Macroeconomic Impacts of the California Global Warming Solutions Act on the Southern California Economy

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ABSTRACT

We evaluate the potential regional macroeconomic impacts of a set of ten greenhouse gas mitigation policy options intended to enable the Southern California Association of Governments to comply with the State's greenhouse gas reduction targets. The Regional Economic Models, Inc. Policy Insight Plus Model, *was applied in the analysis by carefully linking technical and microeconomic aspects of each mitigation option to the workings of the regional economy. We took into account key considerations, such as how investment in mitigation options would displace ordinary private business investment and the time-phasing of renewable electricity generation. Our results indicate that the combined ten mitigation policy options could create an annual average employment gain of 21 thousand jobs over the entire planning period from now to 2035, but could also have a negative net present value impact of $17 billion in regional GDP. In the paper, we explain this and other anomalies. Sensitivity analyses of key assumptions and parameters for the Renewable Portfolio Standard indicate that the results are robust. They also provide policymakers with insights into how to improve the macroeconomic impact of this major policy option.*

Keywords: Climate change mitigation policies, Regional macroeconomic impacts, Renewable portfolio standard, Southern California region economy

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1. INTRODUCTION

California Assembly Bill 32 (AB32), the California Global Warming Solutions Act, calls for the cutback of greenhouse gas (GHG) emissions to Year 1990 levels by the Year 2020, and even more stringent reductions in subsequent years (CARB, 2008). It stipulates the implementation of a combination of cap and trade policy instruments and several complementary, primarily regulatory, policies to achieve these targets (CARB, 2010). Some are concerned that the implementation of AB32 will incur substantial direct and indirect costs to California as a whole, and further that some of the State's sub-regions and sectors (such as the refinery industry) might shoulder a disproportionate share of these costs (Smith et al., 2010; BCG, 2012). At the same time, others suggest that, if structured properly, AB32 can have positive overall economic outcomes (Roland-Holst, 2008; CARB, 2010) and incur limited impacts to small businesses and energy-intensive sectors (Weiss and Sarro, 2009; CARB, 2010).

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To implement AB32, the State and its various sub-regions have developed climate action plans that identify various technological options and regulatory policy designs to reduce GHG emissions. The direct benefits of these plans are the avoided damages from climate change, such as coastal erosion from sea-level rise, loss of water resources from reduced rainfall, and increase in frequency and severity of wildfires from increased temperatures. There are also several co-benefits of implementing climate action plans. One is the reduction in ordinary (EPA "criteria") air pollutants accompanying a shift to renewable energy resources or implementation of energy-efficiency improvements. Another is the decrease in energy use and hence increased U.S. energy security. A third is the possibility that GHG mitigation will have a beneficial effect on the economy in terms of stimulating more "green jobs" than are displaced by the loss of jobs in traditional energy sectors, as well as from any cost increases that cause a dampening of demand for goods and services. Moreover, both the positive and negative stimuli generate ripple effects up and down the supply chain. These indirect effects are much more subtle and require a formal model to evaluate properly.

The purpose of this paper is to estimate the macroeconomic impacts of AB32 on the Southern California Association of Governments (SCAG) Region economy. This is the largest economic region in California in terms of population and economic activity. It is unique in several respects, such as its diverse population, climate, transportation network and economic structure, and its climate action plan has been developed accordingly (see SCAG, 2012a). We examine the economic implications of ten major mitigation options individually and as a group. Our analysis utilizes the results of the findings of Technical Working Groups (TWGs) in the areas of energy supply (ES), residential/commercial/industrial demand (RCI), and agriculture/forestry/waste management (AFW) (transportation emissions are addressed in a separate legislation known as State Senate Bill 375). We insert these microeconomic results into the Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI^+) Macroeconometric Model to ascertain the total economic impacts on the SCAG economy. In so doing, we further refine a methodology for the application of the REMI Model that we have used successfully in evaluating climate action plans in several other states (see, e.g., Miller et al., 2010; Rose et al., 2011; Rose and Wei, 2012).

Overall, the findings from this study suggest that implementing various GHG mitigation policy options would generate net positive employment impacts on the SCAG Region's economy and only very slight negative impacts on GDP. Also, sensitivity tests indicate that the macroeconomic performance of these options can be improved by various ways that help lower the costs of new green technologies and attract investment from other regions. The results provide a basis for government and the private sector to cooperate in achieving the best possible outcome of climate policy.

Note that the estimates of macroeconomic impacts on the SCAG Region do not include the economic value of other benefits of implementing the GHG options, including the avoidance of negative environmental impacts from continued GHG emissions that would be mitigated, the savings from the associated decrease in ordinary pollutants that impact human health, and the reduction in the use of natural resources. We emphasize that job creation is not the primary goal or benefit of AB32, which is the avoided losses from climate change predicted by a consensus of scientists (IPCC, 2007). Regional economic gains that arise are a co-benefit, or "frosting on the cake." Any regional economic losses must be compared with the direct benefits, as well as any other co-benefits relating to reduction in more general pollution and reduction in energy use and other positive implications of GHG emission mitigation.

This paper is divided into eight sections. In Section 2, we summarize the major characteristics of the SCAG economy. Section 3 presents the micro level analysis results of the mitigation policy options analyzed in this paper. In Section 4, we first introduce the REMI Macroeconometric Model and then present a list of major assumptions we used to link the microeconomic analysis results with the REMI Model. Section 5 presents the basic aggregate simulation results. Section 6 presents a sensitivity analysis for the Renewable Portfolio Standard (RPS) option. In Section 7, we interpret our analysis results and summarize the major findings. The paper concludes with a discussion of policy implications in Section 8.

