Climate Policy and Economic Growth in California

A Comparative Analysis of Different Economic Impact Projections

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EXECUTIVE SUMMARY

As California policymakers move to implement the state's Global Warming Solutions Act, Assembly Bill 32 (AB 32), there has been considerable controversy over the economic impacts of this landmark law to reduce global warming emissions. Multiple macroeconomic analyses have been conducted by a variety of economic modeling teams. But, to date, there has been no comparative analysis conducted of the assumptions or models used to produce these macroeconomic results. By providing an examination of the most prominent of these analyses, this report aims to provide context and transparency with respect to these modeling programs to better inform public discourse on the economic impacts of AB 32.

Four Economic Modeling Efforts Examined

The California Air Resources Board (CARB) has developed the most sophisticated state-level economic modeling program in the nation as part of its mandate to implement AB 32. In addition to CARB's analysis, there have been two other principal efforts to quantify the macroeconomic impacts of AB 32 implementation, one by researchers at the University of California (Roland-Holst 2008) and a cooperative effort between Charles River Associates and the Electric Power Research Institute (EPRI/CRA 2007). Broadly speaking, each of these three principal modeling exercises follows a standard approach. The first step forecasts a business-as-usual (BAU) scenario of the size of California's economy for each year going forward to 2020, assuming that AB 32 had not passed (i.e. in the absence of its implementation). Second, a scenario is developed that reflects changes expected due to the implementation of AB 32. Then, the economic impacts of the plan are computed as the difference between the results in the BAU and AB 32 scenarios. Each of these three principal analytical efforts employs a Computable General Equilibrium type of economic model. These models represent the economy as numerous interlinked markets for both inputs to production and finished products, and achieve equilibrium through price changes. Prices rise or fall until supply equals demand.

This report also considers a more recent entry in the modeling debate, a study conducted by Varshney and Tootelian (2009) of the California State University, Sacramento. Unlike the other studies, Varshney and Tootelian do not develop a BAU scenario. Their approach is to impose CARB's estimates of the costs of AB 32 implementation (ignoring the benefits) on 2008 data to evaluate economic impacts. They also use a less sophisticated approach called an input-output model. This is the framework from which the more advanced Computable General Equilibrium type of model evolved. Input-output models such as that used by Varshney and Tootelian do not allow for input substitution effects in production, meaning that such models assume that industrial and commercial firms will continue using fossil fuels even as prices rise to reflect the introduction of a price on carbon pollution.

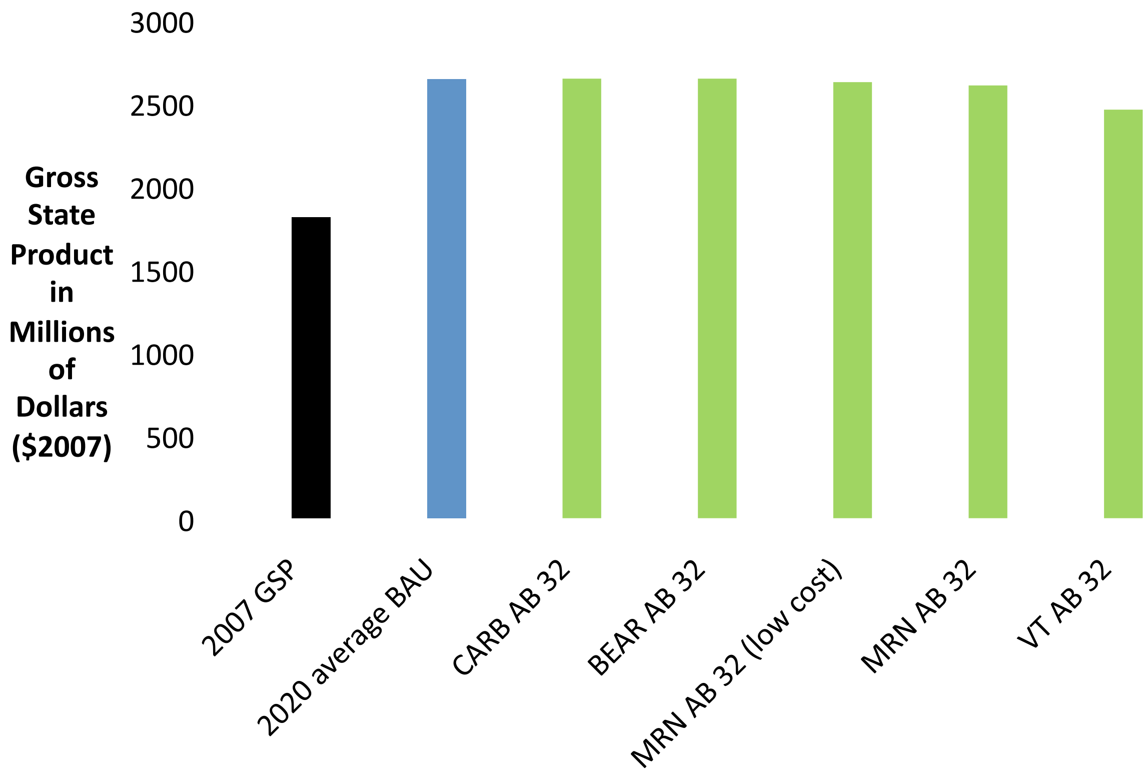
Comparison of Modeling Results

The results of CARB's macroeconomic modeling efforts to date fall within the mainstream of results of macroeconomic analyses, which yield a broad consensus that climate solutions are affordable and economic growth will be robust at the same time that pollution reductions of the magnitude called for by AB 32 are achieved. It is notable that all macroeconomic modeling shows continued strong economic growth even as most of the benefits of climate solutions are typically left out of the models. While all the main costs are incorporated in these macroeconomic analyses, the only benefit typically captured is the value of energy saved due to enhanced energy efficiency.

Despite this, the models uniformly show continued strong economic growth with AB 32 implementation for at least three reasons: 1) The changes that will be required take place over a long time frame and are relatively gradual; 2) energy efficiency investments encouraged by AB 32 will provide energy savings that more than compensate for the modest increase in upfront investment that they sometimes involve; and 3) in addition to the direct benefit of savings due to energy efficiency, there are indirect macroeconomic benefits (a multiplier effect in macroeconomic terminology) that result when spending is diverted from energy to other goods and services that are more likely to be domestically produced.

