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ENERGY, ENVIRONMENT AND THE ECONOMY**

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Expert Evaluation of the Report:
“Understanding the Impacts of AB32”

May 2013

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Background

The UC Davis Policy Institute's mission is to leverage world-class university expertise to deliver credible, relevant, and timely information and analysis to decision-makers to inform better energy and environmental policy. One of the Policy Institute's key activities in support of this mission is coordinating expert evaluations and peer reviews of products aimed at policy-makers that include significant scientific and/or technical components. This may include reports produced by government, NGOs, or private entities.

The Policy Institute coordinates the input of outside expertise for evaluating reports and other products in order to ensure that they meet the highest standards for accuracy and quality among experts in the field. The Policy Institute's review process, targeted specifically at policy-relevant documents, is a key example of our efforts to institutionalize scientific processes within policy-making. The Policy Institute has established a standard evaluation process for the review of products that is objective, timely and cost-effective. This process is modeled after that used by scientific journals with the exception that the evaluation will not necessarily inform a revision of the product.

The Policy Institute works with recognized experts in the initial solicitation of potential expert reviewer names. Once the Policy Institute has identified and recruited scientific experts, they are called upon to provide written reviews on two overarching aspects of project reports:

- **Approach, Results, Discussion and Conclusion** –the degree to which the report is scientifically sound, accurately analyzes the topic, and successfully represents the project's stated objectives.

- **Clarity and Presentation** - the degree to which the style and organization of the report or proposal is cohesive, organized, and clearly written and presented.

The Western States Petroleum Association (WSPA), the Rockefeller Brothers Fund, and the Alliance of Automobile Manufacturers have contracted with the Policy Institute to facilitate an expert evaluation of the report "*Understanding the Impacts of AB32*" and the subsequent analysis "*BCG and CARB LCFS Models: Review of impact of assumptions in three different areas*". These original reports were funded by WSPA and produced by the Boston Consulting Group (BCG).

The review began in late November 2012. The Policy Institute reviewed the report and prepared reviewer instructions. By December 17th, the Policy Institute had solicited and confirmed eight reviewers with expertise in the following areas:

Energy Economics: Microeconomics and macroeconomics focusing on transportation fuels sector including regulatory impacts on fuels markets, costs, labor, GDP, trade flows, etc.

Refinery Economics and Emissions: refinery operations and emissions and techno-economic

potential for emissions reduction opportunities.

Alternative Fuels Markets: Understanding of the current status and likely evolution of the technical and economic potential for low-carbon fuel and vehicle options including biofuels, natural gas, electric and hydrogen vehicles.

Climate Policy: Knowledge of relevant state and federal fuels regulations including LCFS, RFS, Cap-and-Trade, Clean Fuels Outlet, and compliance options and strategies for meeting those regulations.

The reviewers were given five weeks, from December 17, 2012 to January 18, 2013 to review the report. Two calls with the authors (Boston Consulting Group) were held on January 7 and 11, 2013 to allow reviewers the opportunity to ask questions about the report and the proprietary model. The reviewer comments were then organized. The chair of the reviewers served as an expert mediator and assessed and provided a synthesis of the reviewer comments. Prior to releasing the finding to the public the reviewers, authors, and other relevant stakeholders met to discuss the findings on March 22, 2013. The findings were revised with additional input from the reviewers based on the discussion at the meeting.

Report Scope and Goals

The stated scope and goals of the BCG report are as follows:

“We analyzed the likely impact of AB32 fuels policies on emissions and refining economics using proprietary BCG models. We then developed a framework to assess how these changes are likely to impact California’s economy along key dimensions including employment, government revenues, and GHG emissions.”

The Policy Institute coordinated the input of recognized experts to evaluate this report and assess the degree to which the report is scientifically sound, accurately analyzes the topic, and successfully represents the project’s stated objectives. Consistent with typical reviews, it provides recommendations for additional information and analyses meant to inform the discussion and was not intended to provide alternative analyses or solutions. The reviewers were asked to consider the following questions to guide their evaluations to the best of their abilities given their particular expertise:

Guiding Questions for Review

Scientific and Technical Elements

- 1) Are the assumptions, methods and modeling outputs sound, clear and understandable?
- 2) Given the assumptions and methods used, does the report adequately achieve its stated goals (see “Report Scope and Goals” above)?
- 3) Are the report’s findings adequately backed up by the best available, scientifically rigorous information?
 - a) Does the report adequately summarize the state of current research and scientific understanding?
 - b) Does the report accurately characterize debates, gaps, and inconsistencies in the literature? Where gaps in information exist, can you suggest specific references, sources of appropriate data or other useful information?
 - c) Does the report adequately recognize and communicate limitations of the analysis and various forms of uncertainty in the results?
 - d) Are the conclusions accurate and supported by the analyses?
- 4) Do you have additional comments with respect to the scientific and technical elements of the report?

Policy Relevance

- 1) Does the report adequately summarize and describe the relevant fuels regulations and policy related to AB 32? Are there any key elements of the descriptions that are missing?
- 2) Given the model assumptions, outputs and analyses, do the findings, interpretations and conclusions form an accurate and sound basis for informing policy discussions?
- 3) What, if any, alternative assumptions, scenarios, or case studies should be evaluated to inform policy discussions.
- 4) Are there specific ways that this report could be made more useful to its target audience, primarily the legislature, California Air Resources Board, and the Governor's Office?
- 5) Overall, are the report results robust and based on good data and analyses that decision makers and practitioners can confidently rely on to form a sound basis for informing policy discussions? Please consider scientific soundness, originality, and the degree to which conclusions are supported.

Style and Presentation

Organization/Accessibility

- 1) Does the Executive Summary provide adequate context for reviewing other sections? Is the Executive Summary comprehensive and yet concise enough to present the most salient points?
- 2) Is the report organized in a clear and concise way (given the target audience)? Consider organization and clarity, the cohesiveness of argument, and the length relative to information content.
- 3) Are the existing figures and tables effective and central elements of the report? Are there additional figures that would augment or clarify the messages of the report?

- 4) Was the writing style of the report accessible to broad audiences?

Final Question(s)

- 1) Are there any additional comments you would like to provide on ways the report might be improved that were not captured in the preceding questions?

Overview of Findings

The reviewers appreciate the opportunity to review this report and interact with the analysts from its author, Boston Consulting Group (BCG). BCG's client, Western States Petroleum Association, defined the design and objectives of the report, which addresses the possible impacts of the implementation of California's Global Warming Solutions Act of 2006 (AB 32) on the petroleum refining sector. Although the report includes useful information and insights, we are concerned about some of its assumptions, methodologies and results, and we put these results in a broader context. We present three main summary observations and four recommendations for further activities and research.