2. THE SCAG ECONOMY

SCAG is the largest Metropolitan Planning Organization in the United States. It encompasses six of the ten counties in Southern California (Imperial, Los Angeles, Orange, Riverside, San Bernardino and Ventura), 191 cities and over 18 million people. Median household income in SCAG Region counties ranges from $38,000 (Imperial) to $75,000 (Ventura) (U.S. Census, 2010). Total civilian labor force is almost 7.5 million, with a participation rate of 61%. Unemployment in the region is high, having reached more than 12.41% in 2010, and having dropped only slightly below the 12% threshold in 2011 (SCAG, 2012b).

The Service sector in aggregate represents a very large share of the Region's Economy. Manufacturing and Real Estate account for another 15% and 13% of regional total gross output, respectively (REMI, 2012). The largest sub-unit of the SCAG Region is the Los Angeles Metropolitan Area, which produces about 60% of the Region' gross output. This is the largest manufacturing center in the U.S., and is widely known as the hub of the entertainment industry and includes two of the nation's largest ports (Los Angeles and Long Beach).

SCAG (2012b) has projected that population will increase by 23% by 2035 from a base Year 2008 level. The historical average annual growth rate of gross output between 1990 and 2008 was about 1.65%. A baseline forecast indicates that regional gross output in 2035 will reach $2.6 trillion, with a projected average annual growth rate of 2.6% between 2009 and 2035 (REMI, 2012).

3. MICROECONOMIC ANALYSIS

SCAG established the Climate and Economic Development Project (CEDP) to assist in developing a comprehensive strategy and analysis for meeting the mandate of Assembly Bill (AB) 32. This legislation was designed by the California General Assembly to reduce GHG emissions through economically desirable and socially equitable regional policies and strategies. SCAG engaged a diverse and high-level group of stakeholders representing government entities, environmental interests, key industries, and other groups to identify potential regional and local policies that reduce GHG emissions to comply with this legislation in the most economically desirable and equitable manner possible. SCAG contracted with the Center for Climate Strategies (CCS) to conduct effective, stakeholder-based climate planning and policy development processes, as well as related socioeconomic analysis and implementation support.[1]

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[1] At the beginning of the CEDP, SCAG developed a memorandum that established the Project Stakeholder Committee (PSC) as the decision-making group for identifying and approving policies for further analysis. Given the extensive and in-depth work involved with this charge, three technical work groups (TWGs) (Transportation System and Investments (TSI); Transportation

This section summarizes results of the microeconomic impact analysis of the Energy, Commerce, and Resources (ECR) policies identified as priorities for analysis by the ECR TWG through the CEDP. The reader is referred to CEDP (2012) for information that served as the basis for the design and quantification of the potential emission reductions and costs/savings for each policy.

Table 1 presents the estimated microeconomic impacts (GHG mitigation potentials and costs/savings) of the ECR options analyzed.[2] These impacts represent the incremental impacts of the policies relative to the baseline that would otherwise prevail in the SCAG Region.[3] In total, the ten policy options can generate over $3.2 billion net present value (NPV) cost savings and reduce 853 million tons of carbon dioxide-equivalent (MMtCO$_2$e) GHG emissions during the 2012–2035 period. The weighted average cost-effectiveness of the options (using GHG reduction potentials as weights) is approximately minus $4 per MMtCO$_2$e emissions removed. Table 1 indicates that, collectively, the ECR options can potentially mitigate about 22% of 2035 baseline emissions in the SCAG Region.[4]

Among the three broad GHG mitigation categories, RCI options in aggregate have the largest GHG reduction potential. Also, three of the RCI options are highly cost-effective. The level of savings estimated for the RCI options, especially those for the energy efficiency programs, is consistent with past performance of similar programs in California and in other states that have taken an aggressive approach to energy efficiency. The energy savings achieved by customers of individual IOUs in California are reported in CPUC (2013). ACEEE has maintained a *State Energy Efficiency Scorecard* since 2006, which reports the energy-efficiency policy and program efforts and their achievements in each state. For California, the estimated average electricity savings as a percentage of retail sales is 1.12% from 2008 to 2013 (ACEEE, 2013). However, based on an ex-post evaluation of the energy-efficiency programs in California in 2004–2005, Kaufman and Palmer (2010) found that the "realization rate" of energy savings, which is measured as the ratio of ex-post estimated savings to ex-ante projected savings, is about 90% on average. Also, they found that the savings estimated by third-party evaluation are systematically lower than the IOU-reported savings. The average "realization rate" of the former is about 80%. This illustrates the importance of independent evaluations, including

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and Land Use (TLU); and Energy, Commerce, and Resources (ECR)) were created to provide support to the PSC in identifying and recommending policy actions for further analysis. In its January 2011 meeting, the PSC identified a total of 37 policies that it recommended as priorities for analysis. The final design and quantification analysis of the policies were performed by CCS analysts working with SCAG's technical staff and experts identified by SCAG. The comprehensive, multi-sector, consensus-building, stepwise planning and analysis methodology adopted by CCS has been documented and reviewed in McKinstry et al. (2009), Rose et al. (2009), and Rose et al. (2013).

[2] The reader is referred to Sections II through IV in the INDEX section of CEDP (2012) for detailed descriptions of the policy options and the methodologies used to quantify the GHG reductions and costs/savings of the options.

