# Understanding the Challenges of Modeling AB32 Policy

DECEMBER 4, 2008

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## Policy Summary

The Global Warming Solutions Act of 2006 (AB 32) *Proposed Scoping Plan* lays out a set of measures to meet a cap on greenhouse gas emissions by 2020 that will involve investments to modernize and decarbonize California's energy systems, buildings and transportation infrastructure. All sectors of the state's economy will be affected as we redirect the course of our economy toward a future that is lower emitting, secure, more efficient and fair. Such ambition is not new to California; in the 1950s, significant modernization and expansion of the state's transportation system, water supplies and education systems took place and returned substantial rewards for the state.

To accomplish the task of AB32 to combat climate change while achieving cost-effective reductions, state rule-makers attempt to choose the best policy approach for the job. However, economists' tools (computer models that simulate how California's economy will respond to various approaches) have great difficulty capturing in a quantitative fashion the behaviors of producers and consumers that lead to economically beneficial outcomes. Further, the definition of "economic" for the purpose of determining economic impact is too narrowly defined, ignoring broader definitions of well-being which might be better captured by measures such as the Genuine Progress Indicator. Despite known limitations of these models however, the California Air Resources Board (ARB) has attempted to characterize the economic impact of chosen policy options. To accomplish this, ARB used two models to evaluate the economic implications of the *Scoping Plan*. The agency has avoided applying these models to compare alternative policy approaches.

This study finds that attempts to use economic modeling with current techniques to compare different policy approaches are not likely to produce reliable results. Consequently, we argue that ARB's determination of the maximum technologically feasible and cost-effective emissions reduction strategy is better served to focus on lessons from other programs and the economic literature. These lessons and principles coalesce around the advantages of market-based (MB) measures, notably cap-and-trade programs. Worldwide experience also indicates that while MB programs produce results superior to command-and-control (CAC) measures, the need exists for careful description of the characteristics of MB programs to ensure delivery of efficient, equitable, and lowest-cost emissions reductions.

This study also identifies the several advantages of MB measures and the difficultly of eliciting these advantages with existing models. The following table aligns modeling challenges discussed in this report with the advantages of cap-and-trade policy.

| *Cap-and-Trade Advantage Compared with Prescriptive Measures* | *Difficulty in Modeling this Advantage* |
|---|---|
| *Lowers compliance costs*: By acknowledging the differences among firms and by opening up the options available to comply (e.g., fuel switching versus installing a specific technology), MB measures use trading among firms to lower the costs of compliance. | Economic models do not capture well the differences among firms, nor a regulator's inability to fully know these differences, that lead to the incentives to trade among firms. |

| | |
|---|---|
| *Encourages technological innovation*: MB measures encourage both increased R&D and wider, more rapid adoption of new technologies. Innovators are able to profit from introducing technological solutions, and face less risk that these technologies will be rendered obsolete by regulatory fiat. | Technological innovation and diffusion is a complex, dynamic process that is self-reinforcing and adaptive, but that cannot be represented easily in models. These economic models capture a snapshot of technologies rather than changes in the underlying conditions over time. |
| *More adaptable*: MB measures are more adaptable to changing conditions and understanding because they decentralize decision-making and bypass the need to revisit detailed regulatory rulemakings. | The adaptability and robustness of a policy cannot be evaluated easily. Typically only one or two future scenarios are modeled, so it is hard to represent the full range of possible futures. This displaces the advantage of decentralized decision-making and adaptation (as with MB measures) with static assumptions about the rate at which our economy adopts new technologies or better practices. |
| *Relieves regulatory burden on agencies*: MB measures relieve regulators of the need to specify regulations beyond an overall objective. Regulators can set a sector-wide emission target or performance standard and then leave it to firms to decide among themselves how best to comply. Regulators will still be required to verify emissions reports and final compliance with MB standards. | The economic modeling ignores the costs to firms when regulations change; regulatory certainty is very valuable to firms, helping them to plan strategies that minimize compliance costs. These models fail to account for the delays and compliances cost of revising CAC regulations continually. |

Experience with MB policies is now well documented. For example, trading in SOx allowances under the Federal Acid Rain Program enabled utilities to choose among a wide range of compliance strategies, leading to management innovations and reducing the burdens of excessive investments in control equipment.[1] Also, trading lead reductions in gasoline inspired refining innovations that led to the ability to pursue further emission reductions through reformulated gasoline.[2] Further, market mechanisms successfully addressed critical constraints during California's severe drought from 1991 to 1994 and led farmers to realize that investing in efficient irrigation methods could lead to higher profits.[3]

Similar to learning lessons from cap and trade programs over the years, policymakers have faced the implications of modeling limitations. For example, more detailed and precise modeling of statewide impacts is not feasible, and would not add substantial information to distinguish between policy approaches. Also, understanding the limits in our knowledge about individual incentives, mitigation costs and innovation can help guide our selection of policy options. In addition, previous programs provide many lessons about how to proceed. Finally, simpler modeling to look for potential risks across wider scenarios and synergies is preferable once policy approaches have been narrowed.

## Analytic Summary: Findings on the ARB's Economic Modeling

During the second and third quarters of 2008, the California Air Resources Board conducted an evaluation of the potential economic impacts on the California economy in 2020 resulting from the measures in the Global Warming Solutions Act of 2006 (AB 32) *Proposed Scoping Plan*. Results of the modeling were provided in CARB's Economic Supplement.[4] The analyses relied on two macroeconomic models and found the state economy would grow by an additional 0.1 to 0.8 percent after adoption of the proposed measures. This increase is largely attributable to projected fuel savings of $22 billion that counterbalance higher investment costs of lower-carbon and energy saving technologies. In addition, the study found that employment would experience changes in a range from a slight loss to a gain of 0.6 percent. Further, households would gain $400 to $500 annually, with the highest proportionate gains among those in the lowest income groups because energy expenditures are roughly equal across income. Although the study attributes much of the potential benefits to small businesses, it did not quantitatively evaluate either the impacts on small business or other specific industries.

The ARB study acknowledges that its method is inadequate at capturing the differences among policy options to implement the AB 32 objectives: "Such tools and related cost-estimation methods, however, tend to understate the benefits afforded by market-based policies because they cannot accurately model important cost-saving features of market-based compliance mechanisms…"[5] Further, the study includes in its appendix a short listing of how these models fail to account for policy differences.[6] These differences include accounting for uncertainty and risk from external shocks, heterogeneity in the characteristics of firms and individuals in the economy, and understanding the mechanisms that drive innovation. Also, the appendix states that "further progress in the policy dialogue will require greater sophistication in both the positive research and its appraisal."

A reasonable interpretation of CARB's economic analysis and appendices illustrates that agency economists have not conclusively endorsed the proposed policies because of limitations in economic modeling. However, through the output of these models, it is shown that when taken as a whole, the Scoping Plan is unlikely to have significant negative impacts on the state's economy. **Therefore, the analysis does not answer the fundamental question at hand: What is the preferred policy approach and what are the differences among proposed measures?**

### Comparing Market-Based and Direct Regulatory Policies Is Beyond the Capabilities of Current Economic Modeling

The greenhouse gas (GHG) emissions reductions mandated to occur by 2020 as a result of AB 32, and the Governor's Executive Order calling for further reductions by 2050, are likely to lead to substantial changes in the state's economy. This has two important implications for climate change policies. The first is that ***the predominant environmental regulatory approaches in California are not going to be sufficient to affect the evolution of the state's economy, nor may they engender the associated innovation.*** The second is that ***conventional analytic tools are unlikely to capture the effects of different policy approaches when the changes in the economy push it beyond the bounds to which the underlying models are calibrated.***[7] This point has been conceded in the Economic Supplement.[8] These two issues are intertwined because the limitations on economists' current understanding of these processes inhibits the ability to develop accurate and comprehensive parameters and the limited availability of input data affects the ability to evaluate different policy approaches. As a result, ***the state may miss an important opportunity to fully capture the benefits of the coming transformation that could be engendered by using market-based approaches.***

Comments submitted to CARB on its economic analysis such as those by the Analysis Group (on behalf of the AB32 Implementation Group) have similarly focused on the static picture of the state's economy presented in the Economic Supplement.[9] A thorough critique of the Economic Supplement needs to take into account the broader transformations that are intended in AB 32, and whether the proposed policy approaches will accomplish this objective.

