigation options. These include, for example, the avoided negative environment impacts resulting from continued GHG emissions that are mitigated by the CAP policies, the cost savings through improved human health due to the associated reduction of ordinary pollutants, the preservation of natural resources, and many other social and environmental benefits.

The main objective of GHG mitigation is still to reduce atmospheric concentrations, and hence future potential damages, of this class of pollutants. The stimulus to the Baja economy from the implementation of it climate action plan, however, represents a valuable co-benefit. Moreover, it is a tangible one that we can expect to take place in the near term, in contrast to the more long-term and more uncertain benefits associated with reducing climate change damages.

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Appendix A. REMI PI$^+$ Model

The REMI model consists of thousands of simultaneous equations. The overall structure of the model can be summarized in five major blocks: 1) Output and Demand, 2) Labor and Capital Demand, 3) Population and Labor Supply, 4) Compensation, Prices, and Costs, and 5) Market Shares. The blocks and their key interactions are shown in Fig. A1.

The Output and Demand block includes gross output (sales), industry demand, personal consumption, investment, government spending, imports, product access, and exports. Output for each industry is determined by industry demand in a given region and its trade with rest of Mexico and foreign markets. For each industry, input demand is determined by the amount of output, consumption, and investment demand in that industry. Personal consumption depends on real disposable income per capita, relative prices, differential income elasticities and population. Input productivity depends on access to inputs. Investment occurs to fill the difference between optimal and actual capital stock for residential, non-residential, and equipment investment. Government spending changes are determined by changes in the population.

The Labor and Capital Demand block includes the determination of labor productivity, labor intensity and the optimal capital stocks. Industry-specific labor productivity depends on the availability of workers with differentiated skills for the occupations used in each industry. Occupational labor supply and commuting costs determine firms' access to a specialized labor force.

Labor intensity is determined by the cost of labor relative to the other factor inputs, capital and fuel. Demand for capital is driven by the optimal capital stock equation for both non-residential construction capital and equipment. Optimal capital stock for each industry depends on the relative cost of labor and capital, and the employment weighted by capital use for each industry. Employment in private industries is determined by the value added and employment per unit of value added in each industry.

The Population and Labor Supply block is based on detailed demographic information about the region. Population data is given for age and gender, with birth and survival rates for each group. The size and labor force participation rate of each group determines the labor supply. Participation rates respond to changes in employment relative to the potential labor force and to changes in real after tax compensation rates. Economic migration is determined by the relative real after tax compensation rate, relative employment opportunity and consumer access to a variety of goods and services.

The Compensation, Prices, and Costs block includes delivered prices, production costs, equipment cost, the consumption deflator, consumer prices, the price of housing, and the wage equation. Economic geography (relative competitiveness and location) concepts account for the productivity and price effects of access to specialized labor, goods and