[3] Many of the policies proposed in AB32 are extensions of existing policies. For example, the goal of the RPS in AB32 is to achieve 33% renewables by 2020. In the development of the baseline forecast of the GHG emissions from the power generation sector, increasing amounts of renewable generation consistent with the RPS requirements of SB1078, which is 20% RPS by 2020, are included (SCAG, 2012c). As for the RCI policy options, the California Energy Commission (CEC) energy efficiency forecast for 2011–2020 (CEC, 2011) is used as the basis for the baseline forecast of electricity use for the SCAG Region. For RCI-1 (DSM), it is assumed that the IOU and POU energy efficiency programs prior to 2011 are included in the CEC baseline forecast. As for RCI-2 (Building Codes), it is based on and beyond the California Green Building Standards Code (CalGREEN).

[4] Overlaps between policy options can exist both within and across sectors. The only overlap identified by the ECR TWG is between option AFW-2a and RCI-2. 65% of the GHG reductions and net cost of AFW-2a are computed by the micro experts to represent the overlaps between these two policy options.

TABLE 1
Microeconomic Analysis Results of ECR Options

Policy Option Number	Policy Option Description	2020 (MMtCO2e)	2035 (MMtCO2e)	2012–2035 (MMtCO2e)	Net Present Value (million 2010$), 2012–2035 Cost/Cost Savings*	Cost-Effectiveness ($/tCO2e)*
RCI-1	Utility Demand Side Management (DSM) Programs for Electricity and Natural Gas	8.6	24.2	297	− 5,652	− 19
RCI-2	Improved Building Codes	3.1	11	119	− 1,025	− 9
RCI-3	Incentives for Renewable Energy Systems at Residential, Commercial, and Industrial Sites	0.16	0.41	5.1	325	63
RCI-6	Increase Water Recycling and Water End-use Efficiency and Conservation	2.0	3.9	54	− 3,528	− 65
ES-1	Central Station Renewable Energy Incentives and/or Barrier Removal	11.4	11.4	265	5,025	19
ES-2	Customer Sited Renewable Energy Incentives and/or Barrier Removal	1.2	2.9	37.5	4,624	123
ES-5	Public Benefits Charge Funds	Moved to RCI-1				
ES-6	Combined Heat and Power (CHP) Incentives and/or Barrier Removal	1.3	5.0	66.2	− 4,971	− 75
AFW-1	Improve Agricultural Irrigation Efficiency	0.22	0.22	4.4	− 145	− 33
AFW-2a	Urban Forestry	0.05	0.28	2.7	1,359	424
AFW-5a	Increase On-Farm Renewable Energy Production	0.02	0.04	0.65	− 6	− 9
AFW-5b	Increase On-Farm Energy Efficiency	0.05	0.16	2.3	− 47	− 28
All	**Total Stand-Alone Results**	**28.0**	**59.7**	**854**	**− 4,041**	**n/a**
	Total Estimated Policy Overlaps	**0.03**	**0.18**	**1.73**	**883**	**n/a**
	Total After Overlap Adjustments	**28.0**	**59.5**	**853**	**− 3,157**	**− 4**

Source: CEDP, 2012.
* Negative values represent a net cost savings. $\$/\text{tCO}_2\text{e}$ stands for dollars per metric ton of carbon dioxide equivalent.

those by TWGs such as those involved in the CEDP process, in verifying potential and realized energy savings.[5,6]

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[5] There are several well-known market failures that help explain why energy efficiency is not fully implemented despite the cost savings. These include: myopia (unreasonably short payback period requirements), inability to process a large amount of information, and split incentives between developers/owners and renters (see, e.g., National Commission on Energy Policy, 2004; Gillingham et al., 2009; Gillingham et al., 2010).

[6] The cost estimates by the microeconomic analysts include more than just traditional "bottom-up" assessments of engineering costs. They do in fact include foreseen implementation costs (administrative, transactions, etc.). However, they probably omit some unforeseen or frictional costs (practically all assessments do), though these are likely to be relatively minor.

4. MACROECONOMIC ANALYSIS

A. REMI Model

In this study, the Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI$^+$) Model is used to analyze the macroeconomic impacts of the ECR policy options.[7] The REMI Model has evolved over the course of 30 years of refinement (see, e.g., Treyz, 1993). It is a packaged program but is built with 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 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 input-output (I-O) model, i.e., it divides the economy into 169 sectors, thereby allowing important differentials between them. This is especially important in a context 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. In other words, the REMI model incorporates the responses of the producers and consumers to price signals in the simulation, and captures the substitution effects and other price-quantity interactions.[8] The REMI Model also brings into play features of labor and capital markets, as well as trade with other states or countries, including changes in competitiveness.

The microeconomic analysis results were used as inputs to the macroeconomic models. The inputs to the macroeconomic models include mapping of the costs and savings of the policies to the sectors affected by the policies. These costs and savings were identified separately and made compatible with the REMI models' requirements. For example, for the RPS option, we gathered the various cost estimates (including capital, labor, O&M, financing, and administrative) for different generation technologies in the planning horizon from the micro analysis results. Then we linked these direct costs (and in some cases cost savings) to corre-

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[7] 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 general equilibrium (CGE), mathematical programming (MP), and macroeconometric (ME) models. Each has its own strengths and weaknesses (Rose and Dormady, 2011). 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 Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI$^+$) Model. REMI integrates I-O, CGE, econometric, and economic geography methods. At its core, it has I-O features, which means it captures inter-industry production relationships. The REMI PI$^+$ Model is superior to the other widely used macroeconomic models in terms of its forecasting ability and is comparable to CGE models in terms of analytical power and accuracy. With careful explanation of the model, its application and results, REMI PI$^+$ can be made as transparent as any of the others. Moreover, the research team has used the model successfully in similar analyses in the states of Pennsylvania, Michigan, New York, and Florida (Miller et al., 2010; Rose et al., 2011; Wei and Rose, 2011; Rose and Wei, 2012).