With the exception of Varshney and Tootelian, each of these models have run multiple scenarios. This report examines a subset of these to provide a straightforward comparison. Each of the three modeling frameworks produces similar but somewhat different forecasts of macroeconomic activity in the absence of AB 32 implementation, i.e. each forecasts similar but not exactly the same BAU economic growth. While we examine three different baselines in the body of this report, here we provide a summary of results using a standardized BAU scenario developed by taking the mean (average) of BAU forecasts of 2020 Gross State Product produced by the three principal models. Standardizing the BAU level makes the relative impacts of AB 32 more transparent. Varshney's and Tootelian's analysis does not report 2020 growth in either BAU or AB 32 scenarios. However, they do provide an estimate of the overall macroeconomic effect of AB 32, and that figure is used to impute the data point that allows inclusion of "VT AB 32" in the graph below.

Figure ES -1. Results More Similar Than Different, Except Varshney (Standardized 2020 BAU)



Notes:

Three colors are used to distinguish scenarios: (1) Black: 2007 gross state product (GSP) data; this is not a forecast, but an actual measurement; (2) blue: 2020 forecast economic growth in the BAU scenario (i.e. without AB 32); (3) green: 2020 forecast with AB 32 implementation.

The graphic also uses the following acryonyms:

- **CARB**. CARB's technical staff has used the EDRAM (Environmental Dynamic Revenue Assessment Model) model to evaluate AB 32.
- **BEAR.** Professor David Roland-Holst, of Mills College and the University of California at Berkeley, has developed the BEAR (Berkeley Energy And Resources) model of the California economy to analyze climate policy.
- **MRN.** Charles River Associates has applied its MRN (Multi-Regional National) model, which includes a separate, detailed representation of the electricity sector, to assess AB 32 economic impacts under contract to the Electric Power Research Institute.
- **VT.** Input-output modeling with the IMPLAN model by Varshney and Tootelian.

Figure ES-1 shows that the Varshney and Tootelian (VT) study, represented by the column on the far right of the graph, is the outlier among the studies. Their finding of much higher costs relative to the other analyses follows from the fact that their analysis includes only costs and no benefits. Specifically, it does not include the single benefit of the money saved due to energy efficiency investments, as is included in the other models. VT use as inputs the added upfront, incremental costs of improved efficiency that CARB estimated in its measure-by-measure analysis of the Scoping Plan, and then proceed to ignore the stream of energy savings that CARB estimates these investments will produce. After reviewing their report, UCLA

Professor Matthew Kahn concludes that, "[Varshney's and Tootelian's] cost estimates are fatally flawed and vastly over-state the expected costs of compliance with AB 32," (Kahn 2009, p.1).

Figure ES-1 also shows that each of the other three sophisticated modeling efforts forecasts strong economic growth relative to current GSP through 2020 both with and without AB 32. It also shows that the size of expected growth from current GSP is vastly greater than any differences between BAU and AB 32 scenarios, and between different AB 32 scenarios. This graphical analysis shows that CARB's modeling results have been largely consistent with the other principal analytical efforts. Another big picture conclusion drawn from comparison of these modeling efforts is that California's climate policy looks very affordable even when many of its benefits (i.e. all of them except for energy savings) are ignored.

Results of economic assessments at the national level have pointed to this same conclusion: the magnitude of the economic cost of climate action is dwarfed by expected growth with or without climate policy intervention. Section five of this report profiles results of the most recent work on the costs of federal climate policy conducted under the auspices of The Stanford Energy Modeling Forum. The federal and California studies are compared side by side illustrating striking similarity between.

This report is not intended to suggest that CARB's economic modeling work has been flawless. There will always be room for improvement in any complicated, economy-wide modeling effort. CARB is currently in the process of evolving its approach and additional results are expected later this year or in early 2010.

I. INTRODUCTION

As California policymakers move to implement the state's Global Warming Solutions Act, Assembly Bill 32 (AB 32), there has been considerable controversy over the economic impacts of this landmark law to reduce global warming emissions. Multiple macroeconomic analyses have been conducted by a variety of economic modeling teams. But, to date, there has been no comparative analysis conducted of the assumptions or models used to produce these macroeconomic results. By providing an examination of the most prominent of these analyses, this report aims to provide context and transparency with respect to these modeling programs to better inform public discourse on the economic impacts of AB 32.

The California Air Resources Board (CARB) has developed the most impressive state-level economic modeling program in the nation to support the implementation of AB 32. The results of CARB's efforts to date fall within the mainstream of results of macroeconomic analyses, which yield a broad consensus: economic growth through 2020 will be robust at the same time that pollution reductions of the magnitude called for by AB 32 are achieved. This report provides graphical analyses to demonstrate that CARB's modeling results are mostly consistent with credible, independent studies. Though this paper is focused on analysis of the economic implications of AB 32, section five of the report puts the California studies in the context of work done at the national level. Readers are invited to provide feedback on this policy brief. The spreadsheet showing all the calculations and assumptions underlying this work is available upon request.

II. **FRAMING THE FRAME:** HOW TO UNDERSTAND WHAT IS AND IS NOT CAPTURED BY THE MODELING

It is notable that macroeconomic modeling of clime policy impacts in California as well as at the national level shows continued strong economic growth despite the fact that these are essentially models of implementation costs alone. Most of the benefits of clean energy and climate solutions are left out of the models. The value of energy saved due to efficiency or conservation is the one and only benefit that macroeconomic models typically consider.[i] This is true for the California studies reviewed here, except for the study by Varsheny and Tootelian, which ignores all benefits. Despite this, the models uniformly show continued strong growth with AB 32 implementation. There are at least three reasons for this.

First, the changes that will be required are relatively gradual. The Scoping Plan estimates that in real terms, AB 32 will require about a 15% reduction in real terms from 2008 level (CARB 2008, p. ES-1). Second, energy efficiency technologies, including many in use today, often offer energy savings that more than offset the modest increase in upfront investment that they sometimes involve. These attractive investments are often missed due to myopic behavior and/or a variety of other market failures and barriers that exist beyond the lack of a price on greenhouse gas emissions. Third, in addition to the direct benefit of savings due to energy efficiency, there are indirect macroeconomic benefits (a multiplier effect in macroeconomic terms) that result when spending is diverted from energy to other goods and services that are more likely to be domestically produced. While the conventional and commonly accepted practice of modeling reasonably reflects the state of the modeling science as well as resource and time constraints, it is important to keep in mind all that is not included in the macroeconomic modeling. The benefits of climate solutions that are frequently not captured in macroeconomic modeling are discussed further in the Conclusion of this paper.