Traditionally, the Air Resources Board has imposed regulations to control criteria air pollutants that would fall into a category defined by terms such as "direct," "prescriptive" or "command and control" (CAC). These types of regulations mandate adoption of specific technologies or achievement of performance standards on a uniform basis across a set of firms or products. An alternative approach is the use of "incentive-based" or "market-based" (MB) measures, e.g., trading permitted allowances, that enable individuals and firms to find their own unique solution to best achieving reduction goals. Many studies have found that the MB approach is highly beneficial. ***For example, empirical reviews of past programs find savings of 40 to 95 percent from using MB measures.***[a] MB measures lead to more comprehensive responses from the regulated community that lead to emissions reductions in more aspects of the production process, from input use to process intensity to pollution control to output management. CAC measures typically focus on only one step of the production process. ***As a result MB measures that rely on a fixed emission cap are more likely to reliably deliver overall emission reductions.***

So how does an MB program create these benefits beyond CAC? Let us assume that it will cost Company A \$10 per ton of CO2 emissions on average to reduce emissions by 20 percent, but Company B \$20 per ton, and further assume that it costs Company B \$10 per ton to get a 10 percent reduction and Company A \$15 per ton to get to 30 percent. In this case, Company B would be willing to pay Company A \$10 per ton (the difference between \$20 and \$10) for Company A to achieve a higher reduction while the overall industry still achieves a 20 percent reduction at an average cost that is \$1.25 per ton less than if each company had to comply separately at a uniform reduction level.

Yet the influence from the MB approach goes further. Extending this example, Company A can now make even more by investing in new technologies. Whereas the incentive to go beyond a 20 percent reduction under CAC was weak because it would most likely view the regulation as a constraint, now Company A can increase its profits by improving its efficiency to achieve 40 or 50 percent or more because it can sell the excess credits to another manufacture. ***In MB regulations, reducing emissions becomes a clear profit center rather than just yet another environmental regulatory constraint on the production process.*** The ability to multiply the gains from innovation without having to increase primary product market share is what drives this

[a] The *Economic Supplement* acknowledges potential gains of a similar magnitude, but then proceeds no further in evaluating individual *Proposed Scoping Plan* measures. (See p. 6.)

innovation advantage. Importantly for the ARB, ***the revealed information about these innovations can help guide it in determining how best to achieve future emission targets.***

Most importantly, MB measures can be designed to produce real, independently verifiable, permanent, enforceable, predictable, and transparent reductions of similar and even better quality than CAC regulations. Allowance trading will require clearly defined and enforced emission reductions, and due to the financial stake that arises under MB programs, we can expect robust development and job generation in the emissions verification industry.[b]

### The ARB Modeling Cannot Adequately Resolve the Differences in Approaches

The economic evaluation of the *Proposed Scoping Plan* relied on two computable general equilibrium (CGE) models. These CGE models are the most sophisticated representations of the state's economy available, yet they are missing key components that would highlight the differences between CAC and MB policies. As mentioned previously, the *Economic Supplement* similarly lists these limitations.

- ***The modeling presumes a level of knowledge about firms, individual preferences and the future that is unrealistic.*** In fact, much of this knowledge is dispersed among the firms and individuals that are to be regulated, but is not known by regulators being tasked with developing best available technology or performance standards. MB measures reveal this knowledge in ways not possible with CAC regulation, but the CGE models obscure this important advantage.
- ***The modeling does not capture the important internal economic processes associated with technological innovation and diffusion.*** As is typical of the CGE model process, the analytical structure separates the examination of the likely impacts of individual measures from the response of the overall economy to these impacts. That is, measure-specific impacts are calculated outside the model, and then inputted into it. This treatment severs the feedback loops that determine technological development. Instead, each model assumes a fixed rate of technological progress that is inconsistent with many economic studies that demonstrate how different policies and economic structures affect technological change. The economic literature finds the MB measures are superior in accelerating innovation and adoption.
- ***Single-point snapshot forecasts for 2020 were developed that ignore the economic and technological processes up to and after that point, and more importantly, the uncertainty that exists about those processes and external forces.*** This obscures important benefits associated with market-based approaches, including mediating risks and enabling the private sector to adapt more effectively to the new policies.
- ***The statewide economy modeling does not capture the impacts from imposing CAC measures, but instead essentially simulates an overall MB program with no CAC measures.*** The CGE models take as inputs the total costs of the measures from the engineering studies, but do

[b] For example, the need for verification in real estate transactions has lead to the creation of the title insurance industry. As a result of this third-party compliance process, very few disputes arise among the millions of transactions each year.

> not constrain firms to use the same amount and types of inputs as they would under business as usual. That is, the model implicitly allows firms to search out emission reductions from other firms to the extent that the model captures differences among businesses, rather than enforcing reductions within each firm. In the end, the results from the E-DRAM and BEAR models are more likely to accurately reflect a market-based approach than a CAC program.

As a further issue for policy assessment, ***the modeling endeavors to forecast changes in total state income, but does little to address either (i) the distribution of those changes among both businesses and individuals, or (ii) uncertainty, and the associated risk, for any policy approach.*** These two points are of equal importance to policymakers. Information about how costs and benefits are distributed can help in crafting policies to mitigate adverse consequences. Understanding risk can clarify how different policy choices affect potential for regret in the future. Further, using the cash economy as the sole measure of well-being has significant limitations and provides a narrow vision of what is important to society.[10]

At this time the *Economic Supplement* provides little guidance to the ARB on what *type* of regulatory policies should be adopted to achieve AB 32 goals. This conclusion is shared by each of the peer reviewers, including the Legislative Analyst's Office, of the ARB's *Economic Supplement*.[11] ***It does not contain adequate comparative analyses or a rigorous discussion of the advantages and disadvantages of different approaches for specific sectors.*** As a guide, the ARB could rely on the resource planning process developed by energy and water utilities and regulatory agencies over the past three decades as a useful example of how to evaluate individual programs and consider their synergistic effects.[c]

Nevertheless, the ARB has sufficient information available to move forward on adopting a *Scoping Plan*; it just needs to specify a process to evaluate it. ***The MAC and ETAAC Reports provide a useful analytic framework and rigorous analysis to guide the ARB without further modeling.*** The MAC's Option A approach would start with cap-and-trade for large sources including electricity generators and industrial facilities, then include the transportation sector, and finally include all fuel use in the industrial, commercial and residential sectors. Implementing this approach can be left to the rulemaking process after the general approach is adopted in the *Scoping Plan.*

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[c] The ARB was provided with a template for conducting such an analysis of its State Implementation Plan in 1994, and by the California Energy Commission and the ARB in considering how to reduce petroleum dependence. (See M.Cubed, Accurex Environmental, Radian Corporation, and Regional Economic Models Inc. 1996. *Economic Analysis of the Proposed 1994 State Implementation Plan Conducted Prior to Its Consideration by the California Air Resources Board*. Sacramento, California: Prepared for the California Air Resources Board, Research Division.; and Gerry Bemis, Susan Brown, Dan Fong, Sherry Stoner, Chuck Shulock, Eileen Tutt, and Paul Wuebben. 2003. *Reducing California's Oil Dependence*. Sacramento, California: California Air Resources Board and California Energy Commission.)