[8] The REMI Model utilizes the Cobb-Douglas production function, consisting of labor, capital, and energy aggregates, and hence is able to estimate substitutions when the price of energy changes. Other price-quantity interactions stem from indirect effects of these substitutions, as well as from the labor/demographic market equations.

sponding REMI model variables to simulate both the incremental capital and production costs for the power sector and the corresponding stimulus effects to the sectors that provide generation equipment, construction and installation services, and financing services. The analysis also accounted for the indirect (macroeconomic) effects of changes in consumer and business spending resulting from those costs and savings, estimates for displacement of other government spending and ordinary business investment by the new spending and investment anticipated to implement the policies, as well as the extent to which spending was funded by resources from outside the SCAG Region.

The many types of linkages in the economy and macroeconomic impacts are extensive and cannot be traced by a simple set of calculations. It requires the use of a sophisticated model, such as the REMI Model, that reflects the major structural features of an economy, the workings of its markets, and all of the interactions between them.

REMI and various other regional macroeconomic models have been rigorously evaluated and validated in the literature. This includes error analyses to evaluate REMI model outputs by comparing them with other input-output/econometric integration methods (Rey, 1997; Rey, 1998). REMI has also been tested for its consistency across regions for equivalent simulations (Cassing and Giarratani, 1993). There are also a number of studies designed to evaluate the predictive accuracy of the REMI model by testing the prediction errors in post-sample period forecasting (Treyz et al., 1991; Cassing and Giarratani, 1993). Recently, Rose et al. (2011) constructed a reduced form econometric version of the REMI Model to test the full Model's results in an application to estimating the macro effects of a climate action plan in Pennsylvania.

Some major limitations of the REMI model discussed in the literature include its lack of transparency and lack of the flexibility to enable users to adjust equations and parameters within its endogenous model blocks (Charney and Vest, 2003; Morgan, 2010). In our study, we overcome the transparency issue by carefully documenting major assumptions, policy lever selections, and the linkages between the micro and macro impacts in our modeling practice (see CEDP, 2012, for more details). We also perform sensitivity analysis on key policy variables. In cases where we need to alter the default value of the key parameters, such as the Regional Purchase Coefficients (RPCs), in the model, we performed additional side calculations and used a combination of policy levers in REMI to implement the changes. We also identified a few missing linkages in the model structure, such as the displacement of ordinary investment and foregone productivity improvement. In this study, we incorporated those linkages manually.

B. Major Modeling Assumptions

Before undertaking any economic simulations, the key quantification results for each policy option conducted by the TWGs are translated to model inputs that can be utilized in the REMI Model. This step involved the selection of appropriate policy levers in the REMI Model to simulate the policy's changes.

The major data sources for the macroeconomic impact analysis are the microeconomic quantification results on the direct costs and savings of the ECR options. However, we supplement these with additional data and assumptions in the REMI analysis in cases where these costs/savings and some conditions relating to the implementation of the options are not specified in the micro analysis or are not known with certainty. Below are major assumptions we adopted to link the microeconomic analysis with the REMI Model. Most of these assumptions are general ones we have used in prior studies; those tailored to the SCAG Region are indicated as such:

1. In the Base Case analysis, we assume that 50% of the in-region private capital investment will displace ordinary private investment in plant and equipment (i.e., only half of the private investment in mitigation is additive to the regional economy).
2. In the Base Case, capital investment expenditures for power generation are split 60:40 between sectors that produce generating equipment and the construction sector for large power plants (such as NG-fired power plants), and 80:20 for smaller installations (mainly renewables).
3. In the Base Case, the percentages of renewable electricity generation equipment and energy-efficient appliances and equipment purchased from producers within the SCAG Region are assumed to be same as the average in-region production rate of such equipment,
4. For RCI-1, it is assumed that 10% of the utility program cost is administrative, and 90% is attributable to annualized capital and operating costs of this option; it is further assumed that 100% of the utility cost change will eventually be passed onto the ratepayers.
5. For RCI options, we distributed costs and savings of the options among the 169 REMI sectors using baseline sectoral energy consumption as weights.
6. The interest payment is separated from the levelized capital cost using the following assumptions:
   - For RCI-1 and RCI-6, it is assumed that 50% of the capital cost will be covered by debt financing and 50% will be covered by equity financing. For RCI-2 and RCI-3, it is assumed that debt financing will cover 75% of the capital cost.
   - For ES options, except for the federal subsidies and transfers, the remaining costs are assumed to be covered by private investment, which is assumed to be covered 50% by debt financing and 50% through equity.
   - For AFW options, it is assumed that 100% of the capital cost will be covered through debt financing.
7. For the Urban Forestry option (AFW-2), it is assumed that the planting and maintenance costs are split 20:30:50 among local governments, commercial sectors, and the residential sector. The electricity and gas savings are split 30:70 between the commercial and residential sectors.
8. For ES-1 (RPS), in order to meet the 33% RPS goal by Year 2020, the deployment of each type of renewable generation in the SCAG Region, the rest of California, and outside of California is based on California Independent System Operator (CAISO) interconnection queue location. In addition, in all the cases, the displaced power generation is assumed to be natural gas combined-cycle (NGCC) (see CEDP, 2012).