III. SURVEYING ANALYSES OF AB 32'S MACROECONOMIC IMPACTS

In addition to CARB's analysis, there have been two other principal efforts to quantify the macroeconomic impacts of AB 32 implementation, one by researchers at the University of California (Roland-Holst 2008) and one cooperative effort involving Charles River Associates (CRA) and the Electric Power Research Institute (EPRI/CRA 2007). Broadly speaking, each of these three principal modeling exercises follows a standard approach. The first step forecasts a business-as-usual (BAU) scenario of the size of California's economy for each year going forward to 2020, assuming that AB 32 had not passed (i.e. in the absence of its implementation). Second, a scenario is developed that reflects changes expected due to the implementation of AB 32. Then, the economic impacts of the plan are computed as the difference between the results in the BAU and AB 32 scenarios. Each of these three principal analytical efforts employs a Computable General Equilibrium type of economic model. These models represent the economy as numerous interlinked markets for both inputs to production and finished products, and achieve equilibrium through price changes. Prices rise or fall until supply equals demand.

Each of these models has been applied multiple times, but this report considers only a subset of these to provide a straightforward comparison.[ii] For CARB and work done at the University of California, we use results from the Economic Analysis Supplement to the Climate Change Draft Scoping Plan (see CARB 2008b and Roland-Holst 2008 respectively).[iii] For the work of the Electric Power Research Institute (EPRI) and CRA, we use results from their most extensively documented analysis (EPRI/CRA 2007). In addition to CRA's "pure trade" scenario,[iv] we also graph CRA's "low cost assessment" scenario.[v]

This report also considers a more recent study conducted by Varshney and Tootelian (2009) of the California State University, Sacramento. Unlike the other studies, Varshney and Tootelian do not develop a BAU scenario. Their approach is to impose CARB's estimates of the costs of AB 32 implementation (ignoring the benefits) on 2008 data to evaluate economic impacts. They also use a less sophisticated approach called an input-output model. This is the framework from which the more advanced Computable General Equilibrium type of model evolved. Input-output models such as that used by Varshney and Tootelian do not allow for input substitution effects in production, meaning that such models assume that industrial and commercial firms will continue using fossil fuels even as prices rise to reflect the introduction of a price on carbon pollution.

The following acronyms are used in this report to refer to these modeling frameworks:

- **CARB.** CARB's technical staff has used the EDRAM (Environmental Dynamic Revenue Assessment Model) model to evaluate AB 32.
- **BEAR.** Professor David Roland-Holst, of Mills College and the University of California at Berkeley, has developed the BEAR (Berkeley Energy and Resources model) model of the California economy to analyze climate policy.
- **MRN.** Charles River Associates has applied its MRN (Multi-Regional National) model, which includes a separate, detailed representation of the electricity sector, to assess AB 32 economic impacts.
- **VT.** Input-output modeling with conducted by California State University's Varshney and Tootelian (2009).

Each of the three modeling frameworks produces similar but somewhat different forecasts of what macroeconomic activity would look like in the absence of AB 32 implementation, i.e. each forecasts similar but not exactly the same BAU economic growth. Figure 1, below, compares the results of the first three modeling frameworks, including each one's unique BAU scenario. Since Varshney and Tootelian do not develop a BAU scenario, their results are not included in this first figure. As with all the figures in this report, three colors are used to distinguish scenarios.

- **Black:** 2007 data; this is not a forecast, but an actual measurement
- **Blue:** 2020 forecast economic growth in the BAU scenario (i.e. without AB 32)
- **Green:** 2020 forecast with AB 32 implementation

Figure 1. Macroeconomic Modeling Results More Similar Than Different

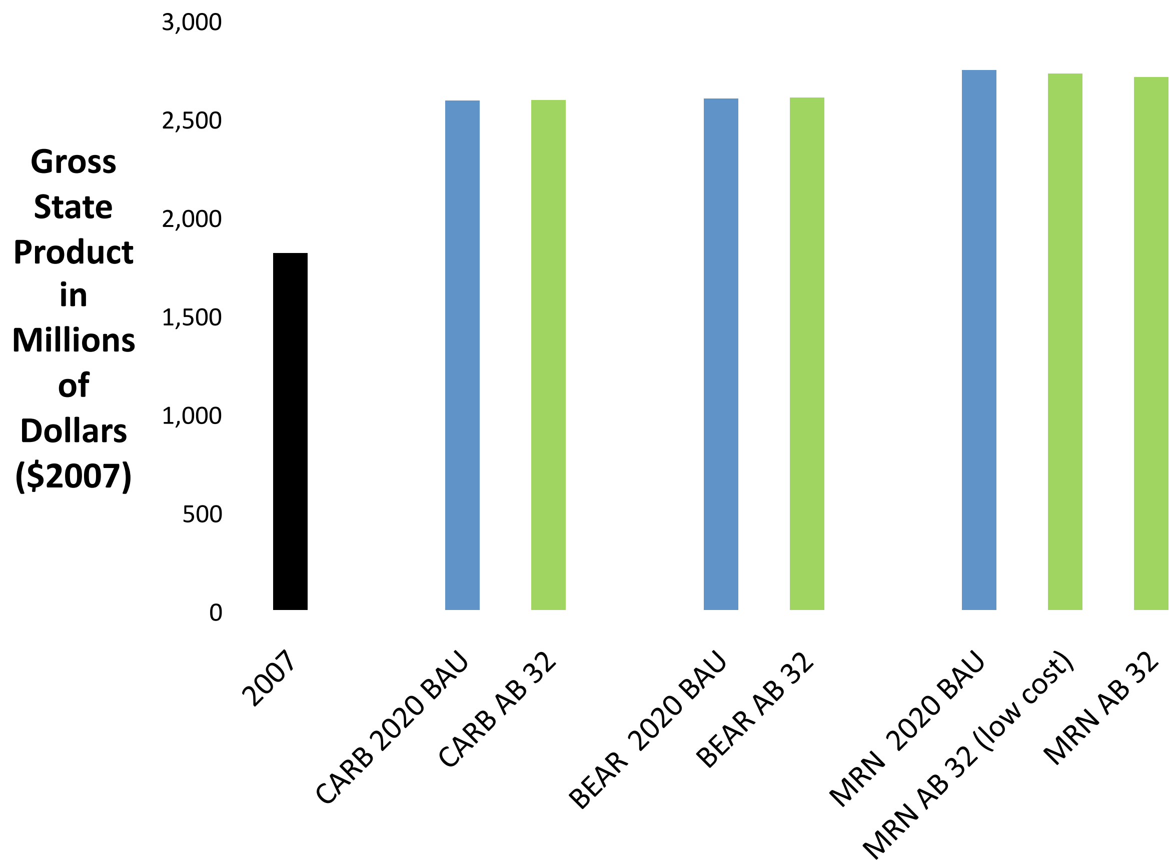


Figure 1 shows that all three models forecast that economic growth is expected to be robust under AB 32. Additionally, results from all models suggest that the economic impacts of AB 32 are likely to be small relative to the growth in the economy between now and 2020. Though commentary has largely focused on the differences between modeling results, this figure illustrates that the results are more similar than different.

