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Options for Cap and Trade Auction Revenue Allocation:

An economic assessment for California

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Research Papers in Energy, Resources, and Economic Sustainability

This report is part of a series of research studies into alternative climate, energy, and resource policy options for the California economy. In addition to disseminating original research findings, these studies are intended to contribute to policy dialogue and public awareness about environment-economy linkages and sustainable growth.

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1 Introduction

California has embarked on one of the world's most ambitious climate and energy efficiency (EE) policy initiatives, and next year the process begun in 2006 with passage of AB32 will reach an important milestone, inception of a Cap and Trade system of marketed rights for greenhouse gas (GHG) emissions. The exact design and implementation of this system remains the subject of active policy dialog and research, but it is generally agreed that tradable emission permits will have pervasive economic, environmental, and technological impacts on the state economy. One important direct economic benefit may arise from competitive auctioning of emission permits. Those who support this approach argue that, because the atmosphere and air quality are public goods, those who "consume" them by emitting GHG should pay for the privilege. Under a variety of auction scenarios, it is estimated that revenues totaling billions of dollars annually will accrue to the state.

How this new revenue source might be used is also a matter of intensive public and private discussion. Both public and private institutions have expressed an urgent interest in strengthening the basis of evidence on this issue. The present study addresses this need to support more effective use of these public funds. In particular, we evaluate the impacts on California economic growth, employment, income, and the state budget of a diverse but representative array of alternative scenarios for auction revenue allocation.

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The assessment tool used in this study is the Berkeley Energy and Resource (BEAR) model. BEAR is a detailed and dynamic economic simulation model that traces the complex linkage effects across the California economy as these arise from changing policies and external conditions. BEAR has already been used to produce estimates for the California Environmental Protection Agency, and its projections are quoted in the Executive Order establishing AB32. Because it follows detailed interactions between California consumers, enterprises, and the state's fiscal activities, BEAR captures the myriad of indirect effects that can arise from more narrowly targeted expenditure decisions. Taken together, the indirect effects often outweigh initial fee collections or disbursements, in many cases in opposite or partially countervailing directions. For example, an emission fee may impose direct costs on polluters, but the economywide benefits, including energy savings, averted pubic health costs and even climate damages, may be much larger. A comprehensive assessment of both direct and indirect effects is essential to fairly appraise the public interest in such policies.

BEAR has been applied to such issues since the legislative run up to passing the Global Warming Solutions Act (AB32).[1] Successive rounds of BEAR analysis were broadly in accord with the state's findings and buttressed public awareness in legislative discussion of Assembly Bill 32 (CARB: 2007). In the current phase of climate action dialogue, more specific policy design features and impacts are being subjected to intensive public and private scrutiny. Rules for allocating emissions permits, as well as those governing the revenues obtained from permit auction programs, will soon be determined, and the potential magnitude of these transactions has naturally aroused public interest. Moreover, allocation rules may have complex incentive effects that bear on both policy effectiveness and equity issues. For these reasons, the basis of evidence for constructive policy dialogue on this issue needs to be strengthened.

The goal of this work is to elucidate the potential benefits of different allocation strategies, with particular attention to the sustained growth and prosperity of Californians. We find that AB32 generally, and Cap and Trade marketed emission permits in particular, can contribute positively to both our quality of life and our livelihoods. Our detailed results reveal that the choice of specific implementation strategies matters a lot, however, and we strongly recommend and careful and consultative approach to choosing exactly which

[1] Indeed, BEAR results are quoted in the Executive Order implementing the Act.

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allocation strategies are implemented, as well as what ex poste performance criteria might be applied to them as this policy evolves over the coming decades. The environmental impacts of Cap and Trade are intuitive and relatively well understood by both the policy and public communities. The economic implications of implementation strategies are, as is apparent from our results, more complex and require careful analysis and interpretation.

The present research in intended to strengthen the basis of evidence in this area, particularly to contribute independent research to the policy dialog how to sustain and propagate the benefits of a more carbon-efficient future. The focus of this study is on emission permits allocation choices and in particular the efficiency and equity tradeoffs these entail as well are their macroeconomic implications.

There are complex dynamics, in both efficiency and justice terms. In 2010, Next10 underwrote five research teams looking at allocation choices and summarized this research as *The Mutli-Billion Dollar Question.* We made progress on the some of the larger questions, in particular supporting CARB's proposal to do significant auctioning of emission permit. We explored the question of the relative merits of using allowance value to lower tax rates or provide a dividend check to California citizens. The dividend option performed surprisingly well: the small increased incentive to work from reduced tax rates was not as stimulating to economic growth. The dividend, also more equitable, shifts spending to lower income levels, which has a more favorable pattern of spending on in-state goods and services.

The question of how to optimally spend auction revenue is a thorny one for a quantitative analyst to confront. The potential changes to spending levels and combinations of potentially dozens or hundreds of potential spending options quickly becomes impossible to manage. That said there is surely a role for analysis to aid decision making. Building on prior work by Farbes and Kammen (2010) and a survey of experts in the field, we have tested the macro effects of spending on a set of eighteen options for recycling revenues from auctions for GHG emission permits.

Five salient insights emerge from the BEAR economic analysis:

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Table 1: Main Findings

1. ***California has a wide array of options for recycling revenues from auctions for GHG emission permits, each of which can contribute to long-term economic growth and job creation.***
2. ***Most of the allocation options considered return more to economic growth than their cost, and in the process increase state revenue, but net benefits differ significantly.***
3. ***The most pro-growth options invest auction revenue in expanded household-level EE and renewable technology diffusion, and all these generate additional new state revenue.***
4. ***Allocations that merely offset existing fiscal commitments, while still fostering some growth, do not yield benefits comparable to committing new revenues to efficiency measures.***
5. ***New employment benefits generally increase with GDP, but vary depending on the demand patterns affected by the policy. Again household efficiency promotion is the most employment-intensive allocation strategy.***

These general conclusions are supported by a myriad of more detailed structural information, the elucidation of which can be essential to design and implement effective policies. Rigorous policy research tools like the BEAR model can shed important light on the detailed economic incidence of energy and climate policies. By revealing detailed interactions between direct and indirect effects across a broad spectrum of stakeholders, simulation methods of this kind can support more effective policy responses to climate change.

2 Scenario Development

Regulatory fees are often levied with specific expenditure goals in mind, such as user fees for public access and infrastructure (parks, bridges, toll roads, etc.). In the case of atmospheric emission permits, there is little precedence for either the collection of or expenditure purpose of emission fees. Because California is at the forefront of such policy development, a myriad of options are under consideration, including free allocation of rights, rebates of fees to households,

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and a wide array of targeted expenditures. Indeed, the policy dialog on this issue now includes so many stakeholders that in all likelihood there will be a variety of approaches adopted in concert.

This study does not advocate any particular approach to auction revenue collection or allocation, but instead strives to better inform public and private audiences regarding the economic impacts of realistically available options for auction revenue recycling. To do this, we developed a representative set of generic allocation scenarios and assessed them with a statewide economic forecasting model. Of course we assumed that some permits would indeed be auctioned as part of a Cap and Trade market mechanism, but we have attempted to develop a series of generic allocation options that reflect those under active consideration and discussion. The final list of eighteen alternatives was produced in a two-step process, using a combination of expert opinion and stakeholder consultation. In the first phase, we convened and consulted a group of climate policy experts and developed an extensive list of allocation options, these were then reviewed for consistency and diversity, and then submitted to a wider audience of stakeholders in an online survey, the results of which are summarized in an annex below. Finally, we returned these results to the expert panel, synthesized and refined the scenarios into the eighteen alternatives listed in the following table.

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Table 2: Auction Revenue Allocation Scenarios

1	Revenue rebates to taxpayers.
2	Energy efficiency improvements on state owned buildings, which could offset General Fund expenditures.
3	Offset General Fund expenditures through new financing approaches.
4	Energy efficiency actions to upgrade residential lighting.
5	Energy efficiency actions including appliance efficiency upgrades and replacements. Example: Rebates
6	Energy efficiency actions to upgrade residential building efficiency.
7	Financing program for renewable energy installations at residential properties.
8	Industrial EE: retrofits and compliance investments for utilities and large industrial activities (energy, cement, etc.)
9	Commercial EE and distributed generation programs.
10	Small business EE - financial and other supporting services to overcome technology adoption and compliance hurdles
11	Programs that provide financing for, or directly fund conservation and EE upgrades in low-income and middle-income dwellings.
12	Financing programs for commercial, industrial and manufacturing facilities to reduce greenhouse gas emissions by investment in EE, energy storage, and clean and renewable energy projects.
13	Accelerated deployment of advanced technology vehicles.
14	Low-carbon goods movement, freight vehicle technologies, public transportation, and infrastructure development.
15	High Speed Rail project - specific to the bookend projects
16	Improve water supply through more efficient storage, conveyance, and management infrastructure.
17	Financial assistance for local governments to implement their Sustainable Community Strategies developed to meet the goals of SB 375.
18	Green Bank or a recurrent Low Carbon and Energy Efficiency lending program.

The scenarios are discussed in greater detail in a separate section after the economic assessment results, while here we only discuss the selection process and how to appropriately interpret the scenario analysis. The eighteen options above comprise a very diverse set of approaches, each with their own objectives, advocates, and possible critics. To make sensible comparisons of them in terms of real economic impacts, we had to develop a scenario approach that reflected the state's diverse objectives and interests. It is more likely that, over the life of Cap and Trade policies, several and indeed many allocation options like those above will be exercised, sometimes in concert. For this reason, we assessed

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allocation to each alternative as a hypothetical commitment of an equal fraction of expected permit revenue. Again, we do not do this because we advocate any specific financial commitment for any specific option, but only to facilitate (apples to apples) comparison of equal allocation.

Authoritative estimates of total permit revenues run into billions of dollars annually. To accommodate the possibility of multiple allocations running simultaneously, we used a hypothetical allocation of $100 million dollars per year over the period 2013-2020. This amount is well within the level of permit revenue expected by most independent observers, and would allow several of these options to run at the same time. To make scenarios comparable, however, we assume that only one option is exercised in each case. Potential policy interactions are not captured in our results in the sense that a single policy – investing $100 million – is run through the model separately for each result.

In all scenarios, we assume that residual permit revenues (beyond the $100 million/yr allocated in the scenario) are recycled into the state's general fund. In reality, all permit revenues might be allocated to new initiatives or used to offset more specific existing expenditure commitments, but again we need simplification to elucidate the impacts of each of the eighteen alternatives considered.

Finally, it should also be emphasized (as discussed more extensively in Section 4) that these are macroeconomic expenditure scenarios, not project evaluations. In particular, the proposals that we model are not fully fleshed out in terms of their structural details. Much more technical work, as well stakeholder and community work would need to be done to go beyond these illustrative results. For example, when we evaluate the so-called Green Bank scenario (18), this does not comprise a detailed lending program such as has actually been implemented by several states, but only an aggregate fiscal commitment to reduce the aggregate private cost of energy efficient technology adoption over the time period being considered. Thus we are evaluating macroeconomic impacts of macroeconomic policies, not detailed climate policy initiatives. Having said this, the structural detail of the BEAR model (50 sectors, 8 household income groups, etc.) is such that these alternatives exhibit quite diverse macroeconomic performance.

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3 Economic Results

For the scenarios discussed above, the BEAR macroeconomic assessment effects are presented in Table 3 below. Estimates are presented for each allocation scenario (rows), showing impacts from three economic perspectives. All these are statewide aggregates, measured as annual difference from the Baseline scenario trend in the year 2020. The Baseline is a hypothetical trend where AB32 is adopted, but emission permits that do not expire are distributed at no charge and traded privately thereafter.[4] The first column estimates overall state economic growth, as measured by real Gross State Product (GSP), in units of inflation adjusted (2012) millions of dollars. The next column measures the net effect on California's total (state and local) fiscal revenues, in the same units as real GSP (2012 constant millions). Finally, the last column measures the policy-induced change state employment, measured in units of Full Time Equivalent (FTE) jobs across all sectors of the economy.[5]

Two general findings are immediately apparent across these results. Firstly, any of these policies would stimulate economic growth and employment in California, but the degree of stimulus varies considerably. This makes policy selection a higher priority. Secondly, all scenarios make some contribution to fiscal revenues because they contribute to GDP growth generally, without undermining the average tax rate in a way that might reduce net revenues. Again, we see important diversity in this respect, and some policies yield higher revenues for state and local government coffers, despite the fact that it is making the same ($100M) to each alternative. Given the high premium on no-load (i.e. no new tax) revenues in California at the moment, selectivity among these alternatives would again seem to be important.