5. BASIC AGGREGATE RESULTS

A. Macroeconomic Impacts of the ECR Options

Table 2 presents the summary results of employment and GDP impacts of the ECR options. In terms of employment impacts, 7 out of the 10 options yield positive impacts. In terms of GDP impacts, 4 out of the 10 options yield positive impacts. The reason for these

TABLE 2
Summary of ECR Options Macro Impacts

Change in Gross Domestic Product from Baseline (millions of constant 2010$)

Scenario	Policy Option	2015	2020	2025	2030	2035	NPV
	ES1	– $1,280	– $2,010	– $2,381	– $2,690	– $3,001	– $23,908
	ES2	$226	– $532	– $1,064	– $1,615	– $2,084	– $7,336
	ES6	– $49	– $64	– $62	$67	$314	– $73
Subtotal - ES		– $1,102	– $2,606	– $3,507	– $4,239	– $4,771	– $31,317
	RCI1	– $326	– $316	– $169	$116	$475	– $3,056
	RCI2	$499	$868	$965	$1,303	$1,565	$10,667
	RCI3	$34	– $47	– $77	– $109	– $147	– $516
	RCI6	$155	$271	$696	$1,259	$1,889	$7,086
Subtotal - RCI		$363	$776	$1,416	$2,570	$3,781	$14,180
	AFW1	$1	$2	$2	$2	$3	$20
	AFW2	– $31	$17	$11	$29	– $2	– $54
	AFW5	$8	$4	$2	– $4	– $4	$46
Subtotal - AFW		– $22	$23	$16	$27	– $3	$11
Summation Total		**– $762**	**– $1,807**	**– $2,075**	**– $1,642**	**– $994**	**– $17,126**
Simultaneous Total		**– $763**	**– $1,830**	**– $2,155**	**– $1,782**	**– $1,162**	**– $17,814**

Change in Employment from Baseline (number of jobs)

Scenario	Policy Option	2015	2020	2025	2030	2035	Jobs per Year
	ES1	– 11,856	– 15,762	– 16,773	– 17,813	– 18,701	– 15,962
	ES2	1,853	– 2,719	– 4,525	– 5,798	– 5,764	– 2,871
	ES6	336	1,254	3,705	7,442	9,859	4,087
Subtotal - ES		– 9,667	– 17,227	– 17,593	– 16,169	– 14,606	– 14,746
	RCI1	– 732	3,873	10,673	19,247	29,015	10,237
	RCI2	6,786	12,523	16,044	22,751	29,170	16,158
	RCI3	289	– 356	– 416	– 444	– 472	– 267
	RCI6	3,446	6,181	10,374	15,237	19,986	10,127
Subtotal - RCI		9,789	22,221	36,675	56,791	77,699	36,255
	AFW1	14	21	19	19	20	16
	AFW2	16	899	1,091	1,440	1,282	871
	AFW5	59	44	44	28	43	48
Subtotal - AFW		89	964	1,154	1,487	1,345	934
Summation Total		**211**	**5,958**	**20,236**	**42,109**	**64,438**	**22,443**
Simultaneous Total		**6**	**5,087**	**18,375**	**39,331**	**61,191**	**20,781**

differing outcomes is that sectors stimulated by AB32 are more labor-intensive than those that are projected to decline.

Options in the RCI sector are expected to result in the highest positive impacts on the SCAG economy. Options in the ES sector are expected to result in overall negative employment and GDP impacts. RCI-2, Building Codes, results in the highest positive economic impacts—an NPV of $10.6 billion GDP gains and an average annual increase of more than 10 thousand jobs. ES-1 RPS yields the highest negative impacts to the economy—an NPV of $24 billion decrease in GDP and a loss of nearly 16 thousand jobs per year on average.

The overall negative GDP impacts from the integrated analysis of the ten ECR options are primarily due to the impacts of the ES options, especially ES-1 and ES-2. From the microeconomic analysis results (Table 1), these two options result in the highest direct net cost ($5.0 billion and $4.6 billion, respectively) among all the options. The negative impacts from these two options mainly stem from the high capital cost of renewable electricity generation compared with the costs of avoided fossil fuel electricity generation.

The last two rows of Table 2 present the summation total and simultaneous total of the ten options. In the simultaneous impact analysis, the simulation is based on an integrated analysis of all the quantifiable ECR options (eliminating the potential double-counting of the impacts among the options) modeled in one simultaneous run in the REMI Model.[9] The results highlight the following impacts of the ECR options on the SCAG economy:

- An employment increase of 61,191 jobs by 2035, or an increase of about 0.49% over baseline;
- An average annual gain of 20,781 additional jobs over the entire planning period;
- A decrease in GDP of $1.16 billion in 2035, or a decrease of about − 0.06% over baseline;
- A net decrease in GDP of about $17.8 billion in NPV over the entire planning period; and
- A net increase in disposable personal incomes of about $10.5 billion in NPV.

A companion piece of legislation that is also addressed by the CEDP process is Senate Bill (SB) 375 — The Sustainable Communities and Climate Protection Act of 2008, which requires the California Air Resources Board to set regional emissions reduction goals for passenger vehicles. The major findings were that the transportation sector options include an estimated net gain of over 13,000 jobs per year and a net increase in GDP of over $22 billion in NPV. Taking into account the broader impact of transportation networks and regional amenity benefits, nearly 4,000 additional job gains per year are projected (CEDP, 2012).