Table 1 provides the data underlying Figure 1 and also shows the percentage change in gross state product (GSP) implied by the different modeling efforts.

Table 1. California GSP Forecasts of Different Modeling Frameworks

	GSP (millions of 2007$s)	Change due to AB 32 (millions of 2007$s)	% change due to AB 32
2007	1,811		
2020 average BAU	2642		
CARB 2020 BAU	2,586		
CARB AB 32	2,590	4	0.15%
BEAR 2020 BAU	2,598		
BEAR AB 32	2,602	4	0.15%
MRN 2020 BAU	2,742		
MRN AB 32 (low)	2,725	-17	-0.62%
MRN AB 32	2,705	-37	-1.40%

The average change in 2020 GSP from BAU to AB 32 scenarios across the four sets of results reported in Table 1 is a decline of 0.43%.

Figure 2 provides a different perspective. We use a standardized BAU scenario, calculated by simply taking the mean of the BAU forecasts of the three models. By standardizing the BAU forecast of 2020 GSP, the relative impacts of AB 32 are more transparent.[vi] Figure 2 also includes the results of Varshney and Tootelian's analysis. Though their study does not report 2020 growth in either BAU or AB 32 scenarios, they do provide an estimate of the overall macroeconomic effect of AB 32 (a decrease of $183 billion, a decrease of 6.9% from the 2020 average BAU forecast of GSP), and that figure is used to impute the "VT AB 32" data point in Figure 2.

Figure 2. Results More Similar Than Different, Except Varshney (Standardized 2020 BAU)

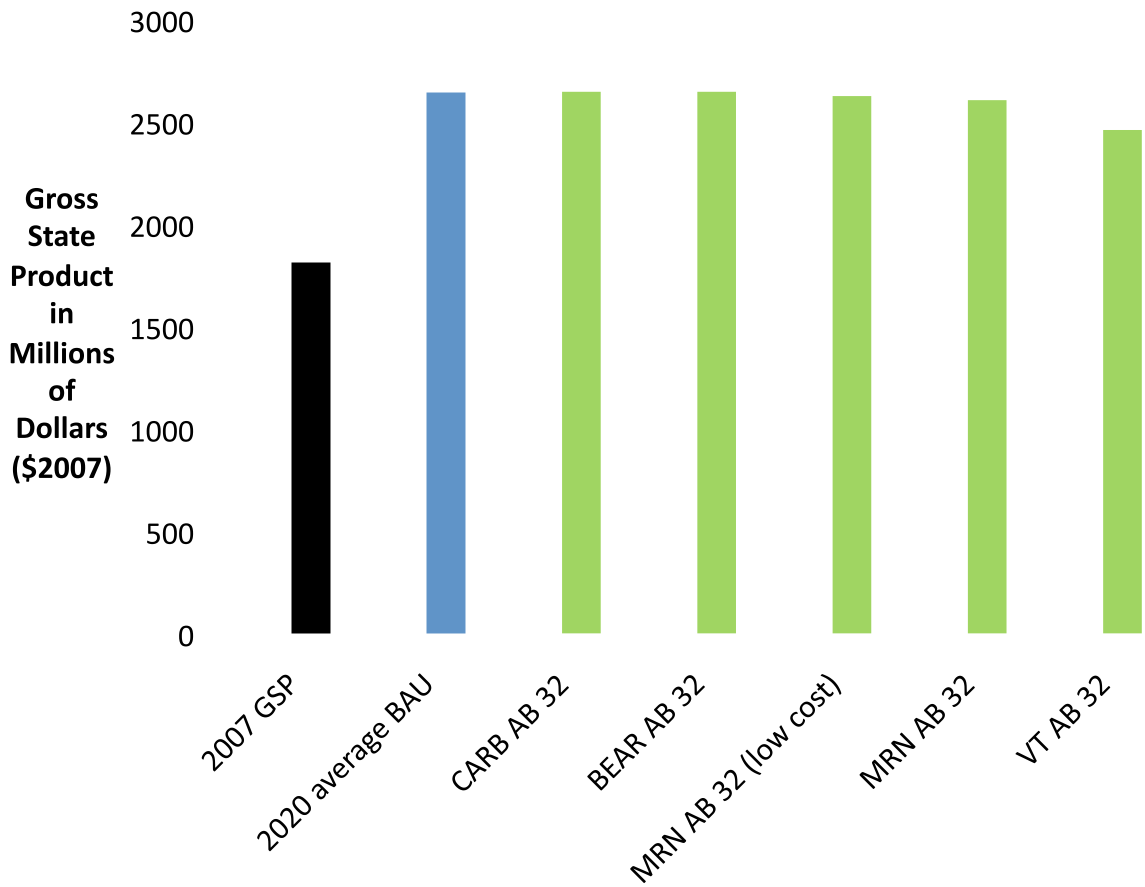


Figure 2 shows that the VT study, which is represented by the column on the far right of the graph, is an outlier among the California studies. This result follows from the fact that the VT analysis includes only costs and no benefits. Specifically, it does not include the benefit of the money saved due to energy efficiency investments, as is included in the other models. VT uses as inputs the added upfront, incremental costs of improved efficiency that CARB estimated in its measure-by-measure analysis of the Scoping Plan. However, the VT analysis ignores the stream of energy savings that CARB estimates these investments will produce. This is analogous to considering buying a hybrid-electric car, but ignoring the improved mileage such a vehicle offers. After reviewing their report, UCLA Professor Matthew Kahn concludes that, "[Varshney and Tootelian's] cost estimates are fatally flawed and vastly over-state the expected costs of compliance with AB 32," (Kahn 2009, p.1).

Other than illustrating the extent to which the VT study is an outlier, Figure 2 reiterates that economic growth is forecasted both with and without AB 32, and the size of this expected growth dwarfs any differences between BAU and AB 32 scenarios, and between different AB 32 scenarios.

To provide greater insight into the relative magnitude of the economic impacts forecast by the different modelers, Figure 3 shortens the vertical axis of the graph to focus only the range over which impacts vary.