Table 3: Macroeconomic Impacts
(changes from baseline values in 2020)

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[4] Technically, the baseline is calibrated to macroeconomic trends published by the California Department of Finance, which are assumed to incorporate existing state policies only. The actual calibration process is described in detailed BEAR model documentation, available from the author on request.

[5] It should be noted that we do not report emissions impacts of individual scenarios because the state economy is operating under a cap on total GHG output, and it is not possible to decompose the net contribution of an individual scenario under this constraint.

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	Scenario	Real GSP (2010 $Millions)	State Revenue ($M)	Employment (FTE)
1	**Rebates to taxpayers - Equal per capita**	**486**	**46**	**4,814**
2	Offset Public Building EE Programs	83	6	467
3	Offset Funds with New Finance	285	26	1,710
4	Residential Lighting Energy Efficiency	997	58	6,902
5	Residential Appliance Energy Efficiency	896	92	7,328
6	Residential Building Energy Efficiency	875	56	8,751
7	Residential Renewable Energy Promotion	664	57	6,765
8	Industrial Energy Efficiency	157	12	1,364
9	Commercial EE and Dist. Generation	143	10	1,100
10	Small Business Energy Efficiency	468	10	6,480
11	Low-Mid Income Residential EE	838	102	6,620
12	Lower Industrial GHG Emissions	142	11	1,162
13	Advanced Vehicle Deployment	739	41	4,157
14	Low Carbon Goods Movement	154	12	1,156
15	High Speed Rail Bookends	442	31	2,651
16	Water Supply Energy Efficiency	181	11	1,962
17	SB 375 VMT Reductions	305	18	2,496
18	Loan Support for EE and Renewables	813	74	5,628

Source: Author estimates from the BEAR model.
Notes: GDP and state budget impacts in constant (2012) millions of dollars. Employment in FTE headcount.

Two general findings are immediately apparent across these results. Firstly, any of these policies would stimulate economic growth and employment in California, but the degree of stimulus varies considerably. This, and the large sums of money derived from access to a public resource, makes thoughtful and evidence based policy selection a higher priority. Secondly, all scenarios make some contribution to fiscal revenues because they contribute to GDP growth generally, without undermining the average tax rate in a way that might reduce net revenues. Again, we see important diversity in this respect, and some policies yield much higher revenues for state coffers, despite the fact that the same amount ($100M) is allocated in each scenario. Given the high premium on

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no-load (i.e. no new tax) revenues in California at the moment, selectivity among these alternatives would again seem to be important.

Turning now to more diverse aspects of the results, a few observations are worthy of emphasis:

1. Scenarios that offset expenditure have lower growth performance. This is of course because the original fiscal stimulus effect is absent in these cases, i.e. auction revenues are “standing in” for other expenditures rather than creating a new source of demand in the economy. Still, these measures contribute to growth because they represent expenditure shifting from those who pay for the emission permits to the government (in the case of new spending) or the average taxpayer (in the case of fiscal offset). In either case, the growth effect is positive because both the government and the average tax payer spend money in ways that have higher multiplier effects than the average buyer of emission permites. For this reason, the new income from their demand greater than that of the polluter’s costs, and the state economy grows because of this fiscal transfer.[6]

2. Subsidizing efficiency and renewables for households (4-7, 11, 13, and 18) generates more GDP and employment growth, directly and indirectly, than doing so in the public or private enterprise sectors. There are two basic reasons for this, one on the supply side and one demand side. Firstly, household EE and renewable measures are more distributed and therefore more job-intensive. Generally, the scale of household EE investments, whether for transportation, appliances, or building, is smaller and further down supply chains, increasing the labor content of both the goods and services involved. Secondly, when households save money on energy, their spending on alternative goods and services is about 16 times more job intensive than the energy fuel supply chain and also more so than enterprise or average public sector spending. Thus the highest “multiplier” growth effects of auction revenue allocation come from measures targeted at households.

[6] It is also worth emphasizing that we get this macroeconomic net benefit without any consideration of the oft-cited innovation dividends of trading schemes that put a price on emissions.

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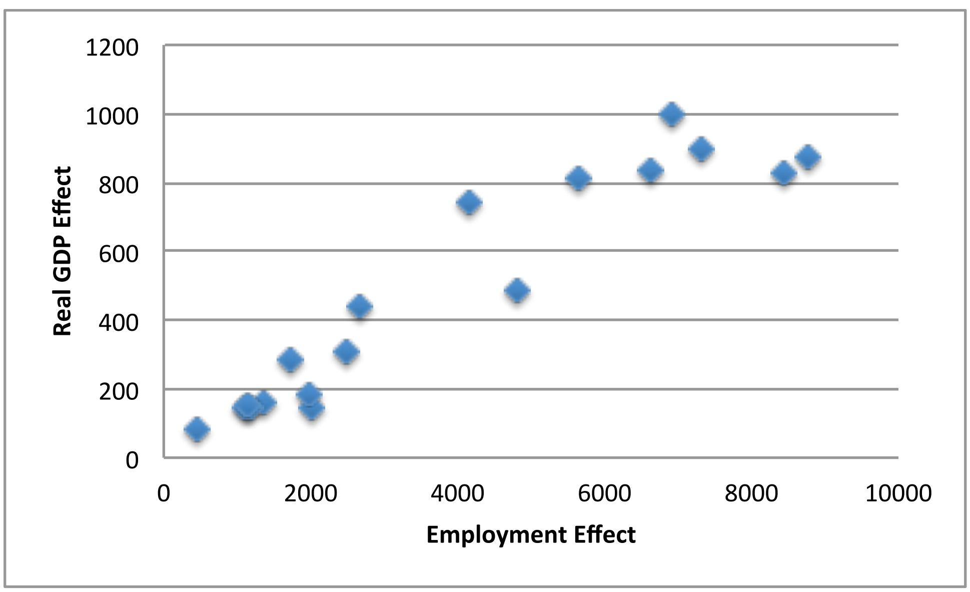
3. Because they promote economic growth, all programs would raise more new long term revenue for the state, suggesting that indirect rebates of revenue value could be part of a growth oriented policy package as long as the rebates are deferred until permit revenue have first been invested in EE or mitigation programs. This finding suggests a way to address the regulatory ("Sinclair") requirements for direct permit revenue allocation, without giving up the prospect of returning the value of environmental royalties to the public. In other words, some of the incremental (and indirect) future revenue resulting from these programs could be rebated to taxpayers or others without contradicting the regulatory intent of the auction revenue mechanism.

4. Employment benefits generally increase with GDP, but vary depending on the demand patterns affected by the policy. As the following figure suggests, some policies (household targeted) policies are also more job-intensive, making the job gains even more significant.

Figure 1: Aggregate Employment Impacts
(Changes from 2020 Baseline in $Millions and FTE jobs)



Source: Author estimates from the BEAR model.

On the subject of employment, it is worth emphasizing that the BEAR model is calibrated to historical estimates of the unemployment rate (very high at the moment) and official statistics on California populaiton growth. In response to

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policy and other economic events, we model employment creation with a standard labor supply function.[8]

3.1 Individual Scenario Results

The diversity of scenarios chosen means that macroeconomic effects will differ for complex reasons. For the package of GHG mitigation policies that comprise AB32, macroeconomic effects will from structural linkages that transmit economic impacts across the state economy. A consistent feature of such complex processes is the importance of cumulative indirect and linkage effects, which in many cases far outweigh direct effects. Although the majority of the GHG responses and direct (adoption and monitoring) costs are easily identified, economic benefits of these policies extend over long supply and expenditure chains. The cumulative effect of all these can only be assessed with methods like the one used here.

The same reasoning applies to any fiscal outlay, that, regardless of its initial intention or direct beneficiary, will lead to extensive demand spillovers and other structural adjustments. These are too complex to be discussed exhaustively for eighteen different scenarios, but we summarize some of the main features of each here to clarify interpretation and, where it seems appropriate, to identify opportuntities extensions of this research. For more detailed descriptions and background on individual scenarios, the reader is refered to Section 4 below.

1 Rebates to taxpayers - Equal per capita

This policy has been studied extensively by this and other authors, and its properties are relatively well understood. As others have found, it has strong multiplier effects (and signficiantly more so than the next scenario), but the legality of direct rebates for an environmental fee is an open question at the time of this writing.

2 Offset Public Building EE Programs

[8] See BEAR technical documentation (Roland-Holst: 2008) for details.

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As an offset policy, this one has limited initial impact because it merely substitutes for preexisting expenditure. Our assumption for this scenario is that $100M is allocated from permit revenue to existing spending, meaning the same amount can be returned proportionately (not per capita) to taxpayers. It's contribution to growth is weak but positive, as a wealth transfer from permit buyers to the average taxpayer, it leads to net positive multiplier effects on GSP and employment.

3 Offset Funds with New Finance

Because this program uses the new revenue to defer current financial obligations, it has a greater growth dividend than fully offsetting current expenditure. However, if the current time interval (2013-2020) were extended to cover all debt service, this benefit might be more limited. In any case, borrowing against the future, as long as the funds are committed to productive current investment, can stimulate growth.

4 Residential Lighting Energy Efficiency

Lighting is well known to be a potent source of EE, with savings of up to 75% in simple incandescent-LED replacement studies. Because of this technology's effectiveness, and the prominent role of households in the overall economy, this scenario provides the strongest growth stimulus of any $100M commitment. It is worth noting the risk of saturation with such a policy, however. It is likely that successive commitments to this approach would have lower marginal benefits, and that this policy should be considered a first, but not exclusive choice for revenue allocation.

5 Residential Appliance Energy Efficiency

Lighting also offers large employment stimulus, but not as much as residential appliances and infrastructure. The reason for this has to do with their respective upstream supply chains. When households replace a light bulb, it is usually purchased directly from a retailer, most often made out of state, and installed by the homeowner. For larger residential appliances and building infrastructure, many local trades are usually involved in fabrication, delivery, and installation, and maintenance.

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6 Residential Building Energy Efficiency

In terms of economic stimulus, this category benefits from labor intensity in both residential demand (from energy savings) and the building services and materials supply chain. It does not generate as much employment as appliances, mainly because building installations have a longer life than most consumer durables.

7 Residential Renewable Energy Promotion

As part of California's general commitment to distributed generation, a variety of renewable energy incentive schemes have targeted households. It would appear from the current results that, by leveraging the multiplier effects of energy saving and more labor intensive installation and management, this category of renewable energy confers significant growth dividends on the rest of the economy.

8 Industrial Energy Efficiency

Efficiency saves money, so enterprise efficiency and renewable deployment can stimulate state economic growth through fuel savings just like households. The main differences, however, are generally higher cost and less labor-intensive technology adoption. The present analysis, however, may be overestimating net effects because the financing horizon for enterprise technologies (20-30 years) reaches beyond that of this study.

9 Commercial EE and Distributed Generation

Again the results mirror residential gains, but are more muted because of how these technologies are installed and the energy savings are spent.

10 Small Business Energy Efficiency

Small businesses, simply put, are more like households, and in this way both their adoption costs and expenditure from energy savings will be intermediate between residential and commercial energy users. After households, they should be a high priority for growth oriented permit revenue allocation.

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11 **Low-Mid Income Residential EE**

While the results for this group look like those for households generally, there is apparently a strong case for public intervention in this category. Indeed, it has been argued by many (and repeated in Section 4 below) that there are reasons to fear that these benefits will not be realized without determined public commitments to overcome financial hurdles.