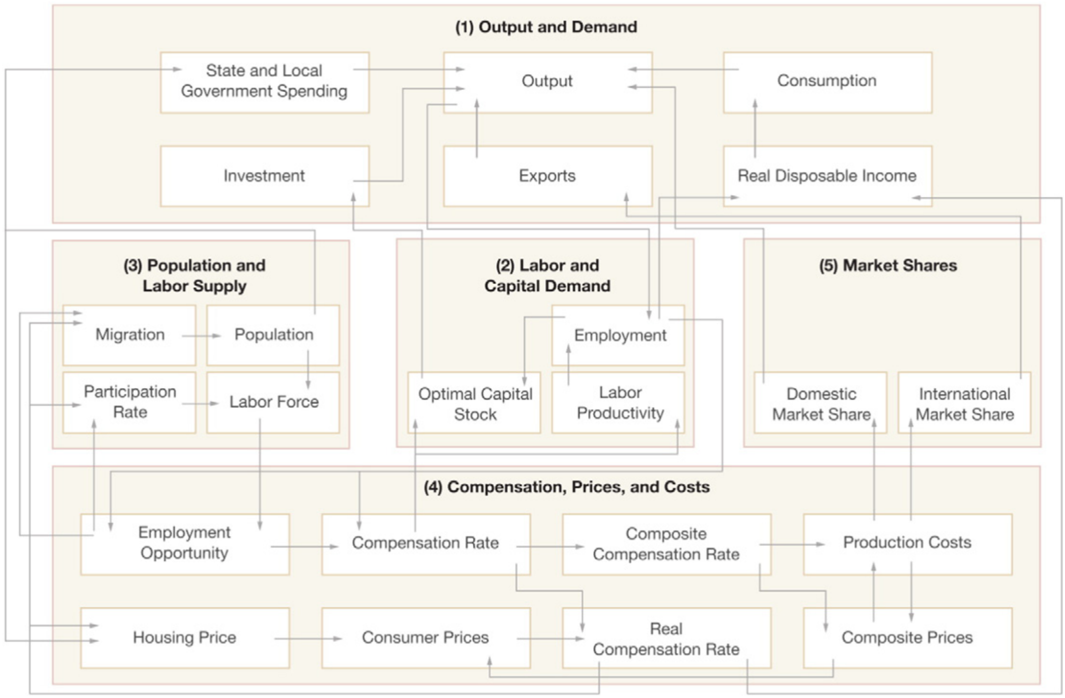

Fig. A1. REMI model linkages (excluding economic geography linkages).
Source: REMI (2016a).

services. These prices measure the value of the industry output, taking into account the access to production locations. This access is important due to the specialization of production that takes place within each industry, and because of transportation and transaction costs associated with distance. Composite prices for each industry are then calculated based on the production costs of supplying regions, the effective distance to these regions, and the index of access to the variety of output in the industry relative to the access by other uses of the product.

The cost of production for each industry is determined by cost of labor, capital, fuel and intermediate inputs. Labor costs reflect a productivity adjustment to account for access to specialized labor, as well as underlying compensation rates. Capital costs include costs of non-residential structures and equipment, while fuel costs incorporate electricity, natural gas and residual fuels.

The consumption deflator converts industry prices to prices for consumption commodities. For potential migrants, the consumer price is