Narrow Scope

While AB32 will affect many industries and individual citizens in the state, the BCG report focuses on the impacts of the legislation on the oil refining industry, on the prices paid for gasoline and diesel fuel, and on job losses in the industries that support refineries. The report does not take into account impacts on other industries, like suppliers and distributors of low-carbon fuels, electric utilities, and other manufacturing enterprises. Nor does it consider impacts on consumer electricity prices, public health effects or changes in employment not directly tied to oil refining. The impacts examined are important and potentially large, but they give an incomplete picture of the range of effects that can be expected.

Plausible Alternatives for Fuel Prices

The report highlights a number of challenges that will need to be met in order to successfully implement AB 32, especially its Low Carbon Fuel Standard (LCFS). The LCFS is essentially a phased in 10% reduction in the carbon intensity of transportation fuels used in the state relative

to 2010 levels by 2020. The report, using a particular set of assumptions, outlines important adjustments that the refining industry will need to make under the LCFS rules.

Specifically, new low-carbon fuel sources and alternative fueled vehicles will likely need to be brought on line in the 2015-2017 time frame to meet the LCFS requirements. The report assumes that ethanol from Brazil is the only significant source of low-carbon fuel available in this time frame. Simultaneously, BCG does not expect much increase in production of Brazilian sugar cane-based ethanol in the next few years. So, it expects California to meet the LCFS simply by outbidding other global consumers of Brazilian ethanol.

The report also assumes that California consumers will not drive less in response to higher fuel prices and that no appreciable number of alternative fueled vehicles will be available during this time period. Furthermore, it assumes that refiners will not bank a significant number of credits for early compliance during the early stages of the program. Therefore, banked credits will not be

available to ease the transition and extend the time to develop new low-carbon fuels necessary to comply with the more stringent standards in the latter phase of the program. This set of assumptions leads to high compliance costs that are mostly passed on to transportation fuel consumers.

Plausible alternative assumptions about fuel supply and demand response could lead to less dramatic cost increases for consumers and the refinery industry, perhaps much less dramatic. The recent behavior of fuels markets in California, much of it observed after the completion of the BCG report, suggests more flexibility in the responses of fuel suppliers, refiners and consumers than assumed in the report. Low-carbon cellulosic biofuels have not yet materialized in large enough quantities to lead to confidence that they will provide a relatively low-cost means of meeting the LCFS, but a number of other low-cost pathways have started to emerge that were not originally anticipated. First, the carbon intensity of conventional biofuels has decreased substantially, which has generated credits within the program. Second, new low-carbon liquid biofuels that do not require dedicated infrastructure or advanced technology vehicles have emerged. Finally, the accumulation of LCFS credits has been substantial in the first eight quarters of the program. If sustained even at current levels, the accumulation seems likely to ease the transition toward satisfying the LCFS.

Plausible Alternatives for Businesses, Workers

Another main conclusion of the BCG report under the above assumptions is that global fuels markets will shift so that California will move from being a net importer of gasoline from Singapore and elsewhere to a net exporter of gasoline to Mexico and other Latin American destinations. This is assumed to lead to much lower profitability for conventional oil refining in the state. In fact, the economics of oil refining in the state are assumed in the BCG report to be so poor that a number of refineries would shut down, leading to direct refinery job losses and job losses in the industries that support it and its workers.

This set of assumptions would lead to direct and indirect job losses, but other plausible assumptions could lead to fewer refinery job losses and far fewer non-refinery job losses. Refiners in California could employ at least two major strategies to stay in operation: (1) they could diversify upstream into the fuels segment of the market in California and in other locations that provide low-carbon fuels to the state, and (2) they could line up new lower-cost domestic supplies for which the state has a net back pricing cost advantage over foreign supplies. Recent industry behavior, again much of it observed since the completion of the BCG report, suggests the refinery industry in California has already started pursuing these two strategies to improve its economics. Some refiners are, in fact, diversifying upstream and seeking lower cost local oil supplies.

With regard to induced job losses outside the refinery industry, the reviewers consider the linear input-output assumptions employed in the report appropriate only for very short-run analyses (less than six months). The report assumes that anyone who loses a job will be unable to find another one, which is inconsistent with observed behavior of the California (and most other) labor markets. The indirect job losses, when based on a more realistic dynamic general equilibrium approach, rather than linear fixed coefficients response of labor markets, could be half or even a third of that projected in the BCG report.

Further Activities and Research

While the reviewers think the report's full set of assumptions is unlikely and have concerns about certain aspects of the methodology used to calculate impacts, we also think that policymakers ought to remain alert for signals that the policy is leading to excessive costs and assess policy actions that might avoid these cost escalations. Specifically, we recommend that policymakers:

- 1) Try to prevent possible excessive costs by promoting additional supplies of low-carbon fuels and consumer responses, as well as by further implementation of additional cost containment mechanisms.
- 2) Continue to collect critical information on: the carbon intensity of fuels, including identification of plausible new low-carbon fuels with their actual and likely future production quantities; sales of advanced

technology vehicles; LCFS credit banking and sales of renewable energy credits; and refinery strategies to improve their economics under the LCFS.

- 3) Consider plausible alternatives to BCG's assumptions about low-carbon fuel demand responses and refinery economics that are consistent with historical experience and consistent with the trends observed in task (2) above.
- 4) Sponsor new analyses of the impacts of AB32 on consumer welfare beyond fuel price changes, and on overall economic growth and job growth in California.

Detailed Findings

This review starts with a discussion of its timing and objectives, followed by a discussion of critical assumptions made in the BCG analysis and some of their immediate implications. This is followed by a discussion and assessment of the report's results in three key areas, an observation about the report's transparency and accessibility, and a set of recommendations for further information gathering and analysis.

Several issues related to the BCG report and this review should be noted. First, the reviewers were not asked to – and did not - take a position on any aspect of the AB 32 legislation and implementation, but were asked simply to comment on the BCG analysis- seeking to clarify what was done, how what was assumed affected the results obtained and whether alternative plausible assumptions could lead to different results. Second, since the report was commissioned by the Western States Petroleum Association (WSPA) it focused almost exclusively on the impacts of AB 32 on the refinery industry in the state and puts much less focus on the overall economic and environmental welfare impacts of the implementation of the legislation on all of the citizens of the state. Third, BCG completed the report in a relatively short period of time which made more extensive analysis and sensitivity testing impossible. Fourth, the original report was completed almost a year ago and several pathways that were not considered in the BCG report have started to emerge. Fifth, the California Air Resources Board (CARB) has recently announced its intention to modify the Low

Carbon Fuel Standard (LCFS) in ways that could enable the generation of additional LCFS credits and possibly include explicit cost containment measures by the end of this year. The latter could substantially reduce the concerns raised in the BCG report concerning cost shocks or wild swings in allowance prices.