12 **Lower Industrial GHG Emissions**

Because energy consumption is linked to 83% of GHG emissions, the two are nearly synonymous. Thus the results for this scenario strongly resemble those of Scenario 8, as does their interpretation.

13 **Advanced Vehicle Deployment**

As discussed in more detail below, CARB has stepped up their commitment to more efficient vehicle deployment in the state, and this would lead to quite substantial reductions in gasoline use by comparison to baseline trends. These savings would be channeled back into the economy, primarily via household spending of its fuel savings on more job-intensive, in-state goods and services. As was mentioned earlier, California household expenditure is, dollar for dollar, 16 times more employment intensive than the carbon fuel supply chain. One dollar saved at the gas pump will thus be recycled into strong net job creation.

14 **Low Carbon Goods Movement**

The complex array of CARB-sponsored measures to reduce transport energy intensity would, if enacted in their entirety, stimulate economic growth and employment through technology adoption, energy savings, and reductions in trade and transport margins.

15 **High Speed Rail Bookends**

The high speed rail project will neither be fully financed by auction revenues, nor does its existence depend on Cap and Trade. If, however, auction revenues contribute the costs of this project (particularly its early, endpoint or "book end' components), and are

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thereby credited with growth dividends of that investment, our estimates suggest this can be justified on economic grounds. Not only are the growth benefits comparable to other uses; the EE/emission benefits of public transit meet the standards of public benefit associated with AB32's mitigation objective.

16 Water Supply Energy Efficiency

As many authors have already observed, systems of water generation, retention, conveyance, and use in California are prime candidate for EE improvements. Our estimates suggest this kind of investment would have a higher macroeconomic return than some industrial measures, and that is could stimulate significant employment creation.

17 SB 375 VMT Reductions

Because vehicles produce about half the state's GHG emissions, mostly in very localized transportation service, the VMT reductions envisioned in SB 375 could make a big contribution to reducing state gasoline demand. As observed by Rosenfeld and others, energy conservation is the cheapest form of EE, and driving less generates very direct energy savings that translate (16 to 1) into greater in-state income and employment.

18 Loan Support for EE and Renewables

A long-term loan program for efficiency and renewable development is one of the highest performing expenditure scenarios. The reason for this is the so-called "wonder" of compound interest.[9] Take $100M of public funds, commit these to capitalize a long term, revolving lending facility for productive (energy) investments, and have a much higher yield program than one that hands over public funds for on-time technology adoption. Essentially a green credit union mechanism, this kind of program leverages future energy savings for higher long-term rates of technology adoption and efficiency growth.

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[9] You don't have to be a genius to understand this, but it helps. "Compound interest is the eighth wonder of the world. He who understands it, earns it ... he who doesn't ... pays it." – Albert Einstein.

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While the scenario comparisons above are quite instructive, a few important caveats must be born in mind. Firstly, we are measuring growth responses to relatively small fiscal stimulus ($100M), and it is not clear for the individual strategies considered that these impacts would be scalable to billions of dollars. Generally, the interpretations above hold for reasonable increases in these spending commitments, as would their ordering. It is unlikely, however, that it would be appropriate or even desirable to concentrate permit revenue allocation in only one or two of these categories, as diminishing returns could set in as technology diffusion progresses.

What we recommend over the long term is periodic reassessment with comparable empirical methods, identifying new opportunities and re-ordering older ones. In any case, the present analysis clearly reveals that, among the many options open for allocation, there are diverse outcomes and care should be taken to commit these new public funds effectively.

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4 Overview of Policies Assessed

As explained in the previous sections, the purpose of this study is to obtain indicative estimates of the macroeconomic impacts of a representative variety of alternative scenarios for allocating revenue from California emissions permits. In this section, we explain the eighteen general scenarios and provide background information relevant to the issues they represent. It should be emphasized at the outset that these scenarios to not represent or evaluate specific program details for a given allocation approach, but only its general macroeconomic characteristics. Our goal is to show the overall growth impacts of revenue allocation among generic groups of stakeholders and sectors of the economy, not to recommend specific programs or techincal standards for awarding permit revenue or other resource income. This is the job of the AB32 implementing agencies, and it should be supported with more intensive empirical analysis than can be accomplished in a broad spectrum comparison such as the present one.

4.1 Rebate Auction Revenues to taxpayers - Equal per capita dividend

4.1.1 Scenario

In this, the first of our fiscal experiments, we assume that $100M of emission permit revenue is returned directly to households, on an equal per capita basis. This is done equally across the state population, without regard to income or tax status. Results for this experiment are discussed in the preceding section.[10]

4.1.2 Background

The general principle behind what is referred to as "Cap & Dividend" is that revenues from carbon emission permit auctions should be divided and distributed as dividends to every man, woman, and child in California. The rationale for this policy is the idea that the air is a common public resource and that companies should pay a fee to the public in order to pollute. However, under permit auctions, companies may pass on the cost of these permits to the consumer, which would

[10] For comparison, the reader can find more detailed results in Roland-Holst et al (2010).

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result in increases in the price of energy. These price increases would primarily affect those in the lower income brackets, who pay a higher than average percentage of their income for energy. Dividends from revenues would serve to offset the losses caused by increased prices.

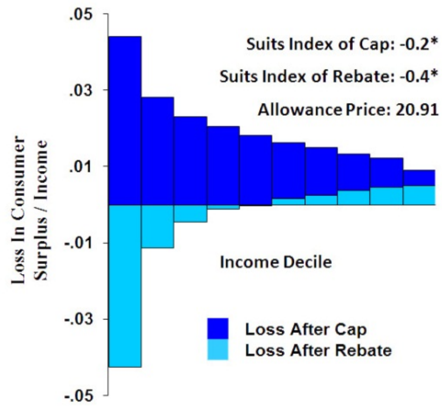
When it comes to returning fiscal revenue to the general population, the amount and the impact of these dividends depend on several factors, including the amount of total revenue generated from auctions, the final auction price of carbon permits, the degree to which polluting companies are able to pass on their costs to consumers (or are allowed to), and the percentage of revenue devoted to dividends. Many of these have yet to be determined, but state government estimates the revenue from the first year of the program to be 1 billion dollars, set to increase in subsequent years (Brown, 2012, p. 98).

Several studies have been conducted regarding the household impact of cap and dividend. Boyce and Riddle, of the University of Massachusetts, Amherst, have studied the effects of a nationwide cap and dividend policy, and analyzed many possible scenarios. Assuming a $200/ton price for carbon, Boyce and Riddle estimated in 2007 that if 100% of the estimated $200 billion are passed on as dividends ($678 per person), then 60% of the population will receive a net benefit from the dividend policy (Boyce & Riddle, 2007). Boyce and Riddle revisited the topic in 2009 in light of the proposed American Clean Energy and Security Act (ACES) bill assuming a $25/ton price for carbon and with 80% of revenue going toward dividends, and still concluded that the bottom six deciles experience net positive benefits in every state from a cap and dividend policy (with dividends coming out to be $386 per household) (Boyce & Riddle, 2009). They revisited the topic one more time in 2010, in particular studying the economic effects of the proposed Carbon Limits and Energy for America's Renewal Act (CLEAR) bill. In this study, they estimated that in 2020, assuming a permit price of $25/ton (resulting in $135 billion in total revenues) and assuming that 75% of revenues will go toward dividends, the dividend amount is $297 per person. For California residents, this means that the bottom eight deciles would receive a positive net benefit from this dividend (Boyce & Riddle, 2010). In these three studies conducted by Boyle & Riddle, the conclusions aligned in that even, across-the-board dividends would be extremely beneficial to the lowest income brackets, and would help offset the costs of the resulting fuel prices. However, it is important to note that neither ACES nor CLEAR passed, and that Boyce & Riddle's studies all assume a nationwide cap-and-dividend policy, whereas our interest lies mostly within the state of California.

A study done in 2009 by Burtraw, Sweeney, and Walls concluded similar results. Estimating $274 per capita to be available as disbursable revenue, this study examined two cap and dividend scenarios; one in which the dividends were taxable, one in which they were not. In the taxable dividend case, the bottom five deciles experienced a net gain in consumer surplus over income, and in the nontaxable dividend case, the bottom four deciles experienced net gains in consumer surplus over income (Burtraw, Sweeney, & Walls, 2009). It's also important to note that this study was also done with a federal-level cap and dividend policy, not one limited to the state of California.

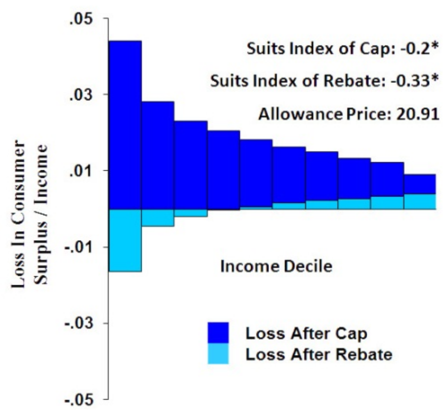
In any event, this cap and dividend policy may not be legally feasible. The California Supreme Court ruled, in a case known as *Sinclair Paint*, that if fees met certain requirements, they could be treated as regulatory fees as opposed to taxes. This is legally important, as taxes require a two-thirds supermajority in the California state legislature in order to be accepted as law. In context of cap and trade in California, this means that the allocation programs must actually further the goal of reducing greenhouse gases, in order to pass the "*Sinclair Paint* test" and avoid being challenged in court as an illegal tax. That said, it is difficult to justify the act of giving away revenues as dividends as a direct method of reducing greenhouse gases in California, and therefore this policy option may have a high risk of failing to pass the *Sinclair Paint* test (Horowitz, Enion, Hecht, & Carlson, 2012). Indeed, according to a testimony by Dallas Burtraw, cap and dividend may not be legally feasible "unless payments could be justified on the basis of compensation to individuals for harm they suffer due to degradation of the environment. (Burtraw, 2012)"

Figure 2: Taxed and Untaxed Distributions



	Average Welfare Loss for Households in the Bottom Two Deciles Nationally		Average Welfare Loss for All Households	
	$	%	$	%
Southeast	-$234	-2.58%	$92	0.16%
CA	-$341	-3.54%	$106	0.15%
TX	-$361	-3.82%	$118	0.20%
FL	-$164	-1.79%	$96	0.18%
Ohio Valley	-$126	-1.47%	$252	0.42%
Mid-Atlantic	-$151	-1.67%	$222	0.34%
Northeast	-$87	-1.08%	$285	0.41%
Northwest	-$253	-2.83%	$91	0.15%
NY	-$193	-2.30%	$165	0.25%
Plains	-$180	-2.12%	$273	0.43%
Mountains	-$253	-2.85%	$143	0.25%
National	-$236	-2.69%	$132	0.23%

Note: Negative numbers in the table reflect gains in welfare. The bottom two deciles nationally consist of households earning less than $19,208 in annual income after taxes and transfers.
*A negative Suits Index number represents regressive taxation and progressive rebates.



	Average Welfare Loss for Households in the Bottom Two Deciles Nationally		Average Welfare Loss for All Households	
	$	%	$	%
Southeast	-$83	-0.90%	$99	0.17%
CA	-$176	-1.76%	$84	0.12%
TX	-$173	-1.78%	$124	0.21%
FL	-$28	-0.35%	$101	0.19%
Ohio Valley	$12	0.04%	$242	0.40%
Mid-Atlantic	-$12	-0.17%	$205	0.31%
Northeast	$38	0.33%	$259	0.37%
Northwest	-$108	-1.16%	$80	0.13%
NY	-$52	-0.67%	$151	0.23%
Plains	-$46	-0.59%	$257	0.41%
Mountains	-$91	-1.00%	$141	0.24%
National	-$91	-1.04%	$132	0.23%

Note: Negative numbers in the table reflect gains in welfare. The bottom two deciles nationally consist of households earning less than $19,208 in annual income after taxes and transfers.
*A negative Suits Index number represents regressive taxation and progressive rebates.

Source: Burtraw, Sweeney, and Walls (2009) (Taxed)

In summary, cap and dividend could effectively offset the impact of increases in prices due to the additional cost of carbon emission permits for a significant amount of the population. However, the fact that these dividends do not directly support greenhouse gas reduction may render this revenue allocation option legally unviable.