Figure 3. Focus on AB 32 economic impacts

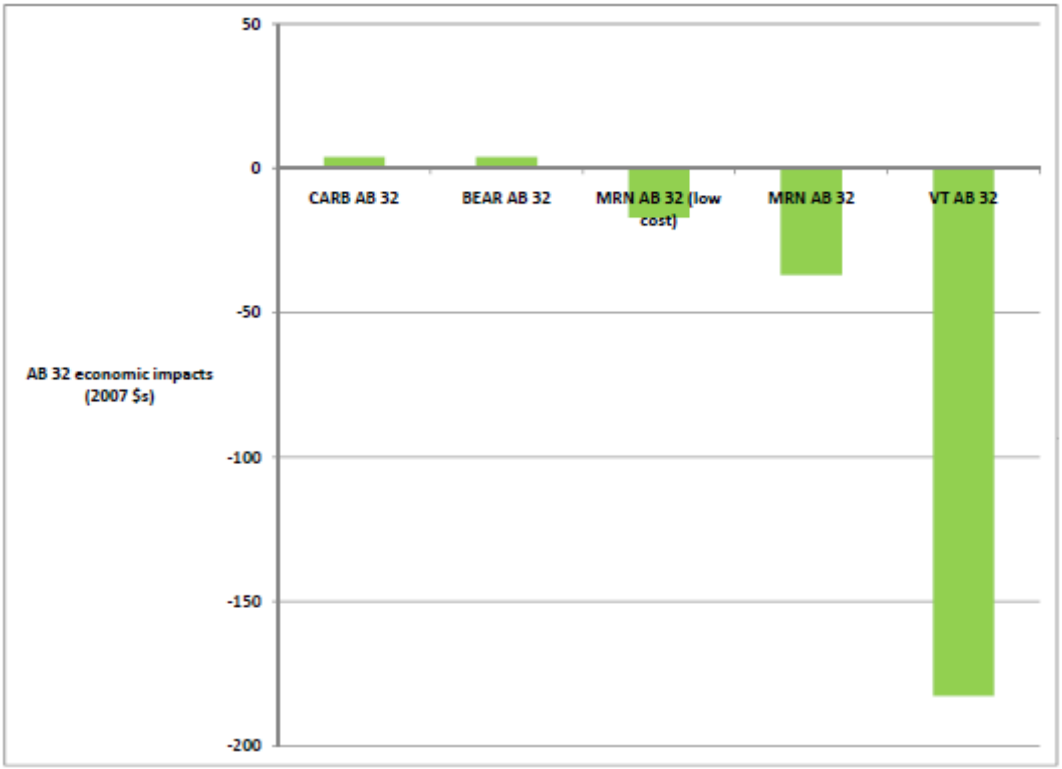
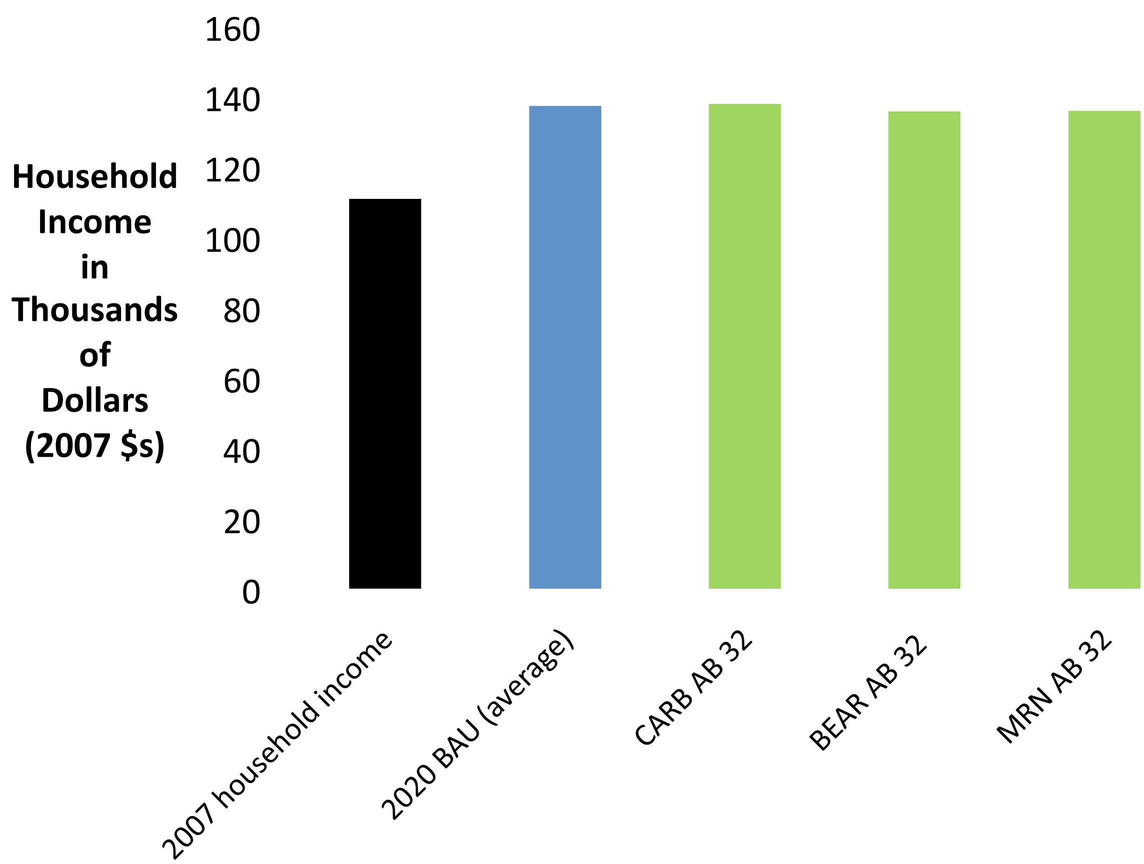


Figure 3 demonstrates even more clearly that, for the reasons discussed above, the Varshney and Tootelian analysis finds much larger economic impacts than the other studies.

In Figure 4, a different metric—expected household income—is used to compare the forecasted economic impacts of AB 32. As in Figure 2, we use a standardized BAU baseline, but calculated as the average of the CARB and BEAR studies only because the EPRI/CRA report does not provide this data point.[vii]

Figure 4. Modeling Results for Household Income Impacts Also More Similar than Different



As was the case in our examination of impacts on GSP, Figure 4 shows that the three modeling framework produce similar results. Growth in household income by 2020 is forecast to be strong in the BAU scenario as well as in the scenarios in which AB 32 implementation takes place.

IV. ADDITIONAL CONTEXT

In some fundamental ways, CARB's modeling efforts parallel those of the US Environmental Protection Agency (EPA), an agency with much greater resources at its disposal. For example, the US EPA has used two Computable General Equilibrium models to evaluate federal climate policy.[viii] CARB has used its in-house Computable General Equilibrium model, EDRAM, and collaborated with Professor David Roland-Holst who runs the BEAR model, also a Computable General Equilibrium model.