# 1 Comparing Incentive- and Prescriptive-Based Programs

The *Proposed Scoping Plan* (PSP) for AB32 by CARB lays out a series of strategies, both prescriptive and market-based, to achieve reductions estimated at 174 mmtCO2e by 2020 when compared against business as usual. As part of the PSP, CARB has used two models, E-DRAM and BEAR,[d] to analyze the statewide combined economic effects of the program. Initially, CARB anticipated analyzing the economic effects of two regulatory increments: (1) model the economics of measures to achieve reductions of 139.6 mmtCO2e,[e] and (2) compare the economic effects of three alternative approaches to achieving the additional 34.4 mmtCO2e of reductions needed to meet the 2020 goal: carbon taxes, cap-and-trade, and additional prescriptive measures. Instead of the incremental modeling comparison, CARB modeled the economy as a snapshot in 2020 for only two scenarios: (a) "business as usual" (BAU) that assumes continued current regulations and economic conditions, and (b) after PSP implementation. This comparison relied on several metrics to conclude that PSP implementation will likely result in a higher GDP and more employment than BAU. Though a useful "first cut", the comparison is incomplete, notably with respect to representing the economic benefits of utilizing a cap-and-trade program in favor of additional prescriptive measures, or replacing the proposed approaches with more effective incentive-based ones.

At the core of the Air Resource Board's economic analysis should be the answer to this question: *Which policy approach is preferable?* The answer will be three dimensional:

- Discerning which policy approach is most likely to incur the least cost (or to result in the greatest net benefits);
- Recognizing potential pitfalls for preferred policy approaches; and
- Identifying which policy does better in terms of equitable outcomes among different groups.

Based on substantial research, there is good reason to believe the market-based programs such as cap-and-trade can provide emission reductions at the lowest cost with the most robust outcomes. However, well-spoken equity concerns have been raised about market-based approaches.[12]

This report discusses why it is difficult for the ARB to quantitatively discern the least-cost policy options at the detailed level required for direct regulatory intervention given the limited abilities of available economic modeling tools. The ability to evaluate how impacts are distributed geographically, across income groups, and among businesses and economic sectors is similarly constrained due to these modeling issues. Although alternative means for assessing potential risks do exist, the modeling approach used by the ARB is not appropriate for that assessment as discussed below.

Without comprehensive accurate quantitative models to compare economic impacts of policy choices, regulators are left to rely on rigorous qualitative comparisons derived from both economic theory and historical events. For this reason, market-based approaches based on

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[d] Both developed by professors in the Department of Agricultural and Resource Economics at the University of California, Berkeley.

[e] = 174 – 34.4 mmtCO2e

allowance trading are particularly attractive. The scope of regulation is so large that leaving most decisions to individuals rather than attempting to rely on only a few agencies promises to find more opportunities and to minimize the impacts of poor decisions. Addressing important equity issues is difficult in any case, but market-based approaches have the advantage of providing a rule-based framework from which to redistribute benefits and costs. Disentangling direct regulatory impacts often leads to a mish-mash of unintended consequences. As such, market-based programs provide the flexibility and robustness needed to tackle such a large environmental issue.

### 1.1 Defining Different Regulatory Approaches

Predominantly, regulators have relied on prescribing specific actions to be undertaken by businesses to achieve environmental objectives. These mandates have included both dictating how firms use their resources, and specifying performance standards for consumer products. Examples include:

- An electric generator or industrial boiler might be required to install a selective catalytic reduction device to limit oxides of nitrogen (NOx) emissions as the *best available control technology* (BACT).[f]
- An automobile manufacturer might be required to limit NOx emissions to a certain emission rate per mile driven as a *performance standard*.[g]

These types of regulations are called "prescriptive", "direct regulatory", or "command and control" (CAC).

An alternative approach has emerged that is based on steering regulated entities toward achieving environmental objectives while leaving substantial room for these entities to choose how to achieve the objectives. These mechanisms are called "incentive-based" or "market-based" (MB) measures. They can include tradable permits or allowances on measured emissions, tradable performance standards for individual products,[h] emission taxes or fees, input or goods taxes, or technology subsidies. Examples include:

- Capping emissions for an economy or sector, and then trading allowances. Two examples of this approach are for NOx emissions under the South Coast Air Quality Management District's RECLAIM program or SOx emissions within the U.S. Environmental Protection Agency's Acid Rain Program;
- Trading gasoline lead content levels among refiners as part of U.S. EPA's lead phasedown program;
- Taxing gasoline and diesel fuel based on carbon content instead of on a per gallon basis;
- Setting up a "feebate" program for automobile purchases that charges less-fuel-efficient vehicles and discounts more-fuel-efficient ones; or

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[f] For examples, see Federal Clean Air Act Title I, Sections 169(3) and 165(a)4.

[g] See FCAA Title II, Section A.

[h] The penalties for noncompliance under a CAC measure are equivalent to an emission tax.

- Subsidized renewable energy projects for cost above a market price benchmark level.

MB measures can either regulate quantity or rely on price signals. For example:

- Allowance and performance standard trading, of which cap and trade is one form, fixes the target amount of emissions, and then lets the regulated entities trade among themselves. The allowance price is determined through negotiation between sellers and buyers or other price settlement mechanisms. The Federal Acid Rain program is of this type for the utility sector, and has been very successful.[13]
- Taxes or fees on emissions, inputs or goods consumed fix the price or cost of the emission reduction, but do not specify the quantity of allowable emissions. As a result, the economic consequences are likelier to fall into a predictable range, but the amount of emissions will vary depending on a range of economic factors, such as economic growth. Unlike cap-and-trade, an absolute emissions limit is not enforceable through taxing.

## 1.2 Important Distinctions in Regulatory Approaches

An important distinction that is often overlooked in evaluating reduction measures is the difference in calculating emission reductions for different sectors and end-uses. For some large emission sources it is possible to measure GHG emissions either through stack monitors or fuel-burn calculations. These *ex-post* measurements are quite accurate. However, this approach is only applicable for electricity generation, large industrial sites, or at the point of sale of fossil fuels. It is not feasible for small distributed sources, such as automobiles, appliances or buildings. For these types of uses, *ex ante* technological standards are more appropriate, but these standards reflect estimated GHG reductions and do not account for changes in behavior and use patterns that will cause deviations from the estimates. Ex post and ex ante measurements are not directly comparable because the latter accounts for changes in economic behavior, while the former can only, at best, estimate potential responses, and more often simply ignores these responses.[i] The solution is designing market-based measures to recognize this distinction and segment the ex ante and ex post markets until appropriate adjustments can be made for comparability that allows trading between sectors.