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4.2 Offset Funds for Energy Efficiency in Public Buildings

4.2.1 Scenario

The state has made commitments to defray the cost of EE investments in public buildings, especially in the state university system. In this scenario, we assume that $100M/yr of these subsidies are financed by emission permit revenue instead of tax collections. This means that the the permit revenues offset existing expenditure, with the latter funds returned to taxpayers in an equiproportionate manner.

4.2.2 Background

One of the major EE programs established within the state college system today stems from a UC/CSU/IOU partnership. More specifically, the Investor Owned Utility (IOU) firms involved are Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E) and Southern California Gas (SCG). Up until now, the partnership has reduced the consumption of 230 million kWhs of electricity, 17.7 million therms of natural gas, and 168,000 metric tons of GHGs[11]. The partnership has implemented three types of projects, Heating, Ventilation, Air Conditioning (HVAC), Monitoring Based Commissioning (MBCx), and Central Plant and Energy Distribution. Monitoring Based Commissioning very particular EE strategy utilized in state schools and will be given more focus here. (This last sentence does not make sense)

MBCx projects are considered a unique approach as it involves combining two common practices in EE, monitoring and retro-commissioning, and creating a "synergy" between the two. The inherent advantage to this is that the energy savings in both maintenance of and upgrades to existing equipment can be empirically confirmed through advanced monitoring. Monitoring can potentially detect any energy savings that fall short of expectations from any upgrades or maintenance done initially, detect degradation over time of upgrades and maintenance done, and can detect any new problems that may occur. MBCx saves more energy than normal retro-commissioning (RCx) in three more ways, as shown in figure 1.

[11] University of California Annual Report on Sustainability Practices, 2011

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Table 1 includes a general summary of how much is expected to be spent over these projects (by the UC/CSU/IOU partnership ?) as well as the expectations in the reduction of energy use. Table 2 contains a more detailed list of what MBCx projects will be implemented and the type of buildings involved. Table 3 is a summary of the results of the MBCx projects in 2005 implemented in Table 2, it is separated by MBCx and combined projects to analyze the effects of the MBCx projects itself.

Overall, the general consensus is that MBCx projects are a cost-effective way to implement energy savings strategies. Though some of these projects do not nearly perform well as others, it is manageable given the high level of success from the other projects. In the future, there will be some cuts in non-lab projects while lab projects will be sustained as they have performed very well. This can be interpreted by number of years needed to payback the initial investment for these projects.

But there is also concern expressed whether or not the MBCx projects can sustain itself over time. There needs to be continued training for operators of these monitoring systems so that these monitoring systems can be maintained at state colleges. The cost of training for operators does seem feasible though, considering the pay back rates for these MBCx projects are relatively fast. The accumulation of savings over time can easily cover the costs of training new operators.

During the partnership, universities in the UC system have avoided "millions of dollars in direct and indirect costs associated with cap-and-trade regulation" as state colleges have received $10.9 million from incentive payments and saved $7.2 million in energy costs[1]. AB32 will further establish cap-and-trade regulation within the UC school system, requiring holding allowances for each ton of greenhouse gases emitted. Future prices on allowances are estimated to be about $10-$40, requiring the UC system to spend $7 million - $28 million on allowances[1]. Instead of buying allowances, the UC system is planning to invest more in the technology to reduce emission of greenhouse gases. This partnership also receives cap-and-trade revenues as one of the programs part of the General Fund. What might limit the ability of the UC school system to reduce greenhouse gases is the older buildings that already exist at the UC schools.

[1] University of California Annual Report on Sustainability Practices, 2011

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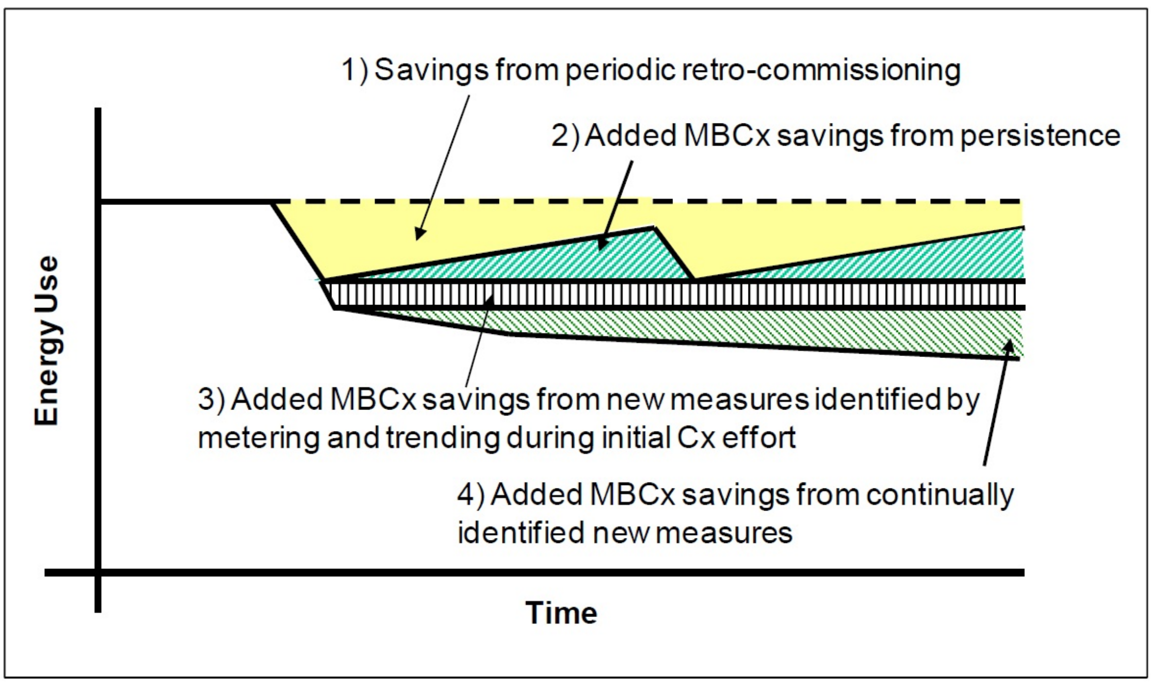
The buildings already built at the UC schools are held to a much lower LEED standard than any future construction projects. There can only be so much potential in reducing energy usage in older buildings due to structural inefficiencies. This is more apparent as UC Merced (is this a relatively new school? When was it founded?) is the only UC school planning on producing zero net greenhouse gas emissions by 2020.

This partnership with Investor-Owned Utilities is one of the primary focuses California state colleges have pursued to follow the Sustainable Practices Policy, but there are other active approaches California state colleges have made as well. To pass the requirement of having LEED-certified buildings, UC schools have made design renovations to buildings, including solar photo-voltaics, as seen in Table 3. Yet, solar photo-voltaics are expensive and generally have low kw capacities, thereby only contribute to part of the energy solution, but not the main focus just yet.

Figure 3: MBCx savings versus retro-commissioning savings



Mills, Evan. "Monitoring Based Commissioning: Benchmarking Analysis of 24 UC/CSU/IOU Projects." *Lawrence Berkeley National Laboratory*, 2009

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Table 4: UC/CSU/IOU Energy Efficiency Partnership MBCx Portfolio Summary

	All Projects Including Plant and District Systems	Building Projects Only
Participating Campuses	22 (8 of 10 UC, 14 of 23 CSU)	
Projects	45	36 (19 with Lab Space)
Gross Floor Area	(1)	6.0 Million
Funding Provided by Program	$5.2 Million	$4.0 Million
Total Anticipated Cost	$5.7 Million	$4.3 Million
Range of Project Funding	$20,444 - $270,000	$25,500 – $270,000
Range of Funding	N/A	$0.30 - $1.75 per gross sq. ft.
Range of Total Anticipated Cost	$20,444 - $380,667	$25,500 - $380,667
Range of Cost per Unit Area	N/A	$0.30 - $1.75 per gross sq. ft.
Electricity Use Reduction Target (3)	9,100,000 kWh per year	(2)
Demand Reduction Target (3, 4)	1.02 Megawatts	(2)
Corresponding Electricity Use Reduction During Summer On-Peak Period (3)	620,000 kWh per year	
Nat. Gas Use Reduction Target (3)	530,000 therms per year	(2)
Nominal Value of Saved Energy (3, 5) @ $1.00/therm $0.10/non-peak kWh $0.25/peak kWh	$1.84 million per year	
Nominal Simple Payback Period for Funding	2.2 years	(2)
Nominal Simple Payback Period for Anticipated Costs	2.3 years	(2)

(1) Accounting of floor area served by central plant or district systems pending confirmation of all project documentation.
(2) Some campuses proposed combined building and plant system projects, and did not separately target savings.
(3) Portfolio targets are the sum of the proposed project targets. These are substantially higher than the overall program goals.
(4) The program definition of peak demand savings is based on peak kWh, averaged over the peak period.
(5) Nominal values based on simplified price structure with approximate average of rates across service types for normalization of project results.

Anderson, Michael, Ann McCormick, Andrew Meiman, and Karl Brown. "Quantifying Monitoring-Based Commissioning in Campus Buildings: Utility Partnership Program Results, Lessons Learned, and Future Potential." *The National Conference on Building Commissioning*, 2007.

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Table 5: UC/CSU/IOU Monitoring-Based Commissioning Project Detail

Project ID[1]	Building Function	Funded Unit Cost ($/gsf)	Meter Cost, If Available (% of total)	Addition or Upgrade to Building Metering	Major Cx Action(s)
2005.01	Laboratory & Classrooms	$ 0.60	15%	Calibration CHW & HW Btu	VAV Fume Hoods: Control Adjustments Sequence of Operation
2005.02	Laboratory & Classrooms	$ 1.13	46%	Calibration Subsystems: VFD Power Air Pressure/Flow	VAV Fume Hoods: Control Adjustment Valve Repair
2005.03	Library	$ 0.39	20%	Power Natural Gas EIS Front End	CHW System: Flow Balance Setpoint Adjustment
2005.04	Laboratory	$ 1.53	63%	Subsystems: Chilled Water Steam Heating/Dom HW	VFD Control Adjustments Chiller Control Setpoints Piping Reconfiguration Vent. Rate Adjustment
2005.05	Offices	$ 1.22	58%	EMCS Interface	Combination Project Controls Upgrade
2005.06	Non-Laboratory, Modern, Small	$ 0.67	41%	Subsystems: Chiller Power CHW Btu Boiler Btu	Controls: Sequence of Operations Setpoint Adjustment Calibration
2005.07	Laboratory & Classrooms	$ 1.06	N/A	Subsystem: Fan Power	Combination Project Air Handlers: VFD Installation Reconfiguration
2005.08	Laboratory & Classrooms	$ 0.79	49%	EMCS Interface	Sensor Calibration Valve Repair Economizer Repair Control Adjustment
2005.09	Classrooms & Offices	$ 1.26	55%	Power	Economizer Repair Control Adjustment
2005.10	Laboratory & Classrooms	$ 1.15	47%	Subsystem: Fan Power	Sensor Calibration Valve Repair
2005.11	Laboratory & Classrooms	$ 1.44	N/A	Subsystem: Fan Power	Exhaust Fan Control Upgrade
2005.12	Offices, Classrooms, Dormitories	$ 0.51	N/A	Power Natural Gas	Sensor Calibration Damper & Valve Repair

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Anderson, Michael, Ann McCormick, Andrew Meiman, and Karl Brown. "Quantifying Monitoring-Based Commissioning in Campus Buildings: Utility Partnership Program Results, Lessons Learned, and Future Potential." *The National Conference on Building Commissioning*, 2007.