Before reviewing the three main sets of conclusions included in the summary of the BCG report on: (1) Cost of Compliance, (2) Impact on the Refining Industry, and (3) Impacts on the California Economy - we identify and discuss some of the key input, parameter, and modeling assumptions used in reaching these conclusions. The reviewers believe that some of these assumptions may be too rigid to capture the full range of fuel demand and supply responses to the implementation of the requirements of Assembly Bill 32.

Key Assumptions Made in the BCG Report and Their Implications

Given that the model used to produce the projections is proprietary, the reviewers were unable to ascertain values for all the key inputs to – and modeling assumptions made in – the analysis, which makes it difficult to fully assess the reasonableness of these cost projections. However, they appear to be driven primarily by a combination of key assumptions and intermediate results that represent assumptions about how the fuels market in California would adjust to the changing input assumptions in their refinery model. Based on the materials provided and discussions with the report authors, key input assumptions are, or appear to be:

- (1) The availability of only a small number of Advanced Technology Vehicles by 2020.
- (2) Limited available quantities of low carbon intensity (CI) sugarcane ethanol from Brazil available through 2020.
- (3) No significant commercially available amounts of cellulosic ethanol or advanced low-CI renewable gasoline/diesel fuels from anywhere by 2020.
- (4) Limited ability to ‘bank’ compliance credits for either LCFS or cap-and-trade requirements which could provide further temporal flexibility and reduce price volatility.
- (5) Incomplete accounting for sales of Renewable Identification Numbers (RINs) by California refiners who over comply with federal Renewable Fuel Standards (RFS)¹ to meet the California LCFS standards.

(6) Relatively high carbon intensities of available biofuels through 2020.

(7) No response of fuels demand to price changes.

Key intermediate results/findings that derive from these assumptions when input to the BCG modeling system include:

- (1) Because low-CI fuels/credits do not materialize, the only way for regulated parties to meet the LCFS standard is to restrict gasoline/diesel sales in the state significantly and blend it with high cost sugarcane ethanol from Brazil, causing motor vehicle fuel prices to rise significantly. Any excess gasoline produced in state is exported to Mexico or elsewhere in Latin America.
- (2) High cap and trade allowance prices, LCFS credit prices, and cap and trade price volatility.
- (3) Because product demands are assumed not to respond to changes in their prices, refined petroleum product prices are assumed to equal

1 The national RFS Program was developed to increase the volume of renewable fuel that is blended into transportation fuels. As required by the Energy Policy Act of 2005, the U.S. Environmental Protection Agency (EPA) finalized RFS Program regulations, effective September 1, 2007. The Energy Independence and Security Act of 2007 increased and expanded this standard. By 2022, 36 billion gallons of renewable fuel must be used per year.

(approximately) input costs plus the estimated markup - rather than resulting from the dynamics of balancing petroleum product and refinery input supplies and demands through price adjustments.

(4) The per barrel profitability of gasoline is projected to be reduced because prior to implementing AB 32, California is a net importer of gasoline from Singapore which sets the equilibrium price at roughly a \$6 per barrel premium above the cost of the marginal gasoline refined in California. The demand for gasoline is reduced significantly and the equilibrium price estimated within the model declines. This reduces profits that California refineries would otherwise earn, due to reduced sales and because the transportation costs of out-of-state marginal gasoline supplies are no longer reflected in the equilibrium price. ²

(5) The projected reduction in the profitability of California refineries lead a number of them to shut down leaving their employees unemployed.

(6) Neither market participants nor regulators act to avoid or minimize the extent of this outcome.

With this background, the key conclusions of the BCG report are now presented and related to the assumptions made. Then, possible alternative

assumptions based on historical experience, and the relevant academic literature are discussed. Finally, relevant data and reports on current trends in California fuels markets are described.

² We note here that when gasoline prices decline refiners make less money but in this case that also means California consumers pay less for gasoline.

Assessment of Key Conclusions of BCG Report

Cost of Compliance

BCG Key Result

“Based on an assumed cost of carbon of \$14/ton to \$70/ton, BCG estimates that the level of cost recovery required by the industry to comply and meet California demand, should these regulations be fully implemented, would likely be in the range of 49-183 cents per gallon (cpg) by 2020. Of this, 14-69 cpg would be due to tailpipe emissions from transportation fuels being included under Cap and Trade; 2-8 cpg would result from stationary refinery emissions and 33-106 cpg (average 70 cpg) would be due to LCFS.”

These results depend on a number of key assumptions about the evolution of fuels markets in California and a number of implementation details of AB 32 some of which have not yet been fully specified by the California Air Resources Board (CARB). Within the report, several key baseline assumptions are reported to be tied to specific CEC and/or EIA assumptions and, in some cases, may be outdated given the state’s and US economy’s rapidly changing economic and energy outlook. Furthermore, these results are not isolated in the report by comparing them to an explicit ‘business-as-usual’ or baseline scenario which would be helpful to separate out the effects of the policy from other trends in the refinery market.

BCG Assumptions and Their Implications

In the report, the level of cost recovery required by the refinery industry is calculated based on the cost of producing relatively high cost sugarcane ethanol in Brazil, transporting it to California, and blending it with California Reformulated Gasoline Blend Stock for Oxygenate Blending (CARBOB) produced in conventional oil refineries in the state. On the supply side of the fuels market, reductions in the carbon intensity of conventional biofuels are assumed to be limited, and no significant new production capacity for either non-biofuel low carbon intensity fuels as well as advanced biofuels (those with carbon intensities under .50) is assumed to come on line through 2020. On the demand side of the fuels market, the response of fuels demand to the projected price increases is projected to be zero and very modest numbers of Advanced Technology Vehicles (ATVs) are projected to be on the road by 2020. Finally, in terms of cost containment measures, California refiners are projected not to bank many carbon intensity credits early in the decade for use when the regulations become more restrictive later in the decade, and refiners in the state are unable to sell Renewable Identification Numbers (RINs) by California refiners who over comply with federal Renewable Fuel Standards.