This issue was addressed by the Market Advisory Committee (MAC) in its "Option A" proposal that calls for phasing in economy-wide cap and trade.[14] This approach would start with cap-and-trade for large sources including electricity generators and industrial facilities, then include the transportation sector, and finally include all fuel use in the industrial, commercial and residential sectors. Implementing this approach can be left to the rulemaking process after the general approach is adopted in the *Scoping Plan.*

A second distinction is that MB measures tend to be more comprehensive in controlling emissions than CAC approaches. The difference between CAC and MB measures is that the former typically regulate the four different "abatement channels", i.e., the different means of

[i] A performance standard provides no more assurance of emission reductions than an emissions tax. Both change the economic cost of using a certain technology—a tax increases the cost of the input to the technology, while a performance standard lowers the comparative operating cost of using an alternative technology. In other words, a performance standard is a form of a subsidy although its influence leaves fewer options for compliance because narrows choices.

controlling pollution from a firm's production or facility, one at a time, while the later leaves it to each individual firm to decide which channel it wants to change, or whether it will purchase that change from a different firm entirely.[15] Those four channels are:

1. Switching to cleaner input materials or fuels (e.g., coal to natural gas)
2. Changing production processes (e.g., from machinery to more labor-intensive)
3. Installing abatement technology (e.g., selective catalytic reduction)
4. Reducing overall production scale.

A CAC measure will typically focus on only one channel, such as installing a BACT on smokestacks (3), or requiring reformulated gasoline (1). MB measures usually provide a signal to firms to reduce emissions from the overall envelope that encompasses all four of these channels, but leaves it to the firm to choose which mix best fits its own situation. Because a CAC measure regulates only a single abatement channel, the certainty of expected reductions is *less* than for a MB measure.

### 1.3 Market-Based Measures Deliver Significant Benefits in Theory and Practice

The advantages of a market-based or incentive-based program have been described in many forums and publications, including in the Market Advisory Committee's and Economic and Technology Advancement Advisory Committee's (ETAAC) reports to the ARB.[16] Enabling trading of emissions allowances lowers costs to the entities covered under the program. In doing so it reduces burdens on jobs and wages, and the costs incurred by consumers and taxpayers. Numerous studies have quantified these benefits in existing settings, finding cost reductions of 40 to 95 percent compared with CAC policies.[17] Market based policies have the following beneficial features:

- Better ability to adapt to changing conditions;[18]
- Cost-savings by enabling emissions reductions to be achieved by those sources most able to obtain them at the lowest cost, thereby providing benefits to individual firms;
- When marginal abatement costs are dramatically different across sectors, trading allows for seeking out and utilizing low-cost reductions, thereby lowering the overall cost of reducing emissions within a sector or the many sectors within a cap and trade program;[19]
- Greater opportunities for profit induce superior innovation compared to direct regulatory mandates;[20]
- The ability to trade emission reductions ahead of the compliance curve induces faster rates of technology adoption, and gives firms an incentive to innovate by multiplying the opportunities to profit from innovations beyond cost savings in a single firm's production process;[21]
- Reduction of uncertainty by firms about regulatory action for setting emission levels over time;[22]

- Anticipation that a regulator will rely on MB policies induces a feedback process in which firms make investment decisions that further increase the cost advantages of the MB policies because they are assured of the opportunity for greater economic gains;[23]
- Easier enforcement and higher rates of compliance result because of the economic gains from over compliance, and the reliance on allowance buyers for the sellers to meet their ongoing obligations to supply those excess allowances, with risks of much larger economic losses associated with economic transactions if the sellers fail to comply;[24]
- Administrative costs can be lower because regulators are relieved of responsibility for establishing specific targets on a facility-by-facility basis, and;[25]
- Avoids the need for regulators to carry-out individual rule-making for each of many CAC policies, such as determining BACT for all technologies within several industrial sectors.

Despite these many clear advantages of MB policies, notably cap-and-trade programs, the ARB economic modeling did not find distinct differences between CAC and MB approaches. As we discuss in the next sections, the limitations of our understanding of economic processes and our limited skill in representing these processes in models should preempt a more explicit comparison of policy approaches. This paper makes two contributions:

- Details the reasons why a modeling comparison of CAC and MB policies is not likely to provide worthwhile or reliable results, and
- Broadly examines why the modeling is not likely to reveal the myriad economic advantages of using cap-and-trade type programs.

# 2 Limitations of Quantitative Economic Modeling

## 2.1 What Is a Preferred Modeling Approach?

A complete economic modeling comparison will include:

- changes in expected annual income and total wealth, and other measures of well-being;
- distribution of that wealth, income and well-being among the population and firms in the state;
- risk of experiencing unforeseen consequences, particularly from changes in outside forces beyond the control of policymakers.

The first metric is a measure of achieving a goal with the greatest net benefit or at the least cost (but not both at the same time—a wishful mistake often made by policymakers). The second one addresses how the costs and benefits are spread through the economy. The third focuses on our uncertainty about the future, the range of what could happen in the future, and what level of insurance might be appropriate.

While the ARB provided some information to assess changes in wealth and some distributional effects (generally confined to examining the effects by income deciles on consumers), it provided no results useful for assessing the risk of unforeseen consequences and little on the impacts on the state's businesses. The results of the economic analysis prepared by the ARB, and by most other commentators, address only the first aspect. To state policymakers, the latter two may be even more important than the former. And just as importantly in a stakeholder-driven process, in almost all cases competing analytic results can be traced back to differing assumptions that cannot be factually resolved. Including these differing assumptions and ordering the results in a systematic way can add useful information on all three dimensions of economic analysis, and can reflect the differing expectations of various stakeholders.

The details of the policies chosen will lead to different sets of "winners and losers"—an aggregated result leaves us with no information to answer that question, nor of how to mitigate unwanted effects. By identifying clearly those who might be made worse off (even if just in relative, and not absolute, terms), we can design policies that ultimately spread the potential gains equitably to all state residents.

Modeling studies should not be limited derivation of an "all is good" result based on a single model run. It should assess the potential (i.e., risk) of regret from pursuing alternative policy paths by identifying potential "worst case" outcomes if underlying assumptions do not hold.[26,j] The lack of risk assessment is unfortunate, because it would likely reveal yet another set of reasons why cap-and-trade and other market-based policies are likely to perform better than conventional controls. Such policies both decentralize decision-making so we do not have "all of our eggs in one basket," i.e., that we have chosen a single path, and allows for more nimble decision making as these can eliminate cumbersome bureaucratic processes that inhibit and slow down critical adaptation.

## 2.2 Modeling AB32 Impacts Is Beyond the Ability of Economists' Analytic Tools

The specifics of the modeling comparison prepared by the ARB address the trees within the forest, but the bigger picture of the forest merits consideration as well. To achieve a 50 to 80 percent reduction in GHG emissions will require fundamental changes in how we use energy, where we live and work, and how we consume goods and services. Yet we do not, and cannot, know whether these changes will be beneficial or detrimental, or to what extent. New highways and water projects were expensive but they returned many times these costs in improved mobility and expanded food supply. The goals of AB 32 similarly are implicitly transformational, but to implement these goals in an effective and efficient way requires that policymakers be well informed with rigorous and robust analysis. The direct benefits to society from improved access and diet are readily apparent, and the returns on investment to these type of projects were readily apparent. That situation is not so true here. Realizing the benefits from not only inducing changes in the climate change trajectory but also in making fundamental changes in our economic infrastructure and relationships will require well-crafted and adaptive policies.