Table 6: UC/CSU/IOU Partnership MBCx Project Result Summary

	Observed Reduction in Energy Use						
ID	Total Electricity (kWh/yr)	Peak Electricity (kWh/yr)[1]	Demand (kW)	Natural Gas (th/yr)	Representative Annual Cost Savings[2]	Total Project Funding	Nominal Simple Payback (yrs)
Results for Straightforward MBCx Projects							
2005.22	526,183	0	0	59,699	$112,317	$75,000	0.7
2005.19	663,184	42,135	69	83,456	$156,095	$131,550	0.8
2005.01	238,571	13,743	23	36,584	$62,502	$67,500	1.1
2005.02	496,619	13,981	18	43,497	$95,256	$14,140	1.2
2005.10	1,348,620	151,969	250	11,787	$169,444	$244,950	1.4
2005.03	454,586	30,186	39	0	$49,987	$83,500	1.7
2005.04	720,038	64,689	84	76,987	$158,694	$270,000	1.7
2005.06	36,754	2,555	4	9,406	$13,465	$25,500	1.9
2005.08	302,579	15,441	30	15,836	$48,410	$110,000	2.3
2005.09	245,010	45,215	74	28,621	$59,904	$144,000	2.4
2005.13	714,430	32,121	42	0	$76,261	$184,900	2.4
2005.21	225,098	13,344	17	5,594	$30,105	$75,000	2.5
2005.18	462,472	0	0	5,462	$51,710	$135,550	2.6
2005.23	170,000	0	0	17,900	$34,900	$113,500	3.3
2005.15	343,412	55,522	73	11,221	$53,890	$192,163	3.6
2005.12	250,009	17,010	28	5,233	$32,785	$152,601	4.7
2005.16	76,670	9,921	13	661	$9,816	$49,300	5.0
2005.14	129,394	7,857	10	11,186	$25,304	$143,000	5.7
2005.17	4,354	436	1	3,587	$4,088	$27,700	6.8
2005.20	128,552	2,596	3	5,354	$18,599	$127,500	6.9
2005.11	164,893	11,449	19	0	$18,207	$128,300	7.0
Subtotal	**7,701,428**	**530,171**	**797**	**432,070**	**$1,281,739**	**$2,595,654**	**2.0**
	124% of Portfolio Target		121% of Portfolio Target	132% of Portfolio Target	135% of Portfolio Target	64% of Portfolio Funding	

Anderson, Michael, Ann McCormick, Andrew Meiman, and Karl Brown. "Quantifying Monitoring-Based Commissioning in Campus Buildings: Utility Partnership Program Results, Lessons Learned, and Future Potential." *The National Conference on Building Commissioning*, 2007.

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Table 7: Photo-voltaic (PV) Projects Installed or In Progress (systems > 50 kw)

Campus	Technology & capacity (kw)	Status	Start date
Berkeley	PV (100)	Installed	11/2003
Davis	PV (782)	Installed/ Under Construction	12/2011
Davis (West Village)	PV (4,000)	Installed/Under Construction	1/2012
Davis Health System	PV (145)	Under Construction	1/2012
Irvine	PV (895)	Installed	1/2009
Irvine	PV (136)	Installed	3/2011
Merced	PV (1000)	Installed	1/2010
San Diego	PV (1330)	Installed	7/2011
San Diego	PV (995)	Under Construction	4/2012
San Diego	PV (150)	Planned	4/2012
San Francisco	PV (250)	Installed	1/2008
San Francisco	PV (250)	Planned	7/2012
Santa Barbara	PV (550)	Design	6/2012
Santa Barbara	PV (225)	Installed	12/2008
Santa Cruz	PV (200)	Design	2/2012
Total PV (by 2012)	**11,008**		

University of California. Annual Report on Sustainability Practices 2011. Budget and Capital Resources University of California, Office of the President, 2012.

4.3 Offset Funds with Creative GHG Mitigation Finance

4.3.1 Scenario

AB32 calls for a range of private investments to reduce state GHG emissions. For this scenario, we aggregated these and assumed that $100M was made available as credit to reduce average mitigation investment costs for hypothetical emitting industry in each sector, with a 5-year payback, or 20% annually with 3% interest. Note that the subsidized initiatives extend across all AB32 activities, beyond EE and renewable measures.

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4.3.2 Background

Subject to legal interpretations of the Sinclair Standard, auction proceeds can offset budgetary expenditure in a wide variety of categories. (A transition sentence here would be helpful) As a three-year appraisal of RGGI notes, those states have used CO2 allowance proceeds creatively. “The states’ use of allowance proceeds not only provides economic benefits, but also has helped them meet a wide variety of social, fiscal, and environmental policy goals, such as addressing state and municipal budget challenges, assisting low-income customers, achieving advanced energy policy goals, and restoring wetlands, among other things.” For the present analysis, we do not wish to pick individual expenditure categories as “winners and losers” for offsetting auction revenue finance. Instead, we simply allocate the designated $100M/yr to the general fund. This will have the net effect of offsetting the state government’s average “basket” of expenditures, including those that mitigate GHG and otherwise.

4.4 Residential Lighting Energy Efficiency

4.4.1 Scenario

Residential lighting is a primary source of energy demand in the state generally, and within households in particular. More efficient lighting technologies also offer substantial opportunties for savings, with up to 75% energy use reduction from replacing incandescent bulbs with comparable LEDs. With this EE potential in mind, this scenario assumes the state dedicated $100M/yr to subsidising more efficient lightbulbs for households.

4.4.2 Background

According to the U.S. Department of Energy (DOE)[12], the annual electricity use for lighting represented 19 percent of the total U.S. electricity consumption in 2010. Residential lighting accounted for a quarter of that use, which is equivalent to roughly 5 percent of the total 2010 electricity consumption. DOE claims that “the residential sector’s large installed base of *low efficiency lighting* causes the

[12] U.S. Department of Energy. *2010 U.S. Lighting Market Characterization (2012).*

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sector to be the second largest lighting energy consumer."[13] Figure below shows the electricity consumption by bulb type for 4 different building categories.

Figure 4

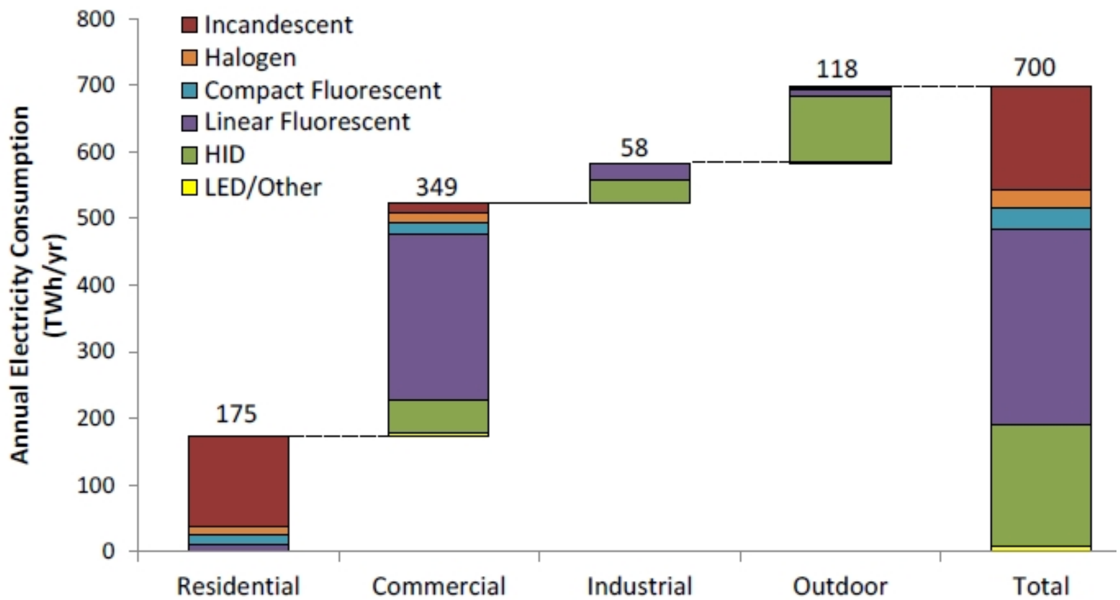

Figure ES-1 U.S. Lighting Electricity Consumption by Sector and Lamp Type in 2010

It shows that incandescent light bulb, which have lower efficacy (higher wattage—higher use of electricity) than other types of residential bulbs, represented the vast majority of the total residential electricity consumption. The proportion electricity used for compact fluorescent lamps (CFLs), known for their energy-efficiency, represented only a small portion. Yet there has been a significant change in the composition of residential light bulb inventory throughout the past decade: the percent of incandescent inventory as a share of the total residential lamp inventory decreased from 79% in 2001 to 52% in 2010 and, the share of CFLs increased from 2% in 2001 to 19% in 2010. DOE's report documents a general movement away from incandescent lamps to more efficient and energy-saving CFLs.

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[13] U.S. Department of Energy. *2010 U.S. Lighting Market Characterization (2012), 12.*

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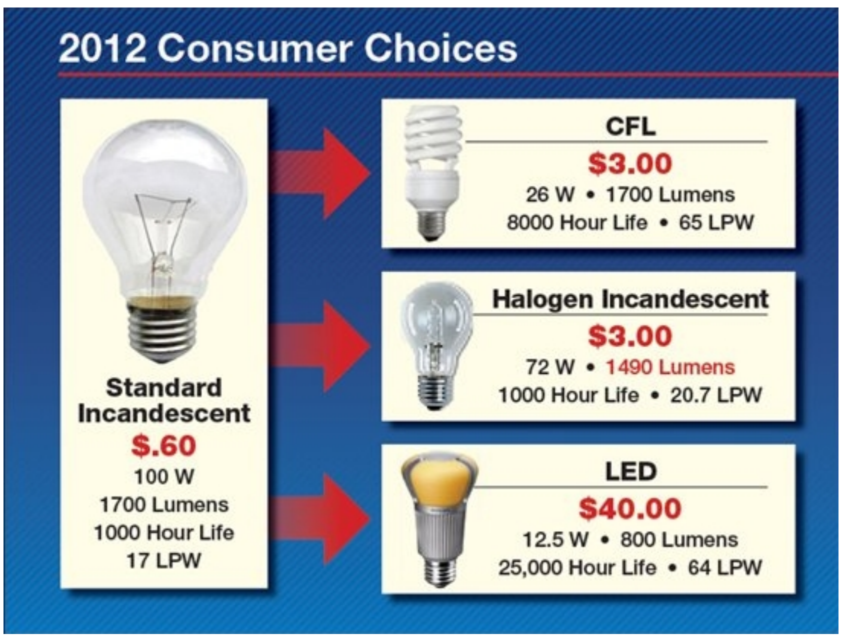
4.4.3 CFL Efficiency and GHG Reduction

CFL is three to four times energy efficient than a regular incandescent lamp. According to ENERGY STAR, a federal government program co-sponsored by the EPA and DOE, "If every home in America replaced just one incandescent light bulb with an ENERGY STAR qualified CFL, in one year it would save enough energy to light more than 3 million homes. That would prevent the release of greenhouse gas emissions equal to that of about 800,000 cars."[14] CFLs reduce GHG emissions indirectly through lowering the demand for energy use thus reducing GHG emissions by electric power plants[15]. CFL also reduces mercury emission. Its total mercury emission throughout its life time is about 70 percent less than those emitted by standard incandescent.

Figure 5



Above diagram[16] shows the differences in costs and energy efficiencies for different types of lamps. In comparison, CFL uses 75% less energy (thus 75% less energy bill) and has about 40% cheaper long-term light-bulb cost than a standard incandescent lamp.

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[14] ENERGY STAR®. "Frequently Asked Questions: Information on CFLs and Mercury." (2010), 1.
[15] U.S. Environmental Protection Agency. "Facts on Compact Fluorescent Lamps & Proper Disposal."
[16] The American Lighting Association

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4.4.4 CFL Use in Practice

Despite the obvious benefits and recent growth of its uses, CFL is still not as prevalent as the standard incandescent lamp. A 2008 study[17] on the Europe's experience with the policies to promote CFL gives many insights into current challenges and potential policy/program solutions. The study highlights several important reasons as current barriers to consumer choice. First is the lack of public education: many consumers are still unaware of CFL's energy saving and environmental benefits. Second, consumers usually don't have a clear understanding about CFL's long-term payoffs and are thus reluctant to pay the high initial light bulb price. Third, the murky lighting color and the low quality of earlier versions of CFLs gave consumers bad perceptions about CFL as being an insufficient substitute to the standard incandescent although these shortcomings are almost nonexistent in today's CFL. Perhaps the most important reason is the false health-related stigma attached to CFL such as its high mercury content and potential dangers related to the exposure. Many studies claim that such problems have been largely exaggerated and if cautions are taken the health costs are minimal (include some cites).