It is also useful to recognize the limitations of economic modeling science. While economic modeling provides useful inputs to climate policy decisions, policymakers should not expect that the results of modeling will provide absolute clarity on the optimum mix of policies. For example, the typical Computable General Equilibrium model (such as those used by the US EPA and CARB) does not reflect the heterogeneity of firms within a sector. Rather, each sector of the economy is represented by a single mathematical equation, which seeks to represent the production decisions of a typical firm. Virtually all CGE models are therefore unable to account for the flexibility of a market-based policy such as cap-and-trade or a carbon fee. The technological specificity of these models is also an issue. In order to include a more detailed representation of the electricity sector, for example, as we see in CRA's MRN model, CARB is working to integrate an energy model, Energy 2020, with the EDRAM model.

Additionally, Computable General Equilibrium models typically do not represent market failures, at least not endogenously. In other words, the internal structure of the model assumes that markets are perfectly competitive and populated by perfectly rational actors. In fact, there is broad recognition that sub-optimal behavior by both firms and households is an important reality (National Academy of Sciences 2009). The Market Advisory Committee to the California EPA recognized this in their report and lists three types of market failures that exist in addition to the lack of a price on carbon emissions (2007, p. 19).[ix]

V. COMPARISON TO NATIONAL RESULTS FROM THE STANFORD ENERGY MODELING FORUM

The Stanford Energy Modeling Forum brings together some of the best minds on the topic of macroeconomic modeling from within and outside of academia. For some further perspective on CARB's modeling work, this report draws on the results of the 22nd and most recent Forum.[x] We focus on the results pertaining to federal climate policy, though a separate set of studies included international emission reduction efforts and produced similar results. Again, the magnitude of economic impacts of climate action relative to the baseline is dwarfed by expected growth with or without climate policy intervention. Just as the California studies are not comprehensive analyses of all the costs and benefits that would follow from policy implementation, these models too mostly focus on costs. They too only consider savings on energy spending due to improved energy efficiency as the one single economic benefit.,.

Unlike the California context, however, in which the law requires a particular level of emission reductions (AB 32 requires the State to return to 1990 levels by 2020), the Energy Modeling Forum results do not take place in the context of a certain legislative mandate. Instead, the Forum chooses to look at three different emission reduction scenarios. The two extremes of these are graphed below in Figure 5, ignoring the central scenario to reduce clutter in the graph. The most ambitious scenario models a reduction of 80% below 1990 levels by 2050. If a linear reduction trend is assumed, this scenario implies a cumulative emission allowance of 167 gigatons of carbon dioxide equivalent through 2050. The least ambitious scenario models a program that caps emissions at 2008 levels, which implies a cumulative emission allowance of 287 gigatons through 2050. The labels "167" and "287" will serve as shorthand for these two scenarios. To provide correspondence to the work that has been done in California, results for the year 2020 are illustrated in Figure 5.

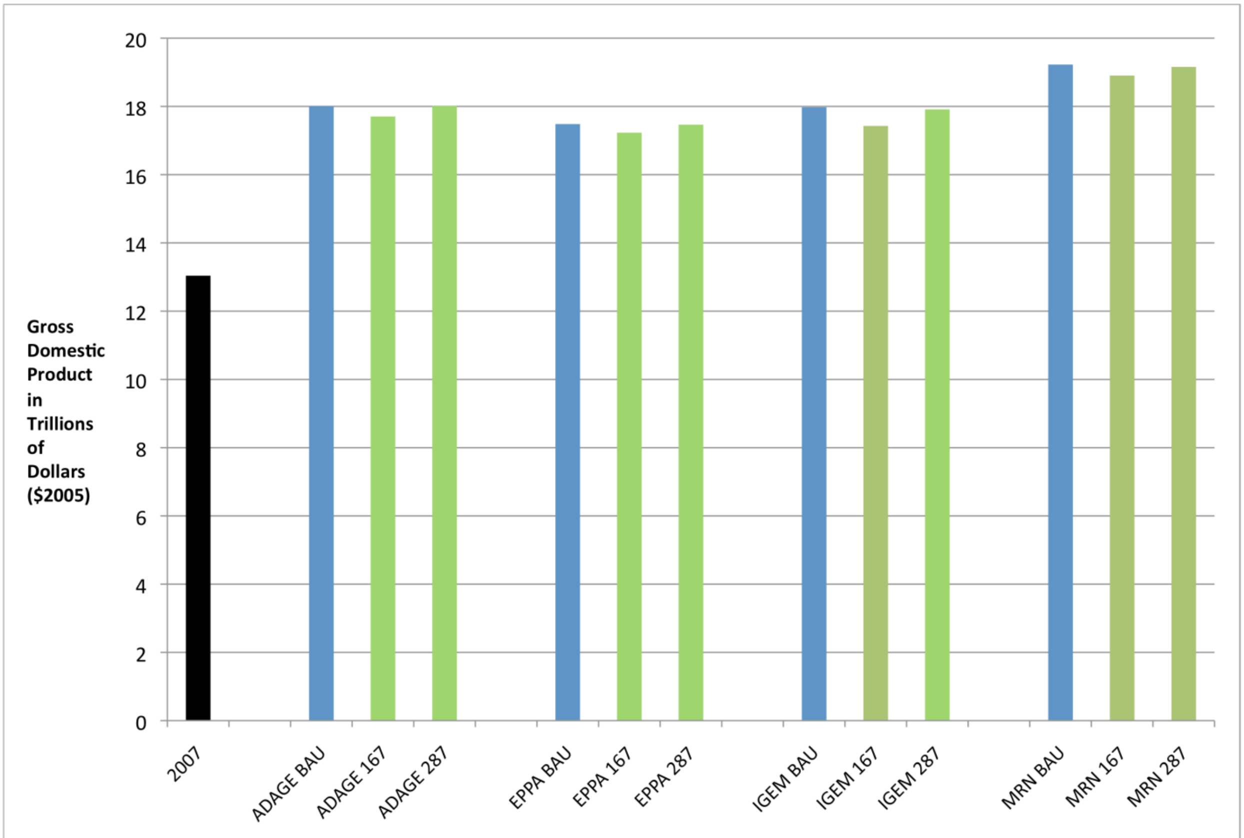
The graph utilizes results from four of the six modeling teams included in the Energy Modeling Forum study (EMF 2009). Two of the models were excluded because the spreadsheet made publicly available did not include relevant data points for these. The remaining four models and the labels for them are as follows:

1. **ADAGE** – a CGE model developed by researchers at the Research Triangle Institute.
2. **IGEM** – a multi-sector, dynamic economic model developed by researchers at Harvard University.
3. **EPPA** – a CGE model developed by researchers at the Massachusetts Institute of Technology.
4. **MRN** – the same model applied by CRA in the California context and graphed in previous Figures.

The US EPA uses two of these modeling frameworks, ADAGE and IGEM, for official assessments of proposed climate legislation.[xi]

Every scenario depicted is for 2020, except for the 2007 Gross Domestic Product (GDP) data point.