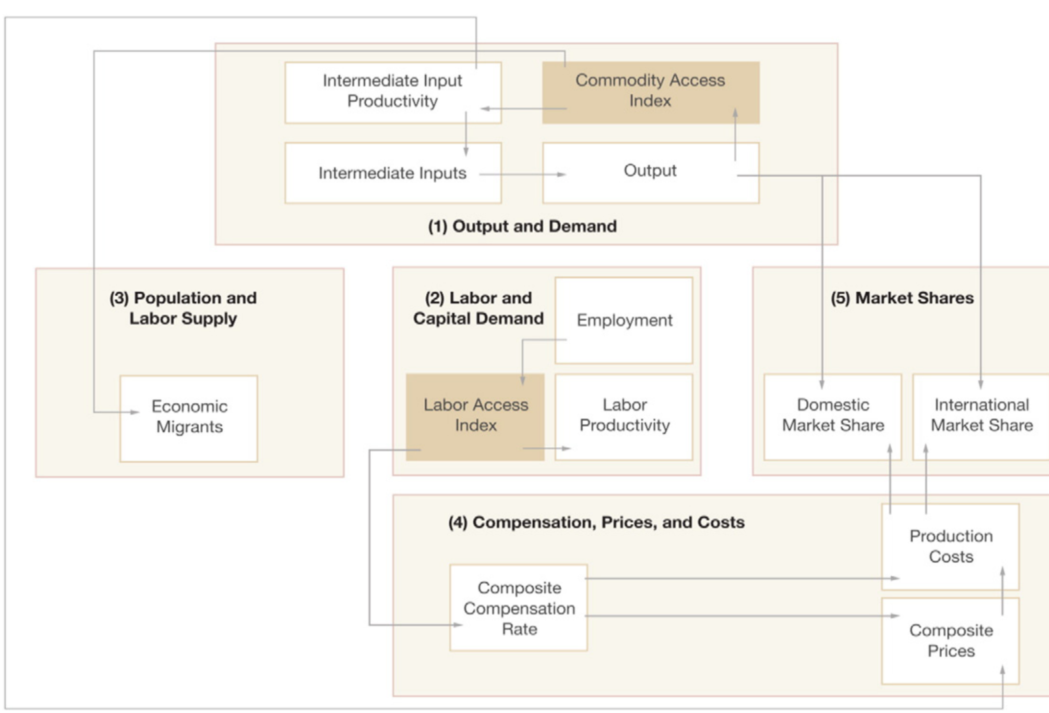

Fig. A2. Economic geography linkages.
Source: REMI (2016a)

additionally calculated to include housing prices. Housing price changes from their initial level depend on changes in income and population density. Regional employee compensation changes are due to changes in labor demand and supply conditions, and changes in the national compensation rate. Changes in employment opportunities relative to the labor force and occupational demand change determine compensation rates by industry.

The Market Shares equations measure the proportion of local and export markets that are captured by each industry. These depend on relative production costs, the estimated price elasticity of demand, and effective distance between the home region and each of the other regions. The change in share of a specific area in any region depends on changes in its delivered price and the quantity it produces compared with the same factors for competitors in that market. The share of local and external markets then drives the exports from and imports to the home economy.

As shown in Fig. A2, the Labor and Capital Demand block includes labor intensity and productivity, as well as demand for labor and capital. Labor force participation rate and migration equations are in the Population and Labor Supply block. The Compensation, Prices, and Costs block includes composite prices, determinants of production costs, the consumption price deflator, housing prices, and the wage equations. The proportion of local, interregional and international markets captured by each region is included in the Market Shares block.

Several major assumptions used in the REMI Model are summarized below:

- The production of goods and services is characterized by Cobb-Douglas production function for each sector. It allows for substitution among labor, capital, and energy (an elasticity of substitution of unity), with constant factor shares. However, intermediate goods are assumed to be used in constant proportions (fixed coefficients).
- The major dynamic feature of the model is reflected by its incorporation of a capital stock adjustment process. The investment for each year is determined by the difference between the optimal (or desired) level and actual (or existing) level of capital. The actual level of capital in each year is computed starting from the base year estimate, with investment added and depreciation subtracted annually. For each industry, the optimal capital stock is based on production levels measured in terms of capital-weighted employment and the relative cost of capital to labor.
- Economic geography is incorporated into the model by two indexes. The commodity access index reflects the relationship between the production cost reduction and competitiveness enhancement of an industry and its increased access to intermediate inputs. This index is also included in the migration equation. Higher access to consumer goods is a factor that attracts in-migration. The labor access index captures the favorable effect on labor productivity when local firms have better access to labor.

Appendix B. Development of REMI Model Input

Table 2 in Section 3.3 presents how we translate, or map, the microeconomic results of options from different sectors into REMI economic variable inputs, using RCII-3 Energy Efficiency Expansion in Existing Buildings as an example. In this appendix, we present more examples on how we prepare the inputs for REMI modeling. Four examples, each for one different sector, are presented in Tables B1 to B4.

In Table B1, the first two columns show the quantification analysis results of this mitigation option according to their applicability to business (commercial and industrial) sectors and the household (residential) sector. The third column presents the corresponding economic variables in the REMI PI$^+$ Model and their position within the Model (i.e., in which one of the five model blocks, as presented in Appendix A, the policy variables can be found). The last column indicates whether the direct shocks entered in the REMI Model are expected to generate positive or negative impacts to the economy. Tables B2 to B4 have the same structure as Table B1.

Table B1
Mapping ES-3 distributed energy supply for building into REMI inputs.