4.4.5 The E.U. Approach to Promote CFL

Several policies and programs were instituted at the E.U. level to increase the awareness of CFL's benefits and promote its uses. These include mandatory energy labels for lamps, creation of the Ecolabels to recognize quality products (similar to U.S.'s ENERGY STAR quality standard), and the draft of the European CFLs Quality Charter to ensure that CFLs meet the claimed quality and life-time standards.

Many programs focused on the promotion of CFLs through rebates, give-aways, and coupons. I will briefly discuss a few of them here:

- Denmark: In 2000, the country launched a campaign to promote the use of CFLs. The 2001 evaluation of the campaign found that the sales of CFLs jumped from 2% (of the total lamp sales) in 1999 to 4.5% during the 10 weeks of the campaign.

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[17] Paolo Bertoldi and Bogdan Atanasiu. "Characterization of Residential Lighting Consumption in the Enlarged European Union and Policies to Save Energy." (2008)

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- Ireland: The country ran a promotion campaign covering all residential customers from September to October 2000 on "the high initial cost of the light-bulb." The number of CFL customers increased from 266,000 in 1999 to 304,500 after the promotion.

- UK: The UK ran several programs to subsidize CFL lamps in residential homes. The Energy Efficiency Commitment (EEC), ran a 3-year program in 2002 that required "all gas and electricity suppliers with 15,000 or more domestic customers [to encourage or assist] customers to take energy-efficiency measures in their homes." This program resulted a total of 86.8 TWh in energy saving. During this period, "about 39.5 million high quality CFLs were supplied to the residential market." And it is estimated that about 25% of the 64 TWh energy saving came from the switch to CFLs.

- Czech Republic, Hungary, Latvia: These three E.U. member states participated in the Efficient Lighting Initiative (ELI), which is considered "one of the most successful programs" focused on transforming markets to accelerate the use of energy-efficient lighting technologies including wider distribution of CFLs.

4.4.6 Programs in the U.S.

To promote the use of energy-efficient residential lamps, states and cities throughout the U.S. also implemented rebate/discount programs to residential customers purchasing CFLs and/or LEDs. The state of California ran the Upstream Lighting Program (ULP) for three years from 2006 to 2008 to expand the energy-efficient light bulb market by providing discounts to manufacturers and distributors on eligible, quality energy-efficient lamps thereby directly reducing consumer price and increasing the quality standard. The three utilities working with this program "provided upstream rebates on over 90 million efficient light bulbs from 2006 to 2008."[18] The program evaluation done by the California Public Utilities Commission concluded that ULP provided about 50 million dollars in net savings in utility and significant pollution reductions. Natural Resources Defense Council's evaluation concludes that ULP provided over $1 billion in net savings (include cite).

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[18] Natural Resources Defense Council. "Reanalysis of the 2006-08 Upstream Lighting Program" (2011).

Detroit's Energy Wise Program offers $2 to $10 rebate per lamp (amount depends on the type of lamp) for Energy Star rated CFLs or LEDs and provides free CFLs to low income residential customers.

The state of Maine is currently running the Residential Lighting Program which works with small to big retailers to provide rebates on energy-efficient light bulbs and other electronic appliances to customers. This includes savings on CFLs. Other states and cities also run small to medium rebate/savings programs to promote CFLs and other energy-efficient bulbs in hopes to transform the market.

4.4.7 CFL and Cap and Trade Revenue

Currently there is no specific discussion to use Cap and Trade revenue for CFL programs except for a general recommendation to use a part of the revenue to improve residential *EE*, which is not a specific recommendation for improving improve *lighting* efficiency. The evaluations for the past CFL programs have documented positive results. And it seems that promoting CFL use alone can substantially achieve energy efficiencies at homes. Getting consumers to switch to CFL can reduce more than half of residential (175 Twh in 2010) energy consumption, save money, and reduce pollution. Since light-bulb turn-over time is very short, we could achieve a substantial energy and cost saving through an effective program.

4.5 Residential Appliance Energy Efficiency

4.5.1 Scenario

Residential households are the largest of the state's energy users, and very diverse in their EE level. California's Energy Action Plan set forth a vision for substantial household appliance EE technology. In this scenario, we dedicate $100M/yr to subsidize these technologies, according to adoption patterns set forth in CPUC (2012).

4.5.2 Background

"When do energy-efficient appliances generate energy savings" examines the appliance upgrade situation in Canada for "refrigerators, freezers, dishwashers

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and clothes dryers". The results indicate that "the age at which appliance are replaced tend to be lowest for dishwashers and highest for freezes". Some policy implications from the research can shed some light on the U.S. case. (Is this a seminal study? You may want to include some language that clarifies why you are calling this study out by name in such a prominent way). The research shows that "many appliances remain in household use far beyond the oldest assumed age at which an appliance might retire in these studies" and thus affect the analysis of energy saving from advanced equipment. Thus the responsibility of accelerating the process largely lies on the government. The paper then points out some socioeconomic factors that influence the age at which an appliance is replaced, such as income. It says that "while the age at replacement is not sensitive to income for most appliances, household with higher incomes tend to replace clothes washers at a lower-income households" (I do not this this quote was copied accurately). This implies that "there may be scope for policies that provide financial incentives for the replacement of their current clothes washers with more energy-efficient models". (There is too much quoting in this section. It would be read easier if the author summarized some of the findings instead of pulling so many direct quotes)

Generally, to offset the costs of replacing old appliances, government initiatives such as the "'EnerGuide' labeling system and 'Energy Star' designations" are proved to greatly reduce the "time costs of searching for a more energy-efficient appliance" (where did this quote come from?) with those easy-to-identify marks. It is another example that government intervention comes into force. Besides the socioeconomic aspect, the necessity of upgrading clothes washers is also proved in terms of energy consumption: "clothes washers constituted one of the top two household appliances (second only to refrigerators) in terms of total energy use in Canada" and "standards on clothes washers have been found to be one of the biggest contributors to energy savings in the U.S.". A successful case in Canada is called "Yukon program" which "offers rebates that range from $75 to $125 on the purchase of Energy Star clothes washer, with the higher rebate amount applying to households located in communities where diesel fuel is used to generate electricity." The latter policy highlights that "while the energy savings due to the purchase of a new appliance are the same regardless of location, the environmental impact will depend on the way in which the electricity used by the appliance is generated". The sensitivity of clothes washer upgrades to income along with its great energy saving contribution makes it a right direction to go for the U.S. government.

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The article above mentions the phenomenon that outdated appliances are still in use which is especially prevalent for refrigerators. This topic leads us to the article “Optimal household refrigerator replacement policy for life cycle energy, GHG and cost”. The article points out that the phenomenon above can sometimes consume “more than twice as much electricity per year compared with modern, efficient models”. Therefore, “replacing old refrigerators before their designed lifetime could be a useful policy to conserve electric energy and GHG. However, the upgrade decisions “induce additional economic and environmental burdens associated with disposal of old models and production of new models”. Thus the purpose of the paper is to find out the “optimal lifetimes of mid-sized refrigerator models in the U.S.” and reaches the conclusion that “optimal lifetimes range 2-7 years for the energy objective, and 2-11 years for the global warming potential (GWP) potential and an 18-year of lifetime minimizes the economic cost incurred during the time horizon”. Also, refrigerators with over 1000kWh/year electricity consumption should be replaced currently. These data provides a reference for policy makers to decide on the refrigerator upgrade standard.

In “Appliance and Equipment Efficiency Standards”, standards are demonstrated to be “cost effective to consumers and result in minimal adverse impacts on manufacturer”. However, the article suggests other complementary policies such as “product labeling voluntary promotion programs (e.g. Energy Star), financial incentives, technology procurement initiatives, and voluntary agreements with manufacturers”. Moreover, “ there is a need for increase evaluation after standards effect in order to determine the actual impacts of standards on product efficiency, prices and manufacturers”, so that the standards can help better achieve energy saving goals.

A less noticeable problem identified by Lucas W. Davis that hinders the upgrade of energy-efficient appliance is that “landlords may buy cheap inefficient appliances when their tenants pay the utility bill”. Research indicates “nationwide an annual increase in energy consumption of approximately 9 trillion BTUs, equivalent to 165,000 tons of carbon emissions annually.” Therefore, the landlord-tenant problem and other principal-agent problems are important when designing carbon policy. “Cap-and- trade programs work by increasing the price of energy, causing agents to internalize the social damages from their choices. Principal-agent problems reduce the effectiveness of this approach because the person experiencing these increased prices may not be the same person who is making decisions about energy use.”

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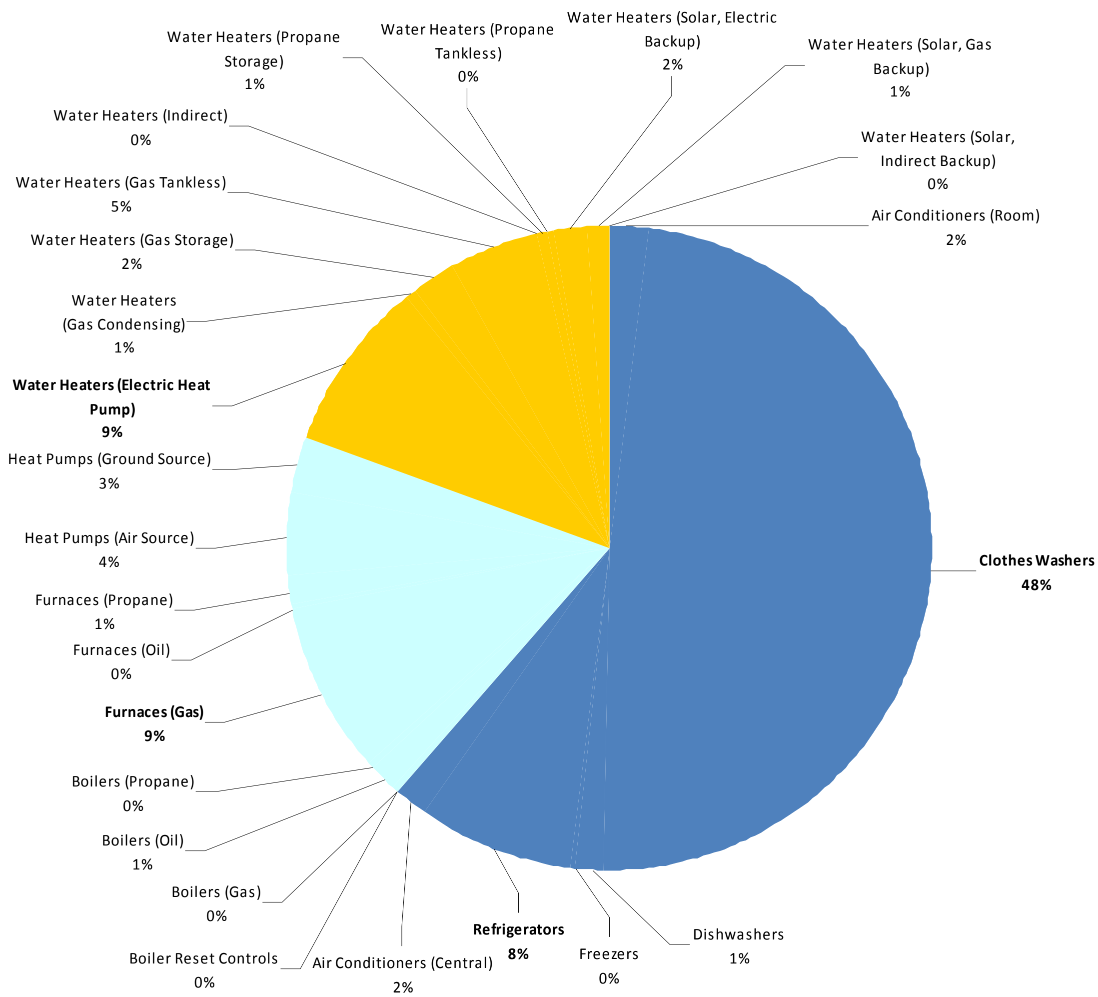
A recent Act added to the Health and Safety Code which approves the Cap-and-Trade revenue to be used for “clean and efficient energy” is a good step taken towards upgrading energy-efficient appliance to reduce GHG by California Government.