This situation leads us to conclusions about two different aspects of this problem. The first is whether we can effectively analyze expected outcomes in a quantitative fashion with conventional economic tools. The second, and more importantly, is what type of policy tools are appropriate

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[j] For example, the state's current fiscal crisis has been attributed in part by many commentators to a failure to ask "what if…?" about potential revenue and spending scenarios. (See for example articles by *Sacramento Bee* columnists Dan Walters, Dan Weintraub and Peter Schrag.)

in this situation given the scale of the necessary transformation and our limited ability to analyze policy options. Modeling two important economic aspects are key:

- How do market-based measures perform compared to more traditional command-and-control?
- What factors induce technological innovation and adoption?

Both of these latter questions are relatively new to large-scale economic modeling, but key to addressing the question of what policies are best for achieving AB 32 goals.

Available economic modeling tools are not well equipped to assess public policies of the scope and scale of the AB32 *Scoping Plan*. The analytic methods available to assess policy options are not well suited to simulating transformative paths that push fundamental economic relationships beyond current boundaries, such as potential segmentation of the automobile market into vehicles for specific tasks. Traditional analyses of small, incremental policy changes, such as from tighter vehicle criteria pollutant standards, are not able to capture the economy-wide transformation likely to be induced by AB 32, or the uncertainties associated with these changes. Achieving reductions of these magnitudes over the next four decades will require changes in production processes, not just installing add-on controls has been the case with most air quality regulation to this point. The ARB model works from the "bottom up" by evaluating the engineering costs and savings of individual measures, aggregating them up to a statewide total and then running them through the CGE model. This contrasts with the "top down" evaluation of the sort prepared by Charles Rivers Associates which rely solely on broad economic parameter estimates in response to added constraints.[27] Neither approach is truly suitable for the long-term, transformative issues of this nature.[28]

Assessing the impacts of a policy require clear and consistent representation of baseline conditions, i.e., business-as-usual. For example, a plethora of other policies have been adopted already or are being considered that will create auxiliary reductions in GHGs. Whether benefits and costs should be attributed to measures already in place, such as more aggressive energy efficiency programs, the existing renewable portfolio standards, and the automobile fleet fuel efficiency standards, add to the complexity of the evaluation.

Available economic analytic tools are particularly ill-suited to distinguish between traditional prescriptive regulatory programs and those that are incentive-based. This weakness is due to several shortcomings in our economic knowledge that makes it difficult to forecast likely differences in outcomes between these two policy frameworks, for the following reasons:

1. *Representing differences amongst firms:* We do not have adequate data on the heterogeneity (i.e., variety of characteristics and tastes) of firms and individuals in the economy. We have been able to partially model the individual characteristics of generators (but not consumers) in the electric utility sector because they are economically and physically regulated and must report individual data that can be used to inform models. But that is not true for most economic sectors. This makes it difficult to evaluate one of the biggest benefits of MB policies over CAC in actual conditions. Markets provide the ability of individuals to trade among themselves so as to meet overall environmental objectives while reflecting individual preferences and constraints. If we were all the same, we would all have identical endowments and preferences and we would not need to trade among

ourselves. That we are different and that it is impossible for one central planning agency to understand all of our disparities is why we use markets to allow us to individually choose low-cost compliance strategies.

2. *Computational limitations:* A related problem is that the computational load of modeling a representation of the true heterogeneity amongst firms is so burdensome as to limit the usefulness of the results. Running such models would make it impossible to produce the many (i.e., hundreds or even thousands) model runs needed to assess the risks associated with any one policy path.[k] How long it takes to run electricity simulation models, particularly ones that address transmission physics, illustrates this problem—the insiders' joke is that these model run in "real time"—they can take a whole day to simulate a single year of operations. To get around this problem, economic modelers often assume that the economy can be represented as a "perfectly competitive" market in which the actors have "perfect knowledge." However, the results from these assumptions will be identical to assuming that the economy is run by an "omniscient central planner." In other words, the modeling assumes away the essential difference between CAC and MB programs.
3. *Representation of Market and Government Inefficiencies and Barriers:* Another related issue is that economists have not quantified well the effects of institutional inefficiencies and barriers that are called "market failures" and "government failures." These inefficiencies and barriers include such aspects as the moral hazards of one agent misrepresenting one's intentions to another agent in a transaction, the inability to fully define the property rights to a "good" such as air quality, or the leakage of policy benefits such as low-income programs to those of higher income groups, i.e., tiered electricity rates that subsidize all residential customers rather than just low-income ones. All of these inefficiencies and barriers increase the costs and undermine the benefits of any policy choice, but they also exist in the status quo. The question is whether MB or CAC better address each of these problems, and can one or the other be designed to mitigate them.
4. *Representation of Innovation and Adoption of New Technologies:* We do not understand several fundamental processes that clearly influence broad economic trends, and thus cannot include these in our models. Processes that are difficult and complex to model include how technological innovation and adoption is influenced by other factors in our economy, such as incentives, subsidies and mandates. Another is the impact of income distributions growth. Much debate exists in the economic literature about how these key processes work. Without a clear understanding, it is difficult to distinguish MB and CAC programs in model representations, and thus impossible to tease out different outcomes from emphasizing one approach over another. Further, the modeling cannot quantify the added benefits from using a MB approach over CAC, or how one MB approach differs from another.

Building on the observations above, the next section discuss the economic modeling conducted by the ARB Staff, identifies the key underlying assumptions and methods, and provides detailed

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[k] Several analytic techniques are available to assess risks including scenario analysis, Monte Carlo simulations, and exploratory modeling with robust decision making. Discussing these techniques here is beyond the scope of this study, but should be explored more deeply by the ARB given its broaden authority and responsibility.

reasons why modeling cannot capture the differences between CAC and MB measures for the *Scoping Plan*.

# 3 Key Modeling Assumptions Obscure Policy Differences

The ARB conducted two studies of the *Proposed Scoping Plan*, in two stages. In the first stage "direct" costs or savings to consumers, businesses and communities of adopting specific lower-emitting technologies or implementing various emission reduction measures were estimated. The economic costs and savings developed in the first stage for individual measures were derived either from internal spreadsheet-based models or received from other agencies, such as the California Public Utilities Commission. While these estimates are not reviewed herein they are key to the results in the second stage. In the second stage how these costs or savings might reverberate through the state's economy, as measured by changes in economic activity and job creation, was forecast. It is this second stage in which the *computable general equilibrium (CGE)* models were used.

The CGE models have several key assumptions that obscure the distinctions between MB and CAC policy choices. The first is of an economy operated by an "omniscient" central planner who knows every detail and preference of all economic actors. The second is that the rate of technological innovation and diffusion is not affected by differences in incentives and interactions that arise from using MB versus CAC approaches. The third is an implied certainty about future outcomes—the models deliver single point forecasts and say nothing about external events might change policy outcomes. Finally, the CGE modeling may be confusing CAC and MB regulatory impacts due to the lack of certain constraints in the CGE models. The implications of these assumptions are discussed after an introduction to the ARB's CGE modeling.

## 3.1 Models' Depiction of the State's Economic Relationships

Both the E-DRAM and BEAR models are based on a CGE framework that is one of the most sophisticated means of representing a large regional economy. Such models are commonly used to assess national development policies in developing countries. The initial formulation of the E-DRAM model is used to forecast the impacts of specific legislative proposals on the state economy by the Department of Finance. The BEAR model relies on E-DRAM as its central core and adds other aspects intended to reflect the dynamic nature of the state's economy.