Figure 5. Economic Analysis of Federal Efforts to Reduce Greenhouse Gas Emissions



Even with immensely different reduction targets, the effects of climate policy on federal GDP are small relative to the anticipated economic growth that will occur with or without climate policy implementation.

Table 2, below, shows the percentage change from the BAU forecast for each of the different models. The average impact for the 167 gigaton scenarios is -2.0% from BAU GDP and the average impact of the 287 gigaton scenarios is -0.19%.

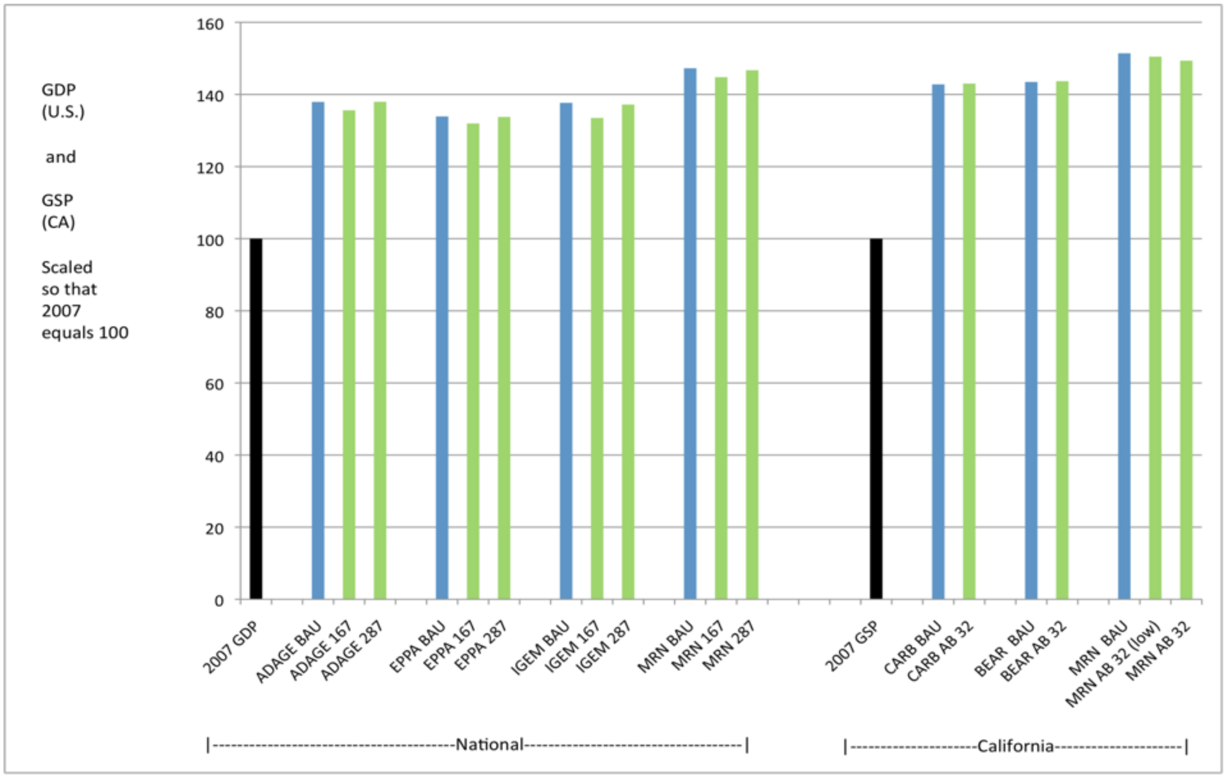
Table 2. U.S. GDP forecasts of different modeling frameworks.

	GDP (trillions of 2005$s)	Change due to climate policy (trillions $2005s)	% change due to climate policy
2007	13.0		
ADAGE BAU	18.0		
ADAGE 167	17.7	-0.30	-1.68%
ADAGE 287	18.0	0.01	0.03%
EPPA BAU	17.5		
EPPA 167	17.2	-0.25	-1.45%
EPPA 287	17.5	-0.02	-0.11%
IGEM BAU	18.0		
IGEM 167	17.4	-0.55	-3.04%
IGEM 287	17.9	-0.06	-0.34%
MRN BAU	19.2		
MRN 167	18.9	-0.32	-1.68%
MRN 287	19.2	-0.07	-0.37%

Because it may be a challenge for the reader to compare the different graphs of federal and California results, Figure 6 combines the information into a single graph. One challenge in doing this is that Gross Domestic Product (for national studies) and Gross State Product (for California studies) are not directly comparable. To solve this, the graph scales both sets of results such that the 2007 level equals 100. Thus, the vertical axis becomes unit-less, and height of the bars representing 2020 forecasts reflects the relative magnitude of the economic growth anticipated under business-as-usual and climate action scenarios.

Again, there is more concordance than discordance between CARB's modeling work and the modeling results of other California studies, as well as between California studies and federal studies.

Figure 6. Forecasts of Climate Policy Economic Impacts in 2020 for California and the Nation



VI. CONCLUSION

The graphical meta-analysis undertaken here shows that CARB's modeling results for the impacts of California climate policy have been largely consistent with the other principal modeling efforts. Each of these shows relatively small effects from climate policy implementation, effects that are dwarfed by expected economic growth between now and 2020. Moreover, for the reasons explained throughout, the results of Varshney and Tootelian are inconsistent with these other studies as well as with the bulk of the economic literature, which suggests that the overall macroeconomic effects of climate policy will be relatively modest.

This report is not intended to suggest that CARB's economic modeling work has been flawless. For example, it would have been preferable if more extensive sensitivity analysis had been conducted earlier. The report that CARB gave to peer reviewers for comment included a single set of analytical results, and it would have been preferable if sensitivity analyses had been provided. Such sensitivity analyses were conducted prior to adoption of the Scoping Plan (see, Kennedy 2008). At the same time, it is important to recognize that perfection is not the proper standard for acceptability, and there will always be room for improvement in any such complicated, economy-wide modeling effort. CARB is currently in the process of evolving its approach and additional results are expected in early 2010.

Another big picture conclusion that these models offer is that climate solutions are very affordable. It is true that the California studies were among the early major ones which used top-down CGE models to find positive economic impacts of the implementation of climate policy. This result followed from the bottom-up integration of engineering studies of the costs and energy savings (where applicable, and taking into account the interactions) of measures that CARB carried out to support Scoping Plan development. These measure-by-measure assessments will continue to be analyzed and refined both as part of on-going analytical work and regulatory implementation. However, critics of CARB's modeling work have provided precious little in the way of concrete criticism of these measure-by-measure engineering assessments. Moreover, parallel studies at the national scale by the consulting firm McKinsey and Company (2007), and in the California context by Stanford Professors Jim Sweeny and John Weyant (2008), found significant potential for efficiency opportunities to produce net economic benefits and that many of these would likely fail to occur spontaneously in the market in the absence of a push from government policy.