Linkage	Microeconomic quantification results	Policy variable selection in REMI	Positive or negative stimulus to the economy
1	Increased demand of Solar PV Panels	Output and demand block → exogenous final demand (amount) for electric and optical equipment sector and construction sector → increase	Positive
2	Increased government spending on Solar PV (offsetting other general government spending)	Output and demand block → government spending (amount) → total → decrease	Negative
3	Increased demand of inspection, maintenance, and repair of solar PV and devices	Output and demand block → exogenous final demand (amount) for renting of machinery & equipment and other business activities sector → increase	Positive
4	Increased government spending on Solar PV O&M (offsetting other general government spending)	Output and demand block → government spending (amount) → total → decrease	Negative
5	Fuel cost savings	Output and demand block → government spending (amount) → total → increase	Positive
6	Reduced demand of electricity	Custom industry → sale for electric power generation, transmission, and distribution sector → decrease	Negative

Table B2
Mapping AFOLU-1 manure management: non-dairy livestock into REMI inputs.

Linkage	Microeconomic quantification results	Policy variable selection in REMI	Positive or negative stimulus to the economy
1	Upfront capital investment on new equipment for anaerobic digestion or composting, and electricity generation from methane	Output and demand block → exogenous final demand (amount) for machinery manufacturing sector → increase	Positive
2	Increased capital cost of the livestock production sector	Compensation, prices, and costs block → capital cost (amount) of agriculture, hunting, forestry and fishing sector → Increase	Negative
3	Interest payment of financing capital investment	Output and demand block → exogenous final demand (amount) for financial intermediation sector → increase	Positive

Table B2 (*continued*)

Linkage	Microeconomic quantification results	Policy variable selection in REMI	Positive or negative stimulus to the economy
4	Increased O&M cost of the livestock production sector	Compensation, prices, and costs block → production cost (amount) of agriculture, hunting, forestry and fishing sector → increase	Negative
5	Reduced electricity cost of the livestock production sector	Compensation, prices, and costs block → production cost (amount) of agriculture, hunting, forestry and fishing sector → decrease	Positive
6	Reduced demand from electric power generation sector	Custom industry → sale for electric power generation, transmission, and distribution sector → decrease	Negative
7	Reduced LPG cost of the livestock production sector	Compensation, prices, and costs block → production cost (amount) of agriculture, hunting, forestry and fishing sector → decrease	Positive
8	Reduced demand from LPG producing sector	Output and demand block → exogenous final demand (amount) for coke, refined petroleum and nuclear fuel → decrease	Negative

Table B3
Mapping TLU-3 on-road fleet efficiency into REMI inputs.

Linkage	Microeconomic quantification results	Policy variable selection in REMI	Positive or negative stimulus to the economy
1	Spending of cash received from old vehicle retirement	Output and demand block → consumer spending → transport → increase Output and demand block → consumption reallocation → all consumption categories → increase	Positive
2	Fuel cost savings	Output and demand block → consumption reallocation → all consumption categories → increase	Positive
3	Reduced demand of gasoline	Output and demand block → exogenous final demand (amount) for coke, refined petroleum and nuclear fuel sector → decrease	Negative

Table B4
Mapping WM-1 landfill gas management into REMI inputs.

Linkage	Microeconomic quantification results	Policy variable selection in REMI	Positive or negative stimulus to the economy
1	Investment in LFGTE systems	Output and demand block → exogenous final demand (amount) for machinery manufacturing sector → increase	Positive
2	Investment in major equipment overhauls	Output and demand block → exogenous final demand (amount) for renting of machinery and equipment and other business activities sector → increase	Positive
3	Increased capital cost of the waste management sector	Compensation, prices, and costs block → capital cost (amount) of public admin and defense, compulsory social security sector → increase	Negative
4	Interest payment of financing capital investment	Output and demand block → exogenous final demand (amount) for financial intermediation sector → increase	Positive
5	Increased O&M cost of the waste management sector	Compensation, prices, and costs block → production cost (amount) of public admin and defense, compulsory social security sector → increase	Negative
6	Reduced electricity cost	Compensation, prices, and costs block → production cost (amount) of public admin and defense, compulsory social security sector → decrease	Positive
7	Reduced demand of electricity	Custom industry → sale for electric power generation, transmission, and distribution sector → decrease	Negative

Appendix C. Additional assumptions used in preparing REMI simulation inputs

Table C1
Additional assumptions used in REMI analysis for individual policy options/policy bundles.