A CGE model is a mathematical programming description of a "text book" economy, that is, these are representations of an economy that are derived from a particular theoretical economic framework.[29] These models rely on area-specific data on industrial and commercial activity to trace how a dollar of investment moves through a regional economy.[1] CGE models, and other regional economic models, estimate the direct, indirect, and induced activity and employment—the "multiplier impacts"—of a given investment. This multiplier effect estimates how many times a given dollar of investment will be spent as it works its way through the economy. In other words, spending one a single item will induce spending on the inputs to make that item,

[1] However, these data are typically old – at least five years – and as a result tend to not reflect the most recent technological changes, and certainly do not speak to current economic conditions.

which will in turn induce spending on the inputs to those inputs, and so on. This multiplier effect is how the direct costs and savings from the PSP are converted to statewide economic impacts. For example, producing a ton of steel may require three workers and a particular set of equipment, which would not be required if the steel were no longer used for a specified purpose. So extending our example, the loss of those three workers might lead to the loss of another three jobs elsewhere in the economy, e.g., in the automaking, service and government sectors.

A CGE model is used in an analysis in the following steps. First a policy scenario is postulated; in this case, the scenario is that a portfolio of control measures are imposed through various regulations to limit GHG emissions. Second, the direct costs or savings to firms are determined. These are results shown for the individual control measures in the ARB's Economics Report.[30] These direct costs are measured as change created by the measure in cost of producing a specific good or service. Third, production sub-models for each sector are designed to mimic how firms change production patterns and pass through those changes in prices in reaction to cost changes estimated in the second step. Finally, the cumulative effects of the changes in prices, costs, production and use of inputs are summed and distributed among the impacted sectors by the CGE model. These are the changes in 2020 shown in the ARB Study.[31]

CGE models, as with most other regional economic impact models, make important unstated assumptions that affect the reliance policy makers should put on their results. These assumptions obscure the differences between MB and CAC policies. This leads to an implied bias toward CAC policies because analysts do not adequately disclose these assumptions to policymakers. We discuss that in the next sections.

### 3.2 Metrics are Incomplete, and Time Dimension is Too Short

The ARB modeling approach has at least two limitations common to most standard analyses:

- It relies on the conventional economic measure of gross state product (GSP). This has the unfortunate characteristic of including many activities that are normally considered to be as detrimental as they are beneficial economically. For example, hiring more security guards and installing more alarms in response to a crime wave raises the GSP. From this perspective, building seawalls and fighting more fires in response to climate change also can raise well-being. Perhaps a better metric is something like the Genuine Progress Indicator[32] (GPI) that measures a broader spectrum of economic activity while also considering effects on natural resources.
- By focusing on a single-year snapshot (2020), the analysis ignores the equally important trajectories of adaptation and mitigation costs prior to and after 2020, the benefits of technological transformation beyond 2020, plus the costs of *inaction* in the future.

The implications of these limitations mean that it is hard assess the reliability of the findings of the ARB evaluation, and the very metrics being used to compare scenarios are in themselves limited in their ability to describe the sustainability attributes of economies.

### 3.3 Incomplete Treatment of Individual Control Measure Cost Uncertainties

We have not reviewed the direct cost estimates for the specific measures or programs included in the *Scoping Plan*. Regardless, our observations are germane to the underlying structure of the

ARB analysis. While the CGE models ARB used are sophisticated representations of the dynamics of the California economy, ultimately the results of these models, consistent with other regional economic models, are driven by the relative direct costs and savings that are estimated for individual programs and measures. In other words, the CGE models have delivered results consistent with conventional expectations once the direction of those costs and savings are determined. The ARB Staff's estimates show significant savings across the portfolio of measures, and E-DRAM and BEAR show statewide benefits commensurate with those savings. The multipliers—the ratio of direct savings to increase overall economic income and added jobs—are about the same as one would expect from a standard input-output model with static economic data. This indicates that neither the E-DRAM or BEAR models include dramatic changes in the state's economic infrastructure from the proposed measures.

To reflect these changes in the infrastructure would require a feedback loop between the direct-cost estimates and the CGE models from the changes in investment patterns supposedly induced in the CGE models back to the direct cost models. These direct cost estimates usually have been prepared without considering the heterogeneity of the marketplace or the importance of inducing technological innovation. The front-end models are static "dead ends" rather than being dynamically linked to the overall economy models. Those direct cost models would need to be constructed to consider how changes in market share might change costs and pricing. For example, the aerospace and computer industries "forward price" in which they discount and sell at a loss early in the product cycle to induce increased demand that leads to improved economies of scale that lead to lower prices in the future. This type of market behavior is not captured in the engineering cost models that drive the ARB economic results.

### 3.4 Modeling Assumes Regulatory Omniscience

CGE and most other conventional macroeconomic models do not adequately capture the costs associated with adjusting to production changes induced by a policy. These adjustments are viewed in the eyes of economists as costs, though in fact may be investments that avoid significant future costs, such as the costs of adapting to the worst effects of global warming. These adjustment costs arise both through transactions, i.e., the costs of having to make decisions and to interact with other entities in the economy, and from a lack of knowledge about both current and future conditions. Transaction costs arise for both marketplace and regulatory interactions, and are often difficult to identify and measure. Not capturing this lack of knowledge and foresight has several important implications for modeling potential effects of policies:

- *Assumption of excessive efficiency:* In the immediate situation, the CGE model assumes that firms and consumers are fully aware of all of their available choices, which is not true in reality. So these actors "overoptimize," i.e., they achieve economically-efficient decisions beyond what is actually achievable given limited knowledge.
- *Risk engenders caution:* Uncertainty about the future causes producers to be cautious about changes and to averse to accepting more risk. These are reflected as "hidden" costs that are often reflected as higher private discount rates for individuals than what society might use for a broader portfolio of potential outcomes. Empirical studies consistently find individual consumers and firms invest with expectations of more rapid payback than

would be socially desirable, thus increasing the apparent private cost of certain actions, e.g., energy efficiency, compared to the social costs. This desire for an accelerated payback reflects, at least in part, the higher risk perceived for a large up front investment compared to smaller discretionary payments over time.

- *Trading mitigates variety:* Another simplification is that these models assume that all of the agents in a single sector or in a few categories within a sector are identical or "homogeneous." The variety within those sectors is lost even though differences exist among sectors.
- *Models provide a false sense of certainty:* Finally, CGE models tend to be run to estimate a "single-point" or a limited number of forecasts that imply more certainty about potential outcomes than is justified by our knowledge about influences that are beyond the control of the various actors within the framework being analyzed, otherwise known as "exogenous" factors, such as fuel prices, economic and demographic growth and political influences, economic relationships such consumer responses to changes in prices and technological innovation and adoption rates, and the effectiveness of policy "levers" such as imposing standards and taxes.

Each of these assumptions or simplifications are particularly important to whether the modeling can capture the difference in implementing market-based policies compared to CAC (e.g., technological innovation; production efficiencies caused by enabling marketing players to make choices about how to respond as opposed to being directed in particular ways.) We further discuss the implications of these assumptions on the modeling results below.

### 3.4.1 Market-Based Programs Convey Information Unknowable to Regulators

CGE models assume perfect knowledge and foresight and frictionless transactions. In this setting, economic theory tells us that the outcomes will be the same for a perfectly competitive market with many participants and full knowledge by all individuals and an economy run by an omniscient central planner who knows the preferences and constraints for all individuals.[33] Such models will show that a planning agency can select the optimal regulatory plan and by definition the marketplace cannot improve on this. And not surprisingly, the CGE model results found no substantial difference between MB and CAC policies. Yet in reality no one is omniscient, uncertainty is rampant, and transaction costs are significant. Appropriately modeling these policy differences must capture these types of imperfections.