Finally, when considering the importance of these models, it is crucial to note that every benefit of climate solutions except the value of energy saved is typically left out. One reason that the VT results are so exaggerated is that their work ignores even this single benefit. These studies that seek to project macroeconomic impacts are primarily cost analyses and not efforts to develop an overall picture of costs and benefits. Some valuable benefits not included are: improved energy security due to increased reliance on clean energy and efficiency; local and regional clean air benefits that will lead to public health improvements and health care savings,[xii] as well as improved labor productivity and student performance; a boost to California's strong emerging clean energy and efficiency firms.

While being cognizant of the limitations of macroeconomic modeling, the state of the economic modeling science should not be blamed for its limitations, and decisions should not be delayed until perfect information is achieved. Uncertainty is part of the territory when it comes to global warming. Lack of precise information about the future should not induce analytical or regulatory paralysis. The potential consequences associated with a lack of action on climate change are significant enough to warrant use of the precautionary principle in the face of uncertainty. There is evidence that California has benefitted economically from past environmental leadership, for example through lower electricity bills and impressive job growth in pollution control, efficiency, and other clean-technology areas. California leadership will also help spur federal action and international cooperation, which are what will ultimately be necessary to solve the challenge of global warming.

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APPENDIX. ADDITIONAL CALIFORNIA DATA

Table 3. Data on household income.

	Thousands 2007$s	AB 32 change
2007 household income	111	
2020 BAU (average)	137	
CARB AB 32	138	0.6
BEAR AB 32	136	-1.5
MRN AB 32	136	-1.3

ENDNOTES

i There are exceptions to this, for example the well known Stern Review, which engages in a more comprehensive evaluation of benefits and costs (Stern 2006).

ii CARB also applied EDRAM as part of the Climate Action Team report prior to passage of the Scoping Plan (CAT 2006) and as part of a Macroeconomic Update report in October 2007 (CARB 2007). David Roland-Holst initially reported results with BEAR in January 2006 (Roland-Holst 2006a), and has periodically released new analyses reflecting different policy assumptions or improvements to the modeling framework (Roland-Holst 2007a, b). Most recently, he has done interesting work with BEAR showing that AB 32 and related policies (such as a 33% renewable electricity standard and energy efficiency measures) provide an important hedge against rising fossil fuel prices (Roland-Holst 2009).

iii We would have liked to include at least one other set of results from later work done by CARB in response to peer review and before passage of the Scoping Plan. This later work included sensitivity analyses on energy prices and alternative definitions of the business-as-usual scenario. (It was a mistake to present a single set of results initially, i.e. to not undertake sensitivity analyses.) However, results of the additional sensitivity analyses that CARB conducted are given as a percentage of change from BAU and the new BAU level is not reported. We considered using the standardized baseline we developed for use in Figure 2 in order to interpret the percentage changes. However, given that this wasn't necessary to compare CARB's results (unlike with the Varshney and Tootelian study we introduce later, which does not provide any BAU figures), we chose not to make this leap. Results of CARB's sensitivity analysis can be found on the CARB website: www.arb.ca.gov/cc/etaac/meetings/120508pubmeet/mtgmaterials120508/etaac_presentation_kennedy_081205.pdf.

iv The pure trade scenario assumes an economist's idealized efficient implementation of the program, involving equalization of marginal costs across all sectors of the economy. CRA would not expect the portfolio of measures in the Scoping Plan to achieve this outcome. This is because of their implicit assumption that markets are perfectly competitive and market actors (firms and consumers) completely rational. Others would argue that there is a significant amount of suboptimal behavior, in part due to market failures described in endnote ix, and that, because of this, the measures in addition to cap-and-trade (which corrects the global warming damage externality) in the Scoping Plan will lead to lower cost action than cap-and-trade alone would achieve.

v CRA itself would likely not consider the low cost scenario to be a highly probable outcome. The focus of this report is not the investigation of the reasons why different models produce different results. Suffice it to say that CRA has a less optimistic view about the supply of negative cost measures, i.e. measures that produce net benefits. Typically, these are energy efficiency measures in which additional, upfront costs are more than outweighed by the value of stream of energy savings over time. CRA takes the position that no such measures exist, due to their belief that markets are best characterized by optimal, rational behavior by firms and people. This view can be contrasted with results of other analyses, such as that by McKinsey and Company (2007), which have found a relatively large supply of negative cost measures.

[vi] Also, note that since the CRA results are based on a different 2020 BAU forecast, and we do not adjust the change in GSP that they predict, Figure 2 slightly exaggerates the percentage change due to AB 32 that follows from work with the MRN model. Put differently, the same absolute quantitative level of change is applied to the smaller, standardized BAU forecast, and this produces a relatively larger change in percentage terms than in Figure 1.

[vii] In general, the EPRI/CRA study prefers to characterize economic impacts in terms of net present value through 2050. Doing so has some advantages from the perspective of economic theory, but makes the results more difficult to interpret for those without advanced training in economics or a related discipline.

[viii] The US EPA uses two Computable General Equilibrium models known as IGEM and ADAGE. For a recent example of this work, see the US EPA's analysis of the clean energy and climate bill just introduced in the US Senate, S.1733: www.epa.gov/climatechange/economics/pdfs/EPA_S1733_Analysis.pdf

[ix] Footnote 7 reads on page 19 of the Market advisory report reads: Other important market failures may include:

- Step-Change Technology Deployment – where temporary incentives will be needed to encourage companies to deploy new technologies at large scale to the public good, because there is otherwise excessive technology, market, and policy risk. Examples of remedies are renewable portfolio obligations, biofuel requirements, and the Low-Carbon Fuel Standard.
- Fragmented supply chains – where economically rational investments (for example, energy efficiency in buildings) are not executed because of the complex supply chain. Examples of remedies are buildings codes.
- Consumer behavior – where individuals have a demonstrated high discount rate that is inconsistent with the public good. Examples of remedies are vehicle and appliance efficiency standards and rebate programs.

[x] More details can be found at http://emf.stanford.edu/events/emf_briefing_on_climate_policy_scenarios_us_domestic_and_international_policy_architectures

[xi] For numerous examples of these applications, see: www.epa.gov/climatechange/economics/economicanalyses.html

[xii] A new National Research Council (2009) report finds huge public health costs from our current energy system, about $120 billion annually, roughly half from electricity generation and half transportation, and CARB has done parallel work showing significant public health benefits associated with reduced fossil fuel combustion due to AB 32.

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