By its own accounting, BCG believes the assumptions used to produce this projection comprise an unlikely scenario. With respect to the LCFS, BCG feels that the most likely scenario

is that compliance will not be achieved because there will not be enough low carbon sugarcane ethanol from Brazil available and all other possible pathways are considered insufficient to achieve compliance.

Reviewers' Assessment

The reviewers believe that past responses to previous regulations (as documented in the literature) and current trends in each of these individual responses has been larger than assumed by BCG, providing more options for compliance than just the Brazilian sugarcane based ethanol option. There is no one compliance option whose pursuit appears capable of achieving compliance on its own, but a group of these responses taken together appear able to satisfy the requirements of AB 32 more easily and potentially at lower cost than the option included in the BCG scenario. The relevant literature on past market responses to similar regulations and emerging trends in each of these responses are now discussed.

a) Flexibility in Compliance Options

An important element of performance-based approaches to regulation is that they convey the decision-making authority to the regulated entity with respect to a strategy for how to achieve the regulatory standard. This is especially useful in an industrial setting where heterogeneity in technology and costs within the regulated entities exists and where that information is not fully available to the regulator. In this case regulated

entities have private information that enables them to identify opportunities for emissions reductions at lower costs.

A second important element when performance-based approaches are applied to environmental problems is the diversity of compliance activities that typically emerge among the regulated entities. Given that firms have unique and private information about technologies and costs they can be expected to identify unique investment opportunities.

Experience in previous regulatory settings that have used performance-based approaches is generally that costs have been less than anticipated and that regulated entities respond with a variety of compliance strategies that were not necessarily anticipated by the regulator. See for example Harrington, et al. (2000). One of the most studied examples is the sulfur dioxide emissions trading program implemented under the 1990 Clean Air Act Amendments. It is generally thought that the expanded availability of low-sulfur coal explained the surprisingly low cost of compliance. This is certainly true in part; however it was the flexibility of the regulation that allowed the market to capitalize on this advantageous trend. Moreover, the similarity to the LCFS are apparent where changes in fuel markets are expected to emerge but exactly how is not certain.

This SO₂ program led to a variety of compliance strategies, some of which had been considered and dismissed previously (see, for example,

Burtraw, 2000). It is noteworthy that under the SO₂ program engineers had explicitly described the limited technical potential for some options such as blending of low-sulfur coal at boilers designed for high-sulfur coal. However, five years later the amount of blending that was being achieved was an order of magnitude greater than anticipated. The reason this was not anticipated is that previously plant managers had lacked any incentive to investigate the technical possibilities. When they had that incentive they found ways to achieve unexpected emission reductions at much lower costs than other means of achieving compliance.

In summary, one can expect compliance to occur through a number of channels and in unexpected ways. The BCG report consistently relies on a single expected compliance strategy for California refineries – imported sugarcane ethanol. Furthermore the expanded demand for that product does not appear to trigger a supply response; the price is anticipated to grow dramatically without an increase in supply even though there is time for supply to expand to meet anticipated demand. Although a number of other strategies are identified, they are given no weight in the calculation of compliance. Even small contributions from the various other strategies would collectively have an important influence on the reduction needed in sugarcane ethanol.

Another adjustment that would reduce the cost of the AB 32 requirements to consumers would be reductions in the demand for transportation fuels in response to the price increases that are

projected. A large literature exists on estimating demand elasticities for oil and gasoline in both the short and long run. Separate literatures also exist looking at the components of these demand elasticities, for example, estimating how fuel economy of new vehicles or vehicle miles travelled is affected by changes in gasoline prices. These literatures strongly suggest that, while demand elasticities in the short run (say up to a one year period) tend to be small, on the order of 0.1, they are not zero. Furthermore, long run demand elasticities (over say a 5-15 year time horizon) can be much larger than short run elasticities, on the order of 0.5 or higher. Graham and Glaister (2002) provide fairly up-to-date review of the literature.

Short-run demand elasticities also appear to vary depending on the source of the price change. Hughes, Knittel and Sperling (2008) estimate one-month gasoline demand elasticities relying mostly on changes in gasoline prices driven by changes in oil prices. They find a short run elasticity of roughly 0.1. Muehlegger, Linn and Li (2012) find, however, that consumers are nearly three times more sensitive to price changes that are more permanent (e.g., changes in gasoline taxes) compared to more transitory price movements (e.g., changes resulting from changes in oil prices).

In the long run, more options are available for consumers to reduce their gasoline consumption. Long run demand elasticities are therefore larger. These might include, for example, changes in fuel economy, commute lengths, or car-pooling relationships. Li, Timmins and von Haefen

(2009) and Busse, Knittel and Zettelmeyer (2013) estimate how changes in gasoline prices affect new-vehicle fuel economy. Knittel and Sandler (2012) estimate how gasoline prices impact vehicle miles traveled (VMT) over two-year periods. They estimate a VMT-elasticity of roughly 0.15. This is just one component of the long-run elasticity. Aggregate long-run elasticity estimates typically exceed 0.5, and can often exceed 1.0. Graham and Glaister (2002) report estimates as large as 1.6.

This price response would be expected to reduce the consumer cost increases estimated in the BCG report, perhaps substantially. The overall impacts of AB 32 on the refinery industry in California are discussed in the next section of this summary.

At a conceptual level, we view all BCG's assumed rigidities in the different ways fuels market participants might respond to the new regulations, individually and collectively, to be possible. However, we feel it is very unlikely that they will all be as non-responsive as assumed in the BCG report. Responses in each of these areas to the imposition of similar regulations in the past have not been as minimal as assumed here and there is already mounting evidence that they will not be so muted in response to the implementation of the LCFS standard during this decade. Finally, the BCG report focuses only on a couple of possible major means of compliance with the LCFS, whereas hundreds of other possible adjustments that could be made are assumed to be insufficient to make much of a difference. Then

the few options considered are assessed to be insufficient to satisfy the LCFS constraint without major dislocation to California's economy. In the opinion of the reviewers this logic suffers from two related shortcomings. First, as discussed above when a standard is imposed fuel suppliers and consumers have a wide range of ways to respond to contain costs – this we refer to as the general equilibrium perspective where essentially everyone in the state can make their own adjustments to the new policy regime. Second, related to the general equilibrium perspective is the “all the above” aggregate response where it is not one or two responses by a few major market players that satisfies the standards, but hundreds of different responses employed by thousands of market participants. Thus, rather than completely ruling out consideration of responses that could provide say 10 percent or even only 1-2 percent of the required allowances, collectively these responses could contribute to more cost-effective compliance. In the words of Neste Oil Company President Neville Fernandes:

“While no one producer or type of low-carbon fuel will be able to replace traditional petroleum transportation fuels in the near term, Neste Oil believes its efforts, along with others like it, can contribute to the continued success of the Low Carbon Fuel Standard (Fernandes, 2013).”

b) Recent Trends in Compliance Options-What's Going on Right Now

Adding to our conceptual concerns about the limited responses assumed by BCG in a number of areas, recent data and reports, some of which have emerged since the BCG report was completed, indicates that the responses of the fuels system in California have already been more substantial in several areas than BCG projected. First, the average carbon intensity of transportation biofuels in the state has dropped steadily over the last two years (CARB, 2013; Yeh, et al., 2013). Second, new sources of "drop-in fuels" such as renewable diesel are coming on line (Fernandes, 2013). Third, refiners have the opportunity to accumulate banks of LCFS credits and continued to do so through 2012 (Yeh, et al., 2013). Fourth, allowance prices are at the low end of the range considered by BCG. Fifth, national RIN values are high enough to significantly offset the cost of compliance to California refiners. Sixth, refiners have diversified upstream into low-carbon production activities (Valero, 2013). Seventh, the demand for liquid transportation fuels in California has been lower than anticipated (this probably reflects lower than expected economic growth in the state and some reduction in demand resulting from the implementation of AB 32).

A good example of an unexpected compliance option is the Neste oil renewable diesel project mentioned above (Fernandes, 2013):

"With the addition of more approved low-carbon pathways, Neste Oil hopes to significantly increase the volume of low-carbon renewable diesel that it will deliver to its California customers.

Using its recently approved CI pathway value and the other pending CI pathway values, Neste Oil anticipates that volume of oil could generate approximately 2.5 million MT of CI credits under the LCFS program during the years 2013 and 2014."

We note here further that CARB projects that the quantities mentioned in this letter would in themselves provide roughly half the CI credits required to satisfy the LCFS in 2013 and 2014. This results in part because the fuel produced (with a carbon intensity about one third that of conventional gasoline) is compatible with the diesel engines currently in use in the state. This then is an excellent example of a possible response to the regulation of the type described above.

c) What if These Trends Do Not Continue – What Other Options Might be Available?

These recent trends indicate that the cost of meeting the LCFS standards to California drivers and oil refiners may not be as large as projected by BCG in the second compliance period (2015-2017). However, since some of them (e.g., banked credits) could be reduced in number as the level of

the standard is tightened, costs could rise rapidly towards the end of the decade unless either some of the other responses already being observed (e.g., lower carbon intensity conventional biofuels) continue, or other options (e.g., advanced biofuels, advance technology vehicles, etc.) can be produced in sufficient quantities by the end of the decade. A recent National Academies report (NRC, 2013) projects that, assuming adequate industry investment, more “drop-in” biofuels could be available starting in 2015 with substantial volumes available by the end of the decade (NRC, 2013; page 50, Table 3.5). Solecki, et al. (2012) shows the potential for significant new supplies of advanced biofuels even by 2015. Although many of the facilities identified in that report are in the construction or advanced planning stages, the reviewers feel that closely monitoring the timing of these facilities coming on line will be extremely important in managing the further implementation of the LCFS. Similarly several recent studies (NPC, 2012; TIAX, LLC. 2012; Navigant Research, 2013)³ suggest the potential for more significant contributions from advanced (electric and natural gas powered) technology vehicles starting before 2020 and building through the next decade as

vehicle stocks turn over. Although the reviewers did not review these studies in detail, they suggest as much as 25% of the LCFS credits required to satisfy the LCFS in California could come from ATVs.

While we view the overall scenario developed by BCG as unlikely, it is useful for decision makers to understand what conditions might contribute to this type of slow response/high cost scenario and what signals would indicate that such a scenario is playing out, e.g. little or no demand or supply response to changing prices, and large quantities of gasoline exports resulting in declining profits. In addition to these results, however, we believe decision makers would benefit from being able to see and understand a full set of sensitivities overall and the key input and modeling uncertainties that have gone into producing them. Since a lot of the difficulty discussed in the BCG report about meeting the LCFS requirements result from the timing of the reduction in the average carbon intensity of liquid fuels required (a ten percent reduction by 2020 relative to 2010 levels), a set of sensitivities built around current trends and directly focused on alternative timelines and alternative scenarios of low-carbon fuel availability would be extremely useful to those considering changes to the policy.

3 Electricity consumption in on road and off road applications has the potential to produce a significant quantity of LCFS credits. On road applications include light duty plug in electric vehicles (PEVS) such as battery electric vehicles (BEVs) or plug in hybrid vehicles (PHEVs). Off road applications include electric passenger rail, electric forklifts and E-transport refrigeration units (eTRUs). (TIAX, LLC., 2012).

Impact on Refining Industry

BCG Key Result

“Given the small number of Advanced Technology Vehicles, no commercially available cellulosic ethanol, and limited available quantities of low carbon intensity (CI) sugarcane ethanol, LCFS is unlikely to be fully implementable by sometime in the second compliance period. As a result, California refiners that risk being out of compliance, may opt to export fuels, versus supplying the local market, potentially creating product shortages. A likely scenario is for cost recovery to exceed 250 cpg coupled with gasoline supply shortages as early as 2015. If LCFS regulation is changed abruptly after 2015, it will likely result in additional costs for refiners, consumers, and suppliers of alternative fuels. LCFS driven demand reduction in the second compliance period (2015-17) shifts gasoline trade balances from Singapore imports to Mexico exports. This shift impacts refinery economics substantially and will likely result in closure of 4-6 refineries representing 20-30% of California’s refining capacity. If LCFS is completely implemented beyond the second compliance period, this will result in the closure of an additional 1-2 refineries, representing 5-10% of California’s refining capacity. Energy efficiency investments in refineries would be minimal because the state’s refineries are already so efficient.”

As mentioned above, many assumptions drive these results. The adjustments omitted from the

BCG analysis described in the last section would lead to lower cost increases to transportation fuels for consumers in the state than projected by BCG. Reductions in costs to consumers do not generally lead to improved economics for refiners during the AB implementation period, however, because refinery profitability depends on how AB 32 and other trends in the global liquid fuels market impacts the revenues and costs of California refiners.