Similar to CGE modeling, implementing CAC measures efficiently relies on a "central planning" regulator having substantial information about the regulated sector, and even having *more* information than the regulated entities. This assumption of omniscience by the regulator shows in the modeling of CAC measures, when in fact regulators know relatively little about actual choices the individual firms and entities face and decisions they make. MB measures reveal more information through "price discovery"—the process of offering and bidding with other market agents—than a regulator can gather and use. The size of the California economy will simply overwhelm any one agency trying to make all decisions across all spectrums. Decentralized market mechanisms can convey the same information so as to spread that decision-making load. This makes MB programs more resilient to changing circumstances because individual agents can make decisions in response rather than waiting for a decision out of a cumbersome regulatory process.[34]

MB measures also better account for the heterogeneity of the entities in the market. CAC almost always presumes "one size fits all" and is not easily adapted to changes for specific circumstances. Much of the drag in adopting regulations is in battles over special circumstances. MB measures allow regulators to bypass that process by adopting a single standard, but allowing firms to sort out their own individual requirements.

### 3.5 Incomplete Modeling of Technological Innovation and Adoption

Technological progress from an economic standpoint is a two-step process. First, innovation creates a new technology or finds new applications for existing technologies. Second, the technology is adopted across the economy, often in a predictable pattern. Having an innovation does not necessarily imply that it will be adopted. For example, the Beta format video tape was acknowledged as technically superior to VHS, but the latter won in the battle for market share for a variety of reasons including relative costs. So lowering costs is just as important as improving the performance characteristics of a technology.

The impacts of the *Scoping Plan* were modeled with two CGE models, E-DRAM and BEAR, and BEAR was included because it more explicitly incorporated a form of technological progress. However, the modeling results were quite similar between the two models, calling into doubt whether BEAR was actually capturing these effects in a manner beyond the more standard framework used by E-DRAM. Reports documenting BEAR indicate that substantial thought has gone into the issues of innovation, but we examined whether *induced* technological progress had actually been implemented in the model. We would expect that innovation in particular would be a function of different policy approaches that allow innovators to capture differing portions of the "rents" or economic gains from the innovations once they are adopted. Similarly adoption rates can be a function of differing responses to incentives, mandates, and the "property" rights to the associated economic gains. In our review, we have not found an example of the BEAR model that treats technological innovation endogenously, *i.e.,* created as a function of policy choices and interactions among the entities within the model.[35] What we have found are several examples where technological innovation is set exogenously, that is, the rate of innovation is fixed regardless of the policy choice or the economic responses. In these instances, an assumed rate of improvement in efficiency or factor productivity is used as a proxy for technological innovation over time.[36] The BEAR model assumes that efficiency improves over the forecast period at some exogenously specified annual rate. Of course, this approach does not provide any insight into how differing GHG control policies may or may not affect the rate of technological innovation over time. It merely shows that improvements in efficiency or factor productivity would be economically beneficial.

Technology adoption rates are a function of both growing demand and replacing existing technologies. The BEAR model includes two vintages of technology investment or capital – "Old" and "New".[37] Old capital is less efficient than New capital. Overall capital investment is endogenous and depends on relative factor prices. Changes in factor prices (e.g. imposition of a carbon tax) can result in disinvestments of Old capital and investments in New capital. The process of capital investment/disinvestment is governed by a "putty/semi-putty" specification that allows for changing technological stock over time but on a lagged basis, which results in a gradual adjustment of the capital stock towards the long-run optimum. The average efficiency of the capital stock adjusts gradually overtime as Old capital is replaced with New capital. This process does not involve technological innovation, however. The efficiencies of Old and New capital are exogenously determined—set by the modeler and not derived through expected changes in the economy over time.

#### 3.5.1 Unexplored Synergies between Market-Based Programs and Technological Progress

Based on this assessment, we cannot see how the BEAR modeling reflects differential technological progress as a function of differing policy approaches. The model does not use different exogenous parameters to reflect differences from using MB versus CAC approaches, nor does it make these parameter endogenous to reflect differing investment patterns. The fact is that there simply may not yet be enough information and research to develop useful empirical estimates of the differences resulting from different policy choices.

In reality, improvement in new and existing technologies' performance and costs is a function of responses to a mix of market and regulatory signals. While a mix of policy approaches is best for inducing the needed innovation, emission pricing ranks highest over performance standards.[38] A strict environmental policy that induces endogenous innovation can lead to higher growth, but a scenario that leads to the maximum social welfare may not be the same as one with maximum growth.[39] Various barriers can reduce technological innovation, but certain policies can help to overcome them. A foremost obstacle results from the spillover of R&D benefits from private investors. The solution is that the optimal ratio of public R&D spending to private investment can be quite high.[40] The lack of knowledge by regulators about individual firms, and uncertainty by firms about regulators' future actions can reduce technology adoption rates, but allowing trading increases those rates.[41] Another impediment is that irreversible investment in older vintage capital can delay technological diffusion.[42] Compensating owners of older capital can reduce this barrier (so long as it is done correctly).

As discussed above, finding empirical measures of differing innovation influences is difficult due to confounding influences. Yet we may be able to look at broader economic trends to discern the relative merit of different approaches. The most salient example could be the assessment of comparative performances after the fall of the Berlin Wall. The Allies conducted a 45-year "experiment" in which Germany was first split after World War II with largely equivalent cultures and per capita endowments, but one used a largely market-based economy and the other relied on central economic planning. When the two nations reunited in 1990, the eastern centrally-planned portion was significantly behind in both overall well-being and in technological innovations and adoption. More importantly, West Germany had become one of the most technologically-advanced and environmentally-benign economies while East Germany was still reliant on dirty, obsolete technologies.[m] For example, a coal-to-oil refinery in the former East Germany was still using World War II-era technology. West Germany had doubled the economic output of centrally-planned East Germany.[43] The transformation of the

[m] The lower environmental consequences probably arose from the fact that firms and the government were in an adversarial setting in West Germany in which the firms focused on the most efficient use of resources and were insulated from political interest group pressures. On the other hand, resource allocation decisions in East Germany had to also consider interest group pressures that tended to protect old technologies and industries.

West German economy, both technologically and institutionally, was akin to what we will need to meet AB 32 goals and beyond. This more clearly than any other example demonstrates how reliance on central planning, as attractive as it appears to achieving specific goals, can be overwhelmed by the complexity of our societies and economies. Despite explicit policies to pursue technological innovations, a market-based system progressed much more rapidly and further.

Among environmental programs, the Acid Rain Program appears to have induced several innovations. These include fuel blending, lower costs and higher effectiveness and reliability for emission controls, and in fuel transportation management and investment.[44] This latter effect spilled over into the general economy, lowering railroad freight costs for all economic sectors.

We can see why these differences occurred in a rapidly-changing world. CAC regulations also usually rely on a static understanding of an economic sector and cannot account for dynamic changes. A MB measure naturally adapts to changing technology and conditions. If a CAC measure requires adoption of a BACT, the regulator will face resistance from entities that installed that BACT if the regulator wants to impose an even stricter standard. Those entities will face "stranded" investments—sunk costs that cannot be recovered from the market--if the BACT is made prematurely obsolete.[45] On the other hand, regulated entities can anticipate future increases in stringency and can smooth their investment patterns by trading with other regulated entities.