B. Sectoral Impacts

In terms of employment impacts, the majority of the most positively stimulated sectors are those related to household spending (e.g., Retail Trade, Restaurant and Accommodation, Health Services, Real Estate, Financial Services, etc.) and the implementation of renewable

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[9] A comparison between the summation of simulation results of individual options and the simultaneous simulation result in Table 2 shows that the former yields higher positive employment impacts and lower negative GDP impacts to the economy. However, the differences are within 8%. The overlaps between the 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.

energy (e.g., Semiconductor and Other Electric Components). The major negatively affected sectors include electric power generation and fossil fuel production sectors due to the reduced demand for electricity associated with end-use energy efficiency improvement.[10,11] From a relative change perspective, Agriculture and Forestry related sectors and some Manufacturing sectors, especially those related to energy-efficiency equipment production, are expected to experience large percentage employment increases. The major negatively affected sectors in terms of percentage employment change are electric power generation, and fossil fuel production and delivery sectors. In terms of GDP impacts, the most impacted sectors are very similar to those in the sectoral employment impact analysis.

C. Economic Impacts Outside of the SCAG Region

The implementation of the ECR options in the SCAG Region is expected to generate slightly negative impacts to regions outside of the SCAG Region: a 0.27% GDP loss in Rest of CA and 0.045% GDP loss in Rest of U.S. in 2035. There are several reasons for this result. First, the flows of capital investment from the rest of CA and rest of U.S. to the SCAG Region tend to decrease the investment activities in regions elsewhere. Second, in ES-1 (RPS), certain portions of the renewable electricity generation will take place outside of the SCAG Region. The overall high capital cost of renewable electricity generation compared with the displaced NGCC generation would result in similar net negative impacts on these regions as in the SCAG Region. Finally, we find that for the RCI options, although the stimulus effects stemming from energy savings in the SCAG Region would generate positive spillover effects on the other two regions, this stimulus effect cannot offset the spillover of the negative effects on the utility sectors resulting from the reduced demand for electricity and various fossil fuels in the SCAG Region. In other words, while more of the positive re-spending effects of energy savings to businesses and households tend to remain in the SCAG Region, the dampening effects on the utility and energy supply sectors are greater in the other regions.

6. SENSITIVITY ANALYSIS

Some of the results might appear counter-intuitive in their own right, or in comparison with findings in other states. A major example is mitigation option ES-1, Renewable Portfolio Standard (RPS). The simulation of this option analyzes the impact of moving from the current 20% renewable electricity generation target to a 33% target by the year 2020 and 40% by the year 2035.[12] Our results (see Table 3) project an annual average loss of nearly 16 thousand

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[10] The promotion of the use of electric cars would result in increased demand for electricity. The impacts of such transportation-related policy options are analyzed in a companion study of this one that focuses primarily on the impacts of SB 375 on the SCAG Regional economy (CEDP, 2012). However, the analysis result of the ordinances/policies to promote alternative vehicles in that study only shows a very limited positive impact on the electric generation sector. This is consistent with the findings from some studies by the utility companies that the impact of electric-car use on total electricity consumption is small (SCE, 2013).

[11] The implementation of energy efficiency policies and the introduction of efficiency technologies can also lead to the rebound effect, which refers to the phenomenon that lower energy bills from efficiency improvements may lead to more energy use. However, many studies indicate that the impact of the rebound effect is not likely to be significant, ranging from about 5 to 10 percent of the direct energy savings achieved (Greening et al., 2000; Nadel, 2012; Gillingham et al., 2013).

[12] The basic "33% Trajectory" scenario published in CPUC (2011) is used as the basis for the specification of the mix of renewable electricity generation technologies. It respsents a mid-range estimate of six alternative RPS scenarios presented in that Report.

TABLE 3
Macroeconomic Impact Analysis Results for Renewable Portfolio Standard (ES-1)

Category	Units	2015	2020	2025	2030	2035	Jobs per Year / NPV
Total Employment	Jobs	− 11,856	− 15,762	− 16,773	− 17,813	− 18,701	− 15,962
GDP	M 2010$	− 1,280	− 2,010	− 2,381	− 2,690	− 3,001	− 23,908

jobs. Our analysis in Pennsylvania on the Alternative Energy Portfolio Standard (AEPS) and the analysis in Florida and Michigan of their state RPS's indicated positive impacts. We summarize two of the major factors that affect these results.

First is the capital cost of the renewable electricity generation. Comparing the weighted average renewable electricity generation cost in PA and MI with the SCAG Region, the latter has the highest weighted average generation cost among the three (MCAC, 2009; PA DEP, 2009; CEDP, 2012).

Second, the price of the fuel used in the displaced electricity generation technology, in this case the price of natural gas, is also a key factor affecting the cost-effectiveness, and thus the macroeconomic performance, of the RPS option. Lower future natural gas prices would lead to lower avoided costs of natural gas combined-cycle (NGCC) generation in the SCAG Region, and thus reduced cost-effectiveness of renewable electricity alternatives. In other words, with a declining natural gas price, renewable generation will become relatively more expensive and less competitive.

Several sensitivity tests were run to analyze how the changes in some key assumptions would affect the macroeconomic impact analysis results for the RPS option. We present the major ones below.