What BCG Assumed and Concluded

The report indicates that California is now a net importer of gasoline from Singapore and implies that it will continue to be one if the LCFS requirement of AB32 is not implemented. Under the LCFS requirement the state’s refiners are projected to export a significant share of its gasoline production at a lower price because it cannot all be consumed in state and satisfy the standard. At the same time, the report assumes that total fuel demand within the state would comply with the LCFS by blending California produced gasoline with new low-carbon sugarcane ethanol from Brazil which is estimated to raise the cost of motor fuels to California consumers significantly. It is also assumed that refiners will not be able to or choose to bank significant LCFS credits in the first compliance period of the program (2011-2014) for use to meet the more stringent targets in later compliance periods (2015-2017 and 2018-2020). Moreover, refiners are treated as passive price takers in the ethanol

market and, for example, that they will not make any large upstream supply chain investments in low-carbon fuel production capacity.

Again BCG considers reductions in imported gasoline prices and lower throughput rates as the only possible changes and assumes that refiners will passively accept these changes with no adjustment in their business planning and no cost relief from the regulations and flexibility in the final implementation of the LCFS by the ARB.

Reviewers' Assessment

The reviewers question whether some of the refineries projected to shut down under AB 32 would have shut down only a few years later anyway because of federal fuels regulations and an overall trend towards reduced demand for gasoline which would either cause some of the refineries in the state to change the mix of products they produce or shut down. Shutting down seems more likely for small simple refineries that can't adjust to meet the new business conditions facing the industry.

In addition, given the expense and irreversibility of refinery closure and the industry's long history of weathering economic cycles, the committee questions whether refineries would really choose to shut down so quickly rather than wait for more favorable financial conditions or redeploy/consolidate refinery assets.

With the larger economic incentives provided by the regulations, we also believe many

more energy efficiency options would become economic with the implementation of AB 32. Some of these might involve investments to expand low-carbon fuel input or product output flexibility which could help speed the adjustment to the new regulations. Some industry analysts even believe oil refineries in California will be converted into biorefineries rather than being shut down or converted to product terminals. Finally, for the efficiency gains that are projected, the analysis assumes these will increase jobs, but it is not clear how (or whether) it projects emission reductions and compliance cost reductions associated with them.

Several other sources of revenues for refiners in the state under AB 32 are also ignored in the report, including re-investment of allowance auction revenues by CARB to facilitate the transition of the California fuels market, use of "banked" allowances, and revenues from selling RINs to out-of-state entities which would provide more time for alternatives to enter the market, keep prices down, and potentially allow the refiners to maintain profitability for a longer period of time.

a) Historical Experience of California Refining Industry

The refinery industry in California has a long history of weathering economic cycles by creatively redeploying and consolidating refinery assets, or simply waiting for more favorable financial conditions or further changes

in regulations. Technological innovation has also enabled it to adapt to new environmental regulations much more easily than originally anticipated. California is an entrepreneurial and innovative state and its refining industry has played a large role in creating that history.

b) Recent Trends in Refinery Strategies

Some California refiners have already diversified upstream into the biofuels supply industries. Valero Energy Corp., the largest independent oil refiner in the world, has in recent years by becoming a major player in ethanol. It made a \$60 million equity investment in late 2011 in Enerkem Inc., a Montreal-based company that converts waste into ethanol. Valero has by now acquired 10 state-of-the-art ethanol plants, making it the first traditional refiner to enter production of ethanol, under subsidiary Valero Renewable Fuels Company LLC, or Valero Renewables for short (Valero, 2013).

California refiners have also started contracting for lower cost U. S. based crude supplies which have a geographical cost advantage relative to current supplies from West Africa or the Middle East .⁴ These strategies should make refinery economics in the state more favorable offsetting part of the impacts of AB 32 impacts which should lead to fewer refinery closures and job losses (see next page).

4 Oil Daily (2013a, 2013b).

Impact on California's Economy

BCG Key Result

"As a result of forecasted refinery closures, largely resulting from full implementation of the LCFS California could lose 28,000-51,000 jobs, including many high-paying skilled manufacturing jobs, as well as indirect job losses due to multiplier effects, up to \$4.4 Billion of tax revenue per year by 2020, experience a wealth transfer of at least \$3.7 Billion per year by 2020 from refineries and fuel suppliers to the California Air Resources Board."

"The state could also see low income households disproportionately impacted, lose manufacturing expertise, experience increased cost of living, see energy intensive industries discouraged from locating in the state and see existing industries relocate to other states or internationally."

What BCG Assumed and Concluded

These results follow from the previously discussed assumptions and findings which are based on an admittedly unlikely scenario. If compliance with the requirements of AB 32 were achieved the report estimates that up to about 50,000 workers could be displaced because of the LCFS, including specialized workers in refinery operations and maintenance. We find this projection implausibly high for two main reasons. First, as discussed in the previous section, it is also possible that California refiners will diversify upstream into biofuels production, contract for newly developed lower cost domestic crude oils or engage in other strategic activities to maintain profitability and avoid shutting down and laying

off refinery workers. Second, another group, the (indirect) majority of projected job losses are in sectors that serve the supply chains of refineries and the consumption needs of its employees. If one accepts the report's pessimistic compliance scenario, highly specialized refinery workers could be threatened with displacement, and the most specifically skilled might have to relocate outside the state. These workers, however, are only a fraction (around 10%) of the total worker displacement estimates that are termed "job losses" in the report. Because these job losses are a very important part of the BCG report's policy impact message, the total employment impact estimates need to be interpreted very carefully.

Reviewers' Assessment

The report's job loss estimates are based on linear multiplier analysis, an economic methodology that has two inherent and well known conceptual weaknesses – the assumptions of constant factor proportions and fixed prices.⁵ The use of multipliers for indirect job losses is based on a "fixed proportions assumption" which means that jobs lost in industries that are complementary to the oil refining industry in the economy will not adjust so that they complement other industries in the state. Furthermore, this assumption

⁵ A nontechnical discussion of these issues can be found in Hughes (2003) and Coughlin and Mandelbaum (1991), both of which clarify the limitations of multiplier results.

implies that once someone loses a job they will not find another job. The reviewers feel these are reasonable assumptions to use in making very short run projections of labor market impacts of the program (say over a few months), but they are inconsistent with the observed dynamics of labor markets over periods longer than six months or so. These direct refinery industry and related indirect job losses are assumed to only marginally be offset by gains in the energy efficiency and renewable's sectors. These assumptions seem too conservative over a two to five year period given the strong technology sector in the state and the increased demand for engineers and technicians to install efficiency and renewable equipment under AB 32.