MB measures also are more likely to inspire accelerate technological investment, particularly when the emission reductions must come from process-embodied changes rather than through add-on control devices. The latter typically are provided by vendors rather than production firms. Creating an assured market, as a CAC measure does when it requires universal BACT, can provide the customer base for a vendor to recover their innovation investment. But controlling GHG emissions generally require an embodied change in a production process, not an add-on to a tailpipe, by reducing fuel use or methane emissions.[46] Add-on technologies are largely not available. Also, it is uncertain about which technologies will be most effective at reducing GHG emissions. Given this situation, MB measures can provide broader incentives for production firms to invest in new technologies, just as occurs in other industries such as computers and aerospace.

Along this line, MB measures also encourage overcompliance with emission targets, particularly if banking of emission credits is allowed.[47] Early innovation is rewarded with reductions that might be held until the value rises in the future.[n] In this way, reductions need not be timed to match a compliance path, unlike CAC which does not reward early implementation.

### 3.6 Modeling Did Not Assess the Uncertainties or Risk Implications

The ARB ran the CGE models usually with a single assumption about future conditions, e.g., population, economic growth rates, fuel prices, technology costs and performances. This gives the mistaken impression that these assumptions have been vetted and agreed upon by experts.

[n] Note that unlike criteria pollutants, GHGs have long, multi-year lives. This means that the timing of the reductions are not as critical, and intertemporal trading with appropriate discounting can be a useful regulatory mechanism. This type of trading is known as "banking."

The fact is that no expert can be certain about what will happen in the future, and these forecasts are built on past experience. And the experts differ about their expectations. These differences reflect uncertainty, but that is not captured in the ARB modeling.

At the core of risk is uncertainty. In developing any public policy, significant uncertainty exists around many factors, including the existing situation and data, how various influential aspects will evolve, and what decisions might be made in the future. Policies related to implementing the goals in AB 32 particularly is subject to uncertainty about current conditions and the future because so little is known and knowable about the resulting new energy infrastructure network. This leads to many more dimensions of uncertainty, and consequently, risk, than for a typical environmental policy.

That there are so many dimensions of uncertainty, and consequently amplified risk, does not mean that California should not pursue a policy that promotes an unprecedented shift in its infrastructure. However, uncertainty in future economic and social growth does imply that the policy development and implementation process should be significantly more adaptive and flexible than any previous environmental or energy regulation. MB measures are more effective than CAC measures for meeting this policy choice. Establishing simple targets or prescriptive standards without allowing for revisiting the regulation could be counterproductive, and more importantly, stifle the technological innovation and dispersion that will be necessary to achieve the ambitious goals set out in AB 32. Instead of "bean counting" to demonstrated compliance, policymakers should think in terms of market innovation, in which the very market "demand" itself may change as our knowledge and technology evolve.

Most of these uncertainties cannot be addressed through probabilistic modeling methods such as Monte Carlo simulation or scenario analysis. Few if any of these are uncertainties (e.g., fuel price and cost trajectories, environmental conditions, political decisions) to which quantitative probabilities can be attached for individual outcomes. For example we cannot say whether the price of oil will go to $200 per barrel with a 5, 10 or 50 percent probability; we only know that it is a potential outcome. Instead, these are *deep uncertainties* that are better represented as "forks in the path," each of which should be explored and planned for in developing AB 32. Policymakers should be made aware of the implications of their choices and range of possible outcomes and associated risks. These should not be masked by either producing only optimistic scenarios or by masking the results with fictitious probably distributions. Exploring these specific outcomes can help inform policymakers about whether policy options might be preferable. Analytic tools such as *exploratory modeling* and *robust decision making* are useful for this type of exercise.[48]

### 3.7 Models Simulate Inter-Firm Differences as Incentive-Based

Attempts to capture sector-specific heterogeneity and transaction costs in CGE models are codified in the equation parameters that measure how costs and quantities change in response to policies. Specifically, unless the equations are directly modified between policy cases, the policy changes are created by changing the cost data for each sector rather than changing the dynamic production processes in those sectors. Imposing a universal process change through universal regulation would change the parameters that describe the production processes, not just the underlying cost data. Changing the cost data is the most common approach simply because the models are formulated to leave the relationship parameters alone (even though there is probably more uncertainty about the parameters than about the data to which the parameters are applied.) The changes in the cost data are then distributed across the sector based on these parameters. But these parameters do not distinguish between the type of cost imposed, whether it is from regulations or higher fuel prices or lower wages. A CGE model then allows each firm to decide how they will change their use of inputs, and even whether to contract with another firm to provide or supply that input in another form rather than purchasing it directly. In other words, the model assumes that firms can respond in a flexible manner to any and all changes in costs.

Yet how these costs change is important. A prescriptive policy that requires all firms to adopt a specific technology will lead to a uniform upward shift in production costs for all firms in the regulated sector. In other words, the costs of all firms is likely to be increased a relatively constant amount. An individual firm will not be able to avoid that cost increment so long as it continues to produce at a given level using a given technology. On the other hand, an incentive-based policy mimics the flexibility implicit in the CGE modeling. A firm is able to choose between adopting a technology that meets the emission requirement or buying allowances from another firm that has emission reductions beyond what it requires. The CGE model assumes that this trading is possible. Mandates do not allow for this type of trading.

The bottom line is that the benefits forecasted by the E-DRAM and BEAR are more likely attributable to implicit adoption of a broad market-based program rather than implementation of individual CAC measures. In fact, these models most closely approximated the results from an emissions tax on these specific sectors. If the CGE results could be mapped back to an emissions inventory, we would most likely find that projected reductions differ from those derived in the initial engineering cost models, just as would be the modeling result if ARB analyzed a carbon tax. This implies that the ARB's economic modeling may not be reflecting a scenario that actually achieves the 2020 emission reduction goals; however, we cannot tell if the results would be above or below the target without mapping back CGE results into the direct-cost models.

## 4 Conclusion: Well-Crafted Market-Based Approaches Are Preferable

The ARB has proposed a *Scoping Plan* that relies significantly on a set of prescribed general measures for a variety of economic sectors. At first glance, it may appear that these measures may only be implemented using CAC regulations that specify BACT to be adopted by all regulated entities. Nevertheless, historic examples and economic principles show that MB instruments can be tailored to meet the special requirements of these sectors in California in compliance with Ab32 and as noted in the MAC report.

More fundamentally than whether MB and CAC policies can be modeled, the need to reduce GHGs to achieve climate stabilization will require reductions across the full envelope of abatement channels, from inputs to processes to discharge controls to outputs.[49] Traditional CAC measures focus only one pathway at a time, have particular problems regulating output in a market economy such as the U.S., and have a poor record regulating across pathways. MB measures, as previously discussed, are better able to allow decentralized decision-making. Individual firms are then able to make deep transformations that cannot be anticipated by a central regulatory agency.

In addition to examples drawn from other MB measures to reduce emissions, recent history offers the results of an experiment on the relative power of using market-based versus command

and control approaches to regulation. When West and East Germany were reunited 45 years later, the market-based system had delivered superior well-being to its citizens, in large part because the complexity of that society had been managed through decentralized decision-making. In the end, despite the economic disparity, West Germany was more benign environmentally than its neighbor.

A final question is then how does the ARB adopt a viable, workable MB program given the diversity of emission sources and the acknowledged shortcomings in MB approaches? The *Scoping Plan* is a useful starting point, but instead of imposing uniform standards on all participants in any one measure, each after a long, extended, cumbersome rulemaking process, the ARB could determine the appropriate metric and then consider how best to implement market-based mechanisms. The MAC Report lays out a viable approach in its Option A that proposes progressive incorporation of regulated emissions into a cap-and-trade program. Specifics can be tailored to individual sectors, and the objections to MB measures can be addressed in this manner.

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## Endnotes

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