Policy option number	Policy option description	Assumptions
RCII-1	Save 23% electricity consumption on new residential buildings through housing shell improvements, year target 2020	Split of capital investment costs: 70% household savings, 20% bank financing by residential sector, 10% state government support
RCII-2	Energy efficiency expansion in new housing design	Split of capital investment costs: 85% residential sector and 15% Construction sector Zero percent of the capital investment is through debt financing
RCII-3	Energy efficiency expansion in LPG and electricity consumption for existing buildings of residential and commercial sector	The capital expenditure is split 30% to building retrofits and 70% to energy-efficient appliances 100% of the capital and administrative costs are borne by residential and commercial sectors 20% of the retrofit investment is financed and zero of the appliance investment is financed
RCII-4	Finance incentives for machinery energy efficiency	100% of the capital and administrative costs are borne by residential and commercial sectors 50% of the investment on energy-efficient machinery is financed
RCII-5	Solar water heaters on housing	Split of capital investment costs: 60% residential sector and 40% state government support All program administrative costs will pass through onto the residential sector
RCII-6	Flow water heaters for residential sector	100% of the capital and administrative costs are borne by residential sector Zero percent of the investment on flow water heaters is financed
ES-1	Micro-hydro renewable energy generation	60% of the capital investment is covered through debt financing and the other 40% is covered through equity
ES-2/AFOLU-3	Energy supply diversification/utilization of wheat straw	All costs (O&M, fuel, transport costs) are borne by the Ag sector; no government cost share 60% of the capital investment on renewable generation is covered through debt financing and the other 40% is covered through equity

(continued on next page)

Table C1 (*continued*)

Policy option number	Policy option description	Assumptions
ES-3	Distributed energy supply for building	Assume zero debt financing
ES-4	Photovoltaic panel electricity generation	100% of the investment is financed
WM-1	Landfill gas management	All costs/savings are borne/accrued by municipal governments 50% of the capital investment is covered through debt financing
WM-2	Indirect potable water *re*-use	10% of the capital investment is covered by state government funding and 90% is financed by the water utility company through an entity such as NADBank
WM-3	Water reclamation	Capital expenditures are split 70% to tubing and 30% to pump 65% of the capital investment is covered by state government funding and 35% by international fund
AFOLU-1	Manure management: non-dairy livestock	All costs are borne by the livestock production sector; no government cost share 100% capital investment is covered through debt financing
AFOLU-2	Manure management: dairies	Split of capital investment costs: 50% federal government support, 25% state government support, 25% Ag sector private investment 100% of the Ag sector investment is through debt financing
AFOLU-5	Livestock grazing management	Split of capital investment costs: 10% state government support and 90% by Ag sector private investment 100% of the Ag sector investment is through debt financing
AFOLU-6	Urban forestry	Split of capital investment costs: 20% state government support and 80% by residential sector private investment 10% of the residential sector investment is through debt financing
TLU-1	Black carbon control measures	All capital investment cost is borne by truck owners
TLU-2/AFOLU-4/WM-4	Alternative fuels/bioethanol production from sweet Sorghum/biodiesel production	For the bioethanol production, federal government funding covers $20 M of the capital cost of the bio-refinery; the rest of the cost is borne by the Chemicals sector 100% of the capital investment of the Chemicals sector is covered through debt financing For biodiesel production, all costs are borne by the state government Gasoline savings are split 50/50 between private vehicles and commercial vehicles Attribute all of the diesel activity to commercial vehicles Capital cost of blending facility is borne by the Chemicals sector; 50% is covered through debt financing
TLU-3	On-road fleet efficiency	All funding is assumed to come from federal government For the cash the government paid to the consumers for their retired old cars, it is assumed that 48% of the cash will be spent on transport purposes, and the rest 52% will be distributed among all consumption goods and services
TLU-5	Smart growth planning	Assume zero debt financing
TLU-6	Energy efficient government fleet	Assume zero debt financing

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