A. Renewable Electricity Generation Equipment Produced within the SCAG Region

Regional Purchase Coefficients (RPCs) in the REMI model determine what percent of the demand for each good or service is produced within the SCAG Region. Sensitivity analyses on this variable enable us to examine the impacts related to business decisions under new regulations, such as whether to purchase goods and services from in-region or out-of-region sources, or whether to locate manufacturing facilities within the region or move existing facilities outside of the region. For example, decreasing a baseline RPC can represent a situation in which businesses leave the region, due to increased uncertainties about the regulations. Conversely, increasing a baseline RPC can represent the attraction of new business into the region, due to aggressive industrial targeting efforts.

In the Base Case, the REMI Model utilizes projected RPCs, estimated using historical data, for the manufacturing sectors of renewable electricity equipment. For the RPS (ES-1), the weighted average of the default RPCs of the renewable electricity generation equipment manufacturing sectors is about 30%, meaning that on average 30% of this equipment can be supplied by the companies located within the SCAG Region. In the sensitivity tests, we assume that the RPCs of these key sectors are 50% higher or lower than the default values used in the Base Case simulations.

The second and third numerical columns in Table 4 show the sensitivity test results of RPC. The results indicate that a 50% increase in the in-region supply of renewable generation

TABLE 4
Sensitivity Analysis Results for ES-1 (RPS)

Category	Units	Base Case	50% Lower Equipment RPC	50% Higher Equipment RPC	50% Lower Capital Cost of Renewable Generation	50% Higher Capital Cost of Renewable Generation	50% Lower NG Price	50% Higher NG Price
Average Annual Employment	Jobs per year	− 15,962	− 17,341	− 14,811	− 311	− 31,490	− 20,047	− 11,394
Gross Domestic Product (NPV)	M 2010$	− 23,908	− 27,282	− 21,043	1,966	− 49,322	− 31,348	− 15,621

TABLE 5
Alternative Natural Gas Price Forecasts (in 2010$)

Forecast/Year	2015	2020	2025	2030	2035
MPR/2011 (+50%)	8.22	8.54	9.12	9.29	9.42
MPR/2006	6.25	6.59	6.60	6.59	n.a.
MPR/2011 (Reference Case)	5.48	5.70	6.08	6.19	6.28
MPR-AEO/2013	3.54	4.50	4.80	4.65	4.83
MPR/2011 (− 50%)	2.74	2.85	3.04	3.10	3.14

Source: California Public Utilities Commission (CPUC) Market Price Referent (MPR) (2006 and 2011); EIA AEO (2011 and 2013)

equipment would improve the macroeconomic performance of the option but only slightly: the negative employment impact of ES-1 can be improved by 7%. In contrast, with 50% lower RPCs, the negative employment impact of ES-1 would be increased by 8%.

B. Capital Cost of Renewable Electricity Generation

In this sensitivity test, we analyze the impacts of variations in the capital cost of renewable electricity generation in ES-1 RPS on the macro impact of this option. Specifically, we assume that the capital cost of renewable generation is 50% lower or higher than the capital cost used in the Base Case analysis. The results are presented in fourth and fifth numerical columns of Table 4. They indicate that, if the capital cost of renewable electricity generation can be decreased by 50%, the macroeconomic impacts of ES-1 can be greatly improved to about $2 billion in positive GDP impacts and only slightly over 300 average annual job losses over the entire planning period. However, if the capital cost of renewable generation is higher than in the Base Case by 50%, the negative impacts on employment and GDP of ES-1 would be more than doubled.

C. Projected Price of Natural Gas

In this sensitivity test, we assume that the price of natural gas for the displaced NGCC generation in ES-1 is 50% lower or higher than the price used in the Base Case analysis. Table 5 presents NG prices for various milestone years of the planning horizon in relation to our sensitivity bounds. MPR/2006 represents the prices that were assumed in background studies for the passage of AB 32, while MPR/2011 (Reference Case) is the data series we used in the CEDP report and this study. MPR-AEO/2013 represents the latest NG price forecasts. We can see that NG price forecasts have continued to drop over time, but are still within +/ − 50% of our sensitivity analysis. There has been a slight reversal in NG prices recently, but this has not yet affected future projections significantly.

The lower the price of natural gas, the less competitive are renewable electricity generation alternatives. As shown in the last two columns of Table 4, with a 50% lower projected NG price, the negative employment impact of ES-1 would be increased by about 25%. A 50% higher projected NG price would improve the macroeconomic performance of ES-1 by about 30% in terms of employment impact. Current projections of natural gas prices are mid-way between the Base Case and 50% lower price, and the associated economic impacts would be mid-way as well.

Overall, the results are most sensitive to capital costs and least sensitive to changes in the RPCs.

D. Other Sensitivity Analyses

Studies (such as Gray and Shadbegian, 1998 and Kolb and Scheraga, 1990) indicate entities that need to make large investments in order to comply with environmental regulations tend to spend significantly less on ordinary investment, especially investment for productivity improvements. On the other hand, many analysts point to the fact that large enterprises and governments can readily access capital markets or utilize a variety of investment mechanisms for additional investment needs (Mendelsohn and Feldman, 2013). Therefore, we assumed that in the Base Case 50% of the in-Region private capital investment will come from the displacement of ordinary investment in plant and equipment. In a sensitivity analysis, we evaluate how the variation in the assumption of percentage investment displacement would affect the macroeconomic impacts of the ECR options. Specifically, we simulate two alternatives: 25% and 75% displacement of ordinary private investment in the simultaneous run of all the ten ECR options together. With the lower-bound assumption, the NPV of the GDP losses is reduced from $17.8 billion to $9.1 billion, and with the upper-bound, the NPV of the GDP losses increases to $26.4 billion.