More advanced economic modeling approaches, including Computable General Equilibrium (CGE) models, when calibrated to the same detailed structural data as constant factor proportion input-output models, take explicit account of market forces and economic scarcity. For these reasons, in these models demand does not iterate indefinitely up or down throughout the economy as the result of a single shock, and markets mediate scarcity with price adjustments.⁶ In the CGE approach, many applications use the so-

6 See e.g. Jorgensen and Dixon (2012) for a general introduction, and many examples contrasting fixed price and CGE impact estimates.

7 See e.g. Roland-Holst and Maechler (1997).

called full employment assumption, i.e. that all workers are able to find new jobs in a reasonable amount of time which is essentially the opposite extreme of the Leontief assumption that they are in perfectly elastic aggregate supply. In the middle of these two approaches lies a variety of studies that have calibrated different labor market clearing mechanisms to econometric structural estimates, and their results are likewise intermediate between the extremes of Leontief (100% employment adjustment) and full employment (100% wage adjustment).⁷

Thus, a more advanced perspective on labor markets recognizes that workers displaced from one job will search for and find a new one. The report could have acknowledged this well-established fact, estimating some adjustment cost rather than counting so-called "job losses" induced by a very high multiplier "estimate" of 7. To put this in a more realistic context, average unemployment duration in California is about 18 weeks, suggesting that the estimates in this report should be divided by three and expressed not as jobs, but as "person-years" (PYs) of FTE unemployment. This is equivalent to a one-time social cost of about 16,000 PYs of total unemployment in the report's pessimistic scenario, or about one percent of California's average one-year unemployment burden of 1,500,000 PYs.⁸

8 <http://www.bls.gov/jlt/>

For the majority of the report's displaced workers, those indirectly affected by adverse demand shocks from refinery displacement, there is a ready labor market waiting. Average monthly job turnover in California is over 450,000 hires/month, suggesting that the economy has more than ample capacity to absorb even the most pessimistic projections of indirectly displaced workers. Even if one accepts the dubious premise of multiplier analysis that factor proportions are constant, it is neither reasonable nor responsible to suggest that the overwhelming majority of these workers will be unemployed for a significant time.

The modeled lost tax revenues and "wealth transfer" from the cap-and-trade program would be smaller if more flexible credit supply, energy demand and price formation assumptions were used in the model. Moreover, the wealth transfer as discussed in the report is really a transfer from refiners to state government which could then be strategically recycled back into the economy in ways that would avoid large economic losses. Low income households do spend a greater percentage of their income on direct fuel purchases, but when the cost of fuels imbedded in products and services is considered, the regressive nature of the fuel or environmental taxes is significantly diminished. Even if this is not the case, allowance revenues could be targeted to low income households to offset this effect. For an expansive discussion on this topic, see the report of the "Economic and Allocation Advisory Committee (EAAC, 2010)".

Energy intensive industries may leave the state as a result of AB 32 implementation, but clean tech oriented firms may be attracted to move in because their products would be more highly valued here and they would bring technical expertise in all aspects of developing, engineering, financing, installing and maintaining these technologies with them. This was not considered in the modeling in the report and only briefly noted in the discussion. A full discussion of the possibility of attracting technical expertise to California would provide more balance and useful information for stakeholders. The report also does not include other positive effects on the health and welfare of the citizens of California that could result from implementation of AB 32, including health benefits resulting from less and cleaner fuel use (resulting in better air quality), reductions in congestion resulting from less driving, and stimulation of innovative activity that might result from its regulations.

Transparency and Comprehensiveness of the Assumptions and Analyses in the Report

Finally, we note that the report would have been easier to review and assess if the assumptions used in the analysis and the modeling methods used were more fully documented. In addition, for a report purporting to address the impacts of AB 32 implementation, this report seems rather narrowly focused on the economic impacts of AB 32 on the state's oil refining industry and does not, in the opinion of the reviewers, include a full accounting of the economic impacts, or the health and welfare impacts of the legislation on the broader population and economy of the state. Given its sponsorship, this may be appropriate, but this more narrow focus should be carefully explained to readers in policy making positions and members of the public at large.

The reviewers feel that the primary relevance of the report is as an assessment of a very bad case outcome for the refinery sector in California and even from that perspective, several questions about the appropriateness of the assumptions and methodology remain.

Recommendations for Further Data Collection and Analysis

Finally, while we believe decision makers in the state should be concerned about the possibility of the kind of high cost outcomes identified in the BCG analysis we recommend that they:

- 1) Try to prevent possible excessive costs by promoting additional supplies of low-carbon fuels and consumer responses, as well as by further implementation of additional cost containment mechanisms.
- 2) Continue to collect critical information on: the carbon intensity of fuels, including identification of plausible new low-carbon fuels with their actual and likely future production quantities; sales of advanced technology vehicles; LCFS credit banking and sales of renewable energy credits; and refinery strategies to improve their economics under the LCFS.
- 3) Consider plausible alternatives to BCG's assumptions about low-carbon fuel demand responses and refinery economics that are consistent with historical experience and consistent with the trends observed in task (2) above.
- 4) Sponsor new analyses of the impacts of AB32 on consumer welfare beyond fuel price changes, and on overall economic growth and job growth in California.

Appendix A: References

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Appendix B: Biographies for Reviewers Selected to Evaluate “Understanding the Impacts of AB32”

John Weyant (chair), Stanford University

John P. Weyant is Professor of Management Science and Engineering, Director of the Energy Modeling Forum (EMF) and Deputy Director of the Precourt Institute for Energy Efficiency at Stanford University. He is also a Senior Fellow of the Precourt Institute for Energy and the Freeman-Spolgi Institute for International Studies at Stanford. Prof. Weyant earned a B.S./M.S. in Aeronautical Engineering and Astronautics, M.S. degrees in Engineering Management and in Operations Research and Statistics all from Rensselaer Polytechnic Institute, and a Ph.D. in Management Science with minors in Economics, Operations Research, and Organization Theory from University of California at Berkeley. He also was also a National Science Foundation Post-Doctoral Fellow at Harvard’s Kennedy School of Government. He currently serves as co-editor of the journal *Energy Economics*. Weyant is also one of three founders of - and serves as chairman of the scientific steering committee of - the Integrated Assessment Modeling Consortium (IAMC), a six year old collaboratory with 55 member institutions from around the world. Weyant was awarded the US Association for Energy Economics’ 2008 Adelman-Frankel award for unique and innovative contributions to the field of energy economics. He was also honored in 2007 as a major contributor to the Nobel Peace prize awarded to the Intergovernmental Panel on Climate Change and in 2008 by Chairman Mary Nichols for contributions to the to the California Air Resources Board’s Economic and Technology Advancement Advisory Committee on AB 32.