Figure 6: Projected Total Cost of Energy Savings

Annual As a Share, Disaggregated by Product, Nationally



Source: MacRae et al: 2009.

Our appliance efficiency scenario is based on an extension of California’s 2005 Energy Efficient Appliance Rebate Progra and ENERGY STAR® Recovery

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Funding (http://www.energy.ca.gov/recovery/energystar.html) (see CEC: 2009 for details. We assume that this program is extended from 2013-2020 with $100M/yr in auction revenues. Energy savings from the program are assumed to follow the average cost recovery estimates (28%/yr) obtained from a comprehensive national appliance efficiency program (MacRae et al: 2010). For the national program, the following figure lays out the pattern of savings by appliance type. Given its diversity, it is expected that California savings would be qualitatively similar.

4.6 Residential Building Energy Efficiency

4.6.1 Scenario

Residential households are the largest of the state's energy users, and very diverse in their EE level. California's Energy Action Plan set forth a vision for substantial household building EE technology. In this scenario, we dedicate $100M/yr to subsidize these technologies, according to adoption patterns set forth in CPUC (2012).

4.6.2 Background

Consumers of energy in residential areas have particular traits about them that effect the planning of residential energy and distributed generation programs. Residential consumers at once have a low price elasticity and a high income elasticity for energy. In the short-term there have been cases when energy demand had not increased much in times of declining energy prices, but in the long-term price elasticity increases as consumers begin forming expectations of higher prices and react accordingly. With higher incomes, consumers are often found buying more expensive, higher efficiency products to reduce energy use. This implies that the Department of Energy's policies on placing higher energy standards on appliances being sold will help reduce energy. The government has predicted a reduction in GHG emissions of 8% - 9% by 2020 due to higher energy standards. Figure @@ shows the energy savings across different types of appliances. (I believe this is referring to the figure at the end of the last section. It should be moved to go with the text).

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Table 8: Comparative High-Level Performance Statistics State Public Benefit-Funded Energy Efficiency Program (This table doesn't seem to go with this section)

State	Year	Budget $mm/Yr	% Elec. Rev's	Savings New MWH/Year	% Electric Sales	$/kWh New 1st Year Savings
CA	2003	240.0	1.5%	933,365	0.8%	0.257
CT	2002	87.1	3.1%	246,000	0.8%	0.354
MA	2002	128.0	3.0%	241,000	0.7%	0.531
NJ	2002	99.6	1.5%	171,692	0.2%	0.580
NY	2002	129.0	1.3%	290,000	0.3%	0.445
RI	2002	16.4	2.7%	50,568	0.8%	0.324
WI	2003	49.7	1.4%	214,800	0.4%	0.231
VT	2003	13.7	3.3%	48,763	0.8%	0.281
VT Res	2003	5.7		18,439	0.9%	0.311

Source: KEMA: 2005.

Residential EE policies are riddled with market failures, which may give us insight on what new policies we can take toward residential energy to reduce GHG emission. First, a market failure exists where energy prices do not take into account the negative externality of air emissions. Because of high long-run price elasticity for energy, this might be something to think about including. Placing a cost on air emissions will help bring GHG emission to a more socially optimal place. There is also a market failure in that there is no real time pricing (RTP) of energy use in residential areas where energy prices become higher at peak times and lower at off-peak times. This project would be infeasible at this time as RTP has very high costs, though studies have shown that RTP does improve social welfare at high peak costing.

There are also asymmetric information problems that lead to market failures in the residential energy. First, there is an asymmetric information problem in which consumers do not have enough information about the true reduction in costs when switching from less efficient goods to more efficient goods. Consumers cannot monitor, or measure completely what a switch to more efficient goods would save them, perhaps allocation of resources in providing

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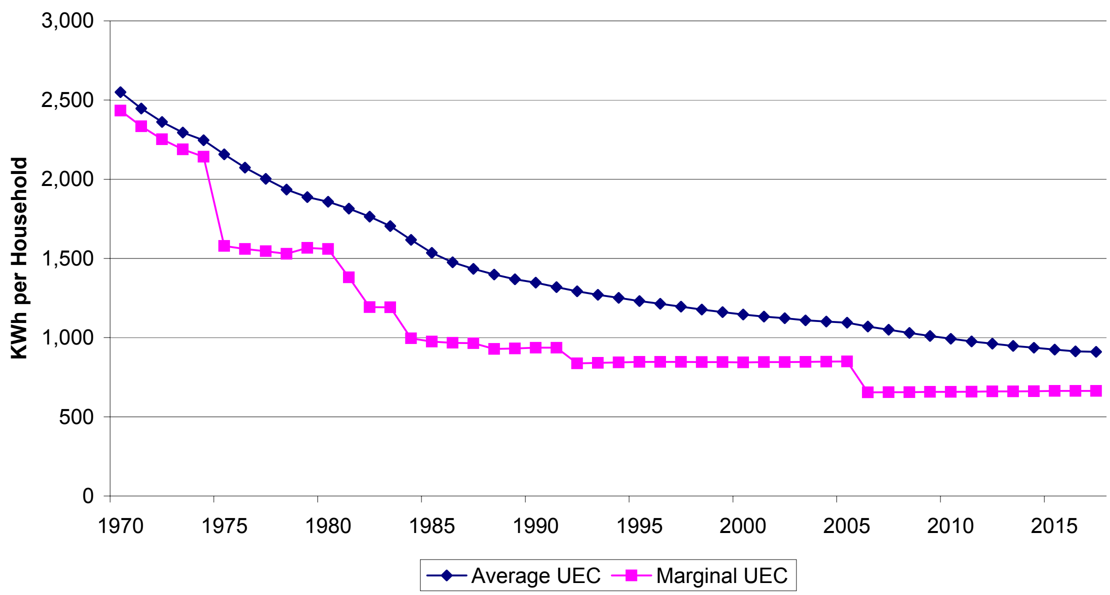
more information to the consumer about this may be useful. There is also an asymmetric information problem in which sellers may claim a certain level of EE of their goods, yet consumers cannot directly observe this. A policy with more government intervention may be needed here, where they can approve certain sellers and their claims about their products' EE. A similar policy has been proposed in which the government provides consumers resources including approved contractors who install air-conditioners (ACs) in homes in California. Some contractors install ACs incorrectly and hinder the AC's potential energy savings. We also see principal agent problems within apartment complexes in California. Landlords often claim that a building is at a higher level of EE than it really is. The landlord usually under-invests compared to what is socially optimal. Some studies have shown misreporting EE by landlords affects 25% of refrigerator use, 66% of water heating energy, 48% of space heating and 2% of lighting.

Lastly, there is a market failure in the availability of financing energy-efficient investments, including solar panels. Distributed generation in a residential setting refers mostly to the use of solar panels, and there has and will be large strides in this industry. But the solar panel industry is constrained by the lack financing as stated before, as well as it has not reached economies of scale and supply cannot meet demands in the economy. The solar panel though or photovoltaic array does reduce GHG emissions as a home would no longer need to use power directly from the central power plant, and is off the grid. But solar PVs as of right now can only absorb so much energy, or PV penetration rates are low. Luckily, there has been major improvements in PV technology by pairing the PV system with combined heat and power (CHP) system, making a PV + CHP hybrid. What this can accomplish in the near future is higher PV penetration, and the ability of the CHP to completely back up the PV. Back up is important as solar flux does not always align with electricity demands, so CHP can come in here and provide needed energy. There are also plans to upgrade CHP to also work with cooling rather than just heating homes which will enable the PV + CHP hybrid to be workable in a larger gergraphic area.

For our residential infrastructure scenario, we assume the state allocates \$100M/yr to incentive programs for new home and retrofit installation of more efficient home insulation, heating, and central air conditioning systems, also eligible could be roofing systems and surface retrofits (including white roof paint). According to scenarios developed in a CEC assessment (Rufio and North: 2007), we assume this efficiency gains in the long term that reduce residential electricity and natural gas 25% below baseline trends by 2020. The following figure shows this schematically.

Figure 7: Central Air Conditioning Average And Marginal Residential Unit Energy Costs (UECs) Weighted Average For All Households With Technology



Source: Rufio and North: 3007, CEC.

4.7 Residential Renewable Energy Promotion

4.7.1 Scenario

Residential households are the largest of the state's energy users, and very diverse in their EE level. California's Energy Action Plan set forth a vision for substantial household renewable adoption. In this scenario, we dedicate \$100M/yr to subsidize these technologies, according to adoption patterns set forth in CPUC (2012).

4.7.2 Background

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Residential Energy usage accounts for a large part of total energy consumption in the U.S. In “Towards Sustainable-energy Buildings”, the author points out that “Energy consumption in the residential and tertiary sectors is especially high in developed countries. (Chwieduk, 2003) It’s “responsible for about 40% of the total final energy demand” (Chwieduk, 2003) (I would paraphrase here instead of using a direct quote). To achieve the ultimate goal of sustainable-energy building, the author suggests a three step methodology: energy-efficient buildings, environmentally-friendly buildings, sustainable buildings. Energy-efficient options include traditional methods like improvement on building envelope, and more importantly introduction of “environmentally-friendly energy-generation installations” and “bioclimatic building design and orientation” (Chwieduk, 2003). The further environmentally-friendly applications emphasize renewable energy which can be summarized as “solar thermal in a form of active and passive systems, daylighting, natural cooling, photovoltaics and biomass” (Chwieduk, 2003). Finally, the sustainable building goal will be achieved when “all energy performance, environmental and indoor climate standards are me” (Chwieduk, 2003), in other words, when a self-energy-sufficient environment is built.

As Chwieduk displays the significance and long-term development schemes for residential renewable energy, Eckhart, in his “Financing Solar Energy in the U.S”, focused on the applications of solar energy in the U.S. His argument lies on that “The degree to which solar energy is financeable represents a key measure of its commercialization” (Eckhart, 1999). The paper was a bit outdated, but some facts still draw attention (If this paper is outdated, is there a more recently study you can pull from?). According to Eckhart, the installation rate of solar photovolaics (PV) is lagging that of Europe, Japan, and many developing countries, because U.S. “solar energy equipment suppliers are finding it difficult to break-even financially” (Eckhart, 1999). Currently, the key financial issues in the U.S. are “cost of money, the ease of obtaining low-cost funds, and institutional complexities” (Eckhart, 1999). Moreover, evidence suggests that “financing can have more immediate impact on the markets for solar energy than technology research or manufacturing cost reductions” (Eckhart, 1999) and end-user financing requires more capital investment than distribution channels. There are already a handful of existing financing programs by government, private sectors, solar industries and nonprofit foundation grants, however, further investment is still necessary. (You don’t need all of those cites to the same paper)

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Similarly, there are some issues concerning further financing of solar energy which should be taken into consideration while implementing installation actions. 1) Ownership – "Today's applications include utility-owned PV systems on customers' property and customer-owned PV systems generating energy into the grid. The lack of clarity on ownership issues tends to make lenders take a wait-and-see attitude" 2) Utility interconnection – for user-owned PV systems, the lack of "standard for interconnection of grid-tied PV/ Inverter system" hinders the development pace of grid-connected market and needs improvements. 3) Regulatory policy – affects the feasibility of financing solar energy. 4) Solar energy equipment and application standards – "the uniform, standardized quality of solar energy systems is still not what it needs to be to attract a mass market supported by financing". 5) Economic Incentives 6) Lender Guidelines – "economic and appraisal guidelines must be modified to accommodate solar system". 7) Insurance – "Lenders require adequate insurance coverage because borrower's insurance policy protects the value of the collateral over the years ahead". 8) Information Dissemination – "Lenders and investors need easy access to reliable information upon which to make decisions". In the long-run, policy makers should first get more involved in supporting financing mechanisms and gradually withdraw over time and let the market operates on its own.[19]