We also perform a sensitivity analysis on the discount rate. When we evaluate the impacts on gross domestic product, it is important to consider the time value of money. People place a higher value on cash flows today than if they are delayed into the future. In the Base Case, we discount the cash flows between 2012 and 2035 to present values at a rate of 5%. In general, the absolute value of the total NPV decreases when the discount rate increases and vice versa. This sensitivity test shows that the NPV of GDP impacts ranges between around − $27 billion and − $12 billion in the simultaneous simulation when the discount rate varies between 2% and 8%.

Sensitivity tests of various other assumptions presented in Section IVB are not presented here because the variations of these assumptions are likely to result in relatively little variation in the results compared with those that are presented. For example, for assumptions #2 (plant/equipment shares), #4 (administrative cost share), #5 and #7 (distribution of costs and savings among sectors), the variations in these assumptions are unlikely to generation significant effects on the aggregate (economy-wide) results (they primarily affect relative sector results, as between machinery manufacturing and construction sectors).

7. INTERPRETATION OF RESULTS

Our results are of interest to policy-makers for several reasons. First, they indicate that the majority of the ten GHG mitigation options yield positive total regional economic impacts. They project that there will be an average annual increase of 21 thousand jobs over the planning time horizon of 2012–35. At the same time, they indicate a decrease of $17.8 billion in GDP (in NPV). The reason jobs increase but GDP decreases is that economic activity is stimulated directly and indirectly in economic sectors that are relatively more labor-intensive than sectors that are displaced. Prime examples of direct job gains are in the installation and operation of renewable energy equipment. Examples of indirect job gains stem from increased consumer purchasing and hence more spending resulting from reduced energy bills associated with energy efficiency improvements. At the same time, the sectors that are offset are relatively capital-intensive, including electric power generation, natural gas distribution, and petroleum refining.

In addition, our results indicate a great disparity in the impacts across individual mitigation options. Energy efficiency improvements, such as energy-efficient building codes, generate positive economic impacts in terms of both their direct effects (e.g. cost savings that lower the price of goods and make them more attractive for regional and export markets) and indirect effects (e.g., demand for inputs up through successive rounds of the supply chain). On the other hand, the RPS is projected to result in a substantial loss of jobs and GDP. The cost of renewable alternatives must be evaluated in relation to the fossil energy generation they replace, and in the SCAG Region, this involves a displacement of relatively cheap natural gas-fired generation. Moreover, the price of natural gas has decreased enormously over the past couple of years. In our previous studies, we found the RPS is likely to generate positive economic impacts in Florida and even in Michigan, but this was under conditions of relatively high gas prices prevailing in 2009–10 and projections into the future on that basis. Another important factor that distinguishes the SCAG case is the fact that projections of capital and operating costs of renewable electricity generation are not expected to decline as much as in previous forecasts.

We undertook a sensitivity analysis of our results for several purposes. One was to validate the results and another to determine their robustness—how sensitive they are to key assumptions and parameters. A side dividend of our sensitivity analysis relates to policy design—it provides a guide to making the results more positive. For example, the negative regional economic impacts of the RPS can be significantly reduced if the region can attract more manufacturers of renewable electricity generation equipment to the state (as opposed to importing a large percentage of this equipment). Incentives to encouraging R&D to bring down the cost of renewable electricity generation can greatly improve the macroeconomic performance of these technologies.

8. CONCLUSION

This paper presents the analysis of the macroeconomic impacts on the SCAG Region economy of ten major point source GHG mitigation options to comply with California's Climate Action Plan (AB 32). We used a state-of-the-art macroeconometric model to perform this analysis. The data inputs to the model are based on the microeconomic impact analysis of the cost and saving estimates associated with the Energy, Commerce, and Resources (ECR) mitigation options, and are supplemented by a set of standard microeconomic and macroeconomic modeling assumptions.

The macroeconomic analysis results indicate that, as a group, the recommended ECR options yield a net positive impact on the SCAG Region's economy in terms of employment but a slightly negative impact on GDP. In percentage terms, the increase in employment represents about a 0.5% increase in jobs above baseline, while the GDP loss only represents a decline of less than 0.1% below baseline. More than half of the individual options themselves yield net positive impacts in terms of employment impact. The Building Codes option is estimated to contribute the highest economic gains. The overall negative GDP impacts from the integrated analysis of the ten ECR options are primarily due to the impacts of the ES options, especially Renewable Energy Incentive Programs ES-1 and ES-2. From the microeconomic analysis results, these two options result in the highest direct net cost ($5.0 billion and $4.6 billion, respectively).

Several analyses were performed to determine the sensitivity of the results to major changes in key variables and assumptions. For example, natural gas prices are based on projections, including changing market conditions. However, others are based on historical experience (e.g., in-region production of green technologies). The in-region production of green technologies is likely to increase as a result of market forces in general and as a result of the fact that California has been a leader in this area, including production for export markets. Also, California may have an edge in attracting investment from outside the State given the fact that it is out front in implementing a climate action plan. Still, the sensitivity analyses provide a basis for government and the private sector cooperation in achieving the best possible outcome of climate policy, such as by attracting more green manufacturing firms to locate within the SCAG Region, investing in R&D in green technologies to bring their costs down, and attracting more federal subsidies and investment from other regions.

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