Bruce Babcock, Iowa State University

Babcock is a Professor in the Department of Economics and the Director of the Center for Agricultural and Rural Development at Iowa State University. His research interests include production economics, technological change, and agricultural policy. Babcock served on a Scientific Advisory Panel to the Environmental Protection Agency. Babcock received a B.S. in Economics of Resource Use and an MS in Agricultural Economics from University of California at Davis. He also holds a Ph.D. in Agricultural Resource Economics from University of California at Berkeley.

Dallas Burtraw, Resources for the Future

Dallas Burtraw, a Senior Fellow at Resources for the Future, is one of the nation’s foremost experts on environmental regulation in the electricity sector. He is particularly interested in incentive-based approaches for environmental regulation, the most notable of which is a tradable permit system, and recently has studied ways to introduce greater cost-effectiveness into regulation under the Clean Air Act. Burtraw has provided technical support in the design of carbon dioxide emissions trading programs in the Northeast states, California, and the European Union. He recently served on the National Academy of Sciences Board on Environmental Studies and Toxicology and on the U.S. Environmental Protection Agency’s Advisory Council on Clean Air Compliance Analysis. He also served on California’s Economic and Allocation Advisory Committee advising the governor’s office

and the Air Resources Board on implementation of the state's climate law. Burtraw received a B.S. in Community Economic Development from the University of California at Davis. He also holds an M.P.P. in Public Policy and Ph.D. in Economics from the University of Michigan.

David Greene, Oak Ridge National Laboratory

David Greene is a senior research staff member for the Center of Transportation Analysis within the Energy Division at Oak Ridge National Laboratory and serves as the manager of the Energy Policy Research Programs. Greene specializes in Energy and Environmental Policy Analysis and has recently analyzed fuel economy policy and the potential to mitigate greenhouse gas emissions from transportation. Greene has been a chairman or member of numerous committees for the Transportation Research Board of the National Research Council, has served as editor-in-chief of the Journal of Transportation and Statistics, and currently serves on the editorial boards of Journal of Transportation and Statistics, Energy Policy, Macmillan Encyclopedia of Energy, Transportation Quarterly, and Transportation Research Part D. David Greene received a bachelor's degree in geography from Columbia University and a master's degree in geography from the University of Oregon. He earned a doctorate in geography and environmental engineering from Johns Hopkins University.

Amy Myers Jaffe, University of California, Davis

Amy Jaffe is a leading expert on global energy policy, energy economics, and energy and sustainability. Jaffe serves as executive director for Energy and Sustainability at University of California, Davis with a joint appointment to the Graduate School of Management and Institute of Transportation Studies (ITS). At ITS-Davis, Jaffe heads the fossil fuel component of Next STEPS (Sustainable Transportation Energy Pathways). Previously, Jaffe served as director of the Energy Forum and Wallace S. Wilson Fellow in Energy Studies at Rice University's James A. Baker III Institute for Public Policy. Jaffe's research focuses on oil and natural gas geopolitics, strategic energy policy, corporate investment strategies in the energy sector, and energy economics. She was formerly senior editor and Middle East analyst for Petroleum Intelligence Weekly. Jaffe has provided testimony on Capitol Hill on energy matters as well as to governments in Europe, the Middle East, and Asia, and is a widely quoted commentator on oil and energy policy in the international media. Jaffe holds the excellence in writing prize from the International Association for Energy Economics (1994). Jaffe received a B.A. in Near Eastern Studies and Arabic from Princeton University.

Chris Knittel, Massachusetts Institute of Technology

Chris Knittel is a Professor of Energy Economics in the Sloan School of Management and the Co-Director of the Center for Energy and Environmental Policy Research at the Massachusetts Institute of Technology. His research focuses on environmental economics, industrial organization, and applied econometrics. He is a Research Associate at the National Bureau of Economic Research in the Productivity, Industrial Organization, and Energy and Environmental Economics groups. Professor Knittel is an associate editor of *The American Economic Journal – Economic Policy*, *The Journal of Industrial Economics* and *Journal of Energy Markets*. His research has appeared in *The American Economic Review*, *The American Economic Journal*, *The Review of Economics and Statistics*, *The Journal of Industrial Economics*, *The Energy Journal* and other academic journals. Knittel received a B.A. in economics and political science from the California State University, Stanislaus, an M.A. in economics from UC Davis in 1996, and a Ph.D. in economics from UC Berkeley.

Richard Newell, Duke University

Newell is the Gendell Professor of Energy and Environmental Economics and the Director of the Duke University Energy Initiative. Newell has experience in the economics of energy and environmental markets, policies, and technologies; climate change; energy efficiency; and market-based environmental policy. He serves as a member of the Board of Directors and a University Fellow at Resources for the Future, a Research Associate for the National Bureau of Economic Research, a member of the Editorial Board for the *Review of Environmental Economics and Policy*, a member of the Coordinating Sub-Committee for the National Petroleum Council for the Study on the Future of Transportation Fuels, a lead author for the U.S. National Climate Assessment Effects on Energy Production, and a contributing author to the IPCC Fifth Assessment Report. Previously, Newell served as the Administrator of the U.S. Energy Information Administration, U.S. Department of Energy, the Senior Economist for Energy and Environment on the President's Council of Economic Advisers, and a Senior Fellow at Resources for the Future. Newell received a B.S. in Materials Engineering and B.A. in Philosophy from Rutgers University, an M.P.A. in Public Policy from Princeton University, and a Ph.D. in Public Policy (Environmental and Resource Economics) from Harvard University.

David Roland-Holst, University of California, Berkeley

David Roland-Holst is a Professor in the Departments of Economics and Agricultural and Resource Economics at the University of California, Berkeley. Dr. Roland-Holst is one of the world's leading authorities on economic, energy, and climate policy modeling. He has extensive research experience in economics related to environment, development, agriculture, and international trade, authoring three books and over 100 articles and chapters in professional journals and books. Professor Roland-Holst has served in several academic posts in the United States, Europe, and Asia. He also conducted research in over 40 countries, working with many public institutions including Federal and state agencies, the Asian Development Bank, Inter-American Development bank, Organization for Economic Cooperation and Development (OECD), World Bank, and several United Nations agencies, as well as governments in Asia, Latin America, Europe, and Africa. Most recently, his research has been central to the passage, design and implementation of California's path breaking Global Warming Solutions Act (AB32). Professor Roland-Holst holds a Ph.D. in Economics from the University of California, Berkeley.

Expert Evaluation of the Report: “Understanding the Impacts of AB32”

May 2013



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