As Eckhart addresses the general issues faced by promoting solar energy in residential sector, "Municipal Financing for Energy Efficiency and Solar Power" gives practical examples of how it's financed at municipal level. The paper points out that the biggest barrier of increasing use of renewable energy is high first cost. By using "life-cycle cost analysis", policies should stick with "a positive value for life-cycle cost" which balances the "up-front costs of adoption" and "the energy savings over time" (Fuller, 2009). The paper listed an interesting example of municipal financing for renewable energy – "Berkeley FIRST" which "catalyze the transition to a more sustainable use of energy and also deliver benefits beyond emissions reductions, including a new source of job growth, reduced strain on the electric power system, and more comfortable and well-maintained buildings" (Fuller, 2009). Berkeley FIRST works by offering funds "through the issuance of a special tax bond that is repaid semi-annually over 20 years through special taxes collected on only the property tax bills of participating property owners" (Fuller, 2009). It is seen to be the major program to cut GHG emissions in Berkeley through energy-efficiency improvements and initial signs show large

[19] Eckhart 1999

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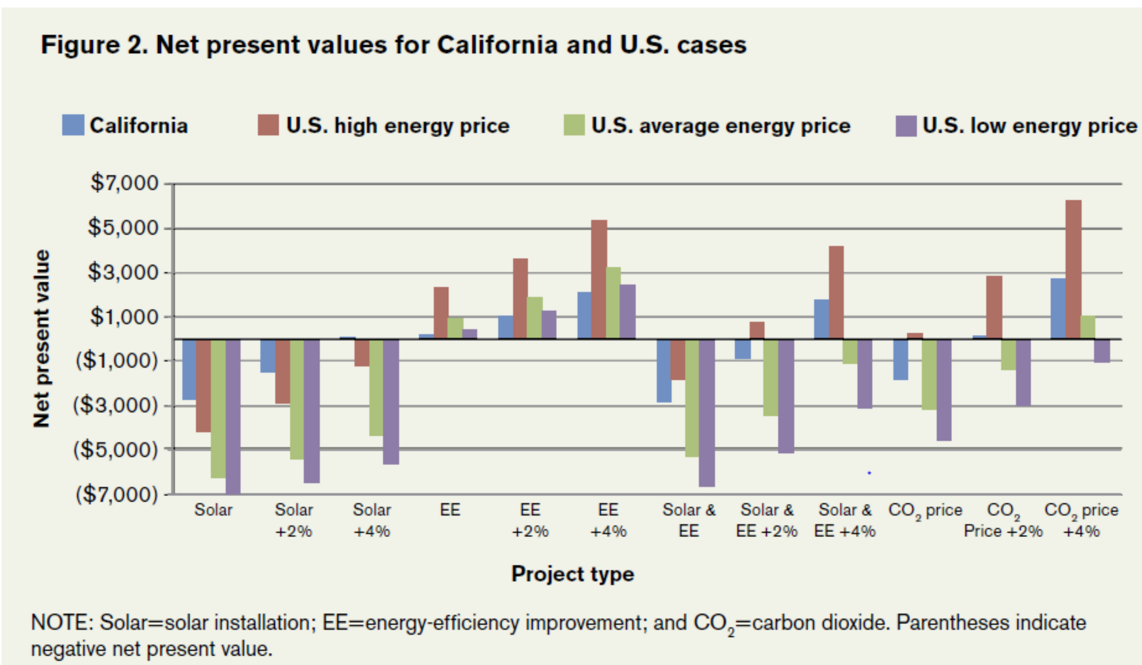
demand for the program. To estimate the influence of the systems like Berkeley FIRST, the research team set up a model comparing "net present value of annual cash flows over 25 years using an 'average' California home and three U.S. cases with high, low, and average energy prices" (Fuller, 2009). (Seen Figure.2 attached) They demonstrate the economic effectiveness of the system. Moreover, by comparing with alternative financing measures, "clean energy municipal financing is superior because it gives the participant the tax advantage of deducting the interest payments" (Fuller, 2009). The team reached a conclusion: Given that the Cap-and-Trade might push up the electricity prices towards the high energy assumption, along with the decreasing solar energy costs, can largely promotes the "economic benefits of solar installations" (Fuller, 2009).

Figure 8



Fuller, Merrian C., Stephen Compagni Portis, and Daniel M. Kammen. "Toward a Low- Carbon Economy: Municipal Financing for Energy Efficiency and Solar Power." *Environment Vol.5 No. 1*, 2009: 24-32.

For our residential renewable program, we synthesize state estimates for Oregon, Nebraska, California, Kansas, and New Mexico to derive a cost recovery rate of 1.45 as the ratio of household energy savings to program (tax rebate) fiscal cost (see Grover: 2007, 2010, and Barbosa et al:2010).

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4.8 Industrial Energy Efficiency

4.8.1 Scenario

Because of its relative energy intensity, industry is a primary consideration in California's Energy Action Plan. In this scenario, we dedicate $100M/yr to subsidize these industrial EE technologies, according to adoption patterns set forth in CPUC (2012).

4.8.2 Background

The EAAC recommended a part of C&T auction revenue to be invested in EE (This (EE) should be attached to the first reference of Energy Efficiency if the term EE is going to be used on second reference and thereafter) programs because of their proven dual-benefit in cost-effective environmental benefits and job creation. EAAC believes that a part of EE effort need to involve continued EE improvements in the energy sector whose existing programs can be further expanded and funded through C&T revenue[20]. EAAC also suggested using C&T revenue under alternate mechanisms such as Investment Tax Credit or Zero to Low Rate Loans that can encourage firm investments in green technology and equipment purchases. The Scoping Plan also suggested using a part of C&T revenue as subsidies to industries that face high upfront investments as a result of the C&T Program.[21]

No organization has suggested a specific plan for allocation, but the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) have jointly advocated that all auction revenues generated from the electricity sector be used for investments benefiting that sector.[22] They argue that since consumers will inevitably see higher electricity costs as a result of GHG reduction plans, part of the revenue generated should be used as consumer "bill relief." They also suggested a portion of the revenue to be returned to the electricity retail providers who can reinvest it in EE and renewable energy thus reducing cost transfers to consumers.

[20] EAAC. "Allocating Emission Allowances Under the Cap and Trade Program." (p51-52)
[21] The Scoping Plan (p90)
[22] "Joint CPUC and CEC Staff Paper on Options for Allocation of GHG Allowances in the Electricity Sector." (p35)

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4.8.3 Current CA Programs for Industrial Energy Efficiency

CPUC has drafted the California Long-term Energy Efficiency Strategic Plan (published in 2008, updated in 2011) that guides the state's long-term EE strategy for commercial, residential, industrial, and other sectors. Specifically for the industrial sector, which accounts for 20% of CO2 produced in CA, the Plan has proposed to increase EE through combination of regulation, resource assistance, and audits.

In 2009, CPUC approved $3.1 billion dollars of ratepayer-supported funding for various EE programs (for 2010-2012 cycle) for the four IOUs (PG&E, Edison, SDG&E, SoCalGas) to be administered independently by each company. 13% of the budget was assigned to the industrial EE programs that will help the four IOUs' industrial customers become more energy efficient. The whole EE agenda is projected to create about 15,000 to 18,000 new jobs and help avoid 3 million tons of GHG emissions[23].

Many industrial EE projects are administered by third-party implementers rather than the IOUs themselves. The PG&E industrial EE projects are incentive-based and the program generally works in the following way: first, the PG&E program implementer sends out auditors to identify cost-effective ways to improve an eligible facility's EE; second, auditors submit the project proposal for technology installation; third, upon the project's completion, the facility is eligible for incentive payments based on the amount of energy saved.

P&E is currently running the Cement Production and Distribution Energy Efficiency Program, which helps cement production plants/distribution facilities/concrete manufacturing facilities improve EE in gas and electrical use. The cement industry is one of the sectors susceptible to "leakage" —that is, moving production outside of CA due to intense environmental standards and result in either further increase or no change in GHG[24]— because of its energy-intensity and thus may need significant assistance from the C&T revenue to keep them at home.

For the oil industry, PG&E has two programs at hand:

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[23] CPUC "Fact Sheet: Energy Efficiency Program Summary." (p1)
[24] The Scoping Plan (p50)

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1. Refinery Energy Efficiency Program: PG&E oil refinery customers are eligible to get technological consultation (engineering, designing, and planning) for installing technologies such as pumping systems or waste heat recovery systems and receive financial incentives based on energy savings.

2. Energy-Efficiency Services Program for Oil and Gas Producers: PG&E oil producers, but not refineries, are eligible for technological consultation for installing EE technologies and receive financial incentives based on energy savings.

4.9 Commercial Energy Efficiency and Distributed Generation

4.9.1 Scenario

California's Energy Action Plan provides for substantial EE and renewable adoption by commercial enterprises. In this scenario, we dedicate $100M/yr to subsidize these technologies, according to adoption patterns set forth in CPUC (2012).

4.9.2 Background

California currently funds programs that fund the installation of renewable energy stations and distributed generation programs, however there is some debate as to if the amount of funding for these programs is sufficient. The California Solar Initiative (CSI) is a program that provides incentives for various solar installations in residential and commercial customers. This program is currently funded by $2.167 billion from 2006 until 2016. A small amount of the budget is allocated for commercial classified with multi-family incentives, the two programs total 108 million over the 10 year program to fund solar water heating programs. These programs are commercial used by laundromats, restaurants, food processors, agricultural processors and car washes. The main commercial funding comes from solar installation incentives which have comprised $586 million to date since the beginning of the program. In installations smaller than 50 kW capacities, the investor has the opportunity to decide to take the incentive in one payment in that year or over 60 monthly payments for 5 years while investors in installations of 50 kW and over must take the incentive over a 5 year period. This could be a good opportunity for small business owners who would

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like to offset some taxes from a larger than average income by installing solar panels.

The Self-Generation Incentive Program is another program in California that provides incentives for renewable energy installations including wind turbines, fuel cells, pressure reduction turbines, advanced energy storage, micro-turbines, and other eligible programs. This program also implements the distributed generation program, which allows small producers to sell their excess generated energy to major energy producers, whom are forced to buy the self-generated energy. The program budget for 2010 was $83 million from PG&E, SCE, So Cal Gas, and SDG&E. Incentives decrease as the projects increase in size or Megawatts to be produced, with a cap on incentives after 3 Megawatts. The funding for this program has no restrictions between residential and commercial, all funding is available to any parties who want to invest in small, self-generated energy. In 2010 680,000 MWh of self-generated power was generated in California by this project or enough to power 100,000 homes.

A concern raised by the California Large Energy Consumers Association (CLECA) was that the Joint party's proposal included residential rebates but would not provide funds to agricultural, commercial or industrial customers that were non-EITE (Non-Emissions-Intensive Trade-Exposed). CLECA advocates some rebate to the previous groups as well as residential consumers in order to offset at least some of the cost to their customers so that the cost of the Cap and Trade program does not hurt their business and lead to leaking. NRDC argues that with the rebates, residents and by extension businesses have no incentive to become more energy efficient, invest in renewable energy or reduce energy consumption if the price they realize for energy does not change because of a rebate or dividend. NRDC argues that the elasticity of demand for energy will increase as more options that are environmentally friendly become economically feasible with the help of some of these programs.

4.10 Small Business Energy Efficiency

4.10.1 Scenario

In this, the first of our fiscal experiments, we assume that $100M of emission permit revenue is returned directly to households, on an equal per capita basis.

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This is done equally across the state population, without regard to income or tax status. Results for this experiment are discussed in the preceding section.[25]

4.11 Low and Middle Income Residential Energy Efficiency

4.11.1 Scenario

In this scenario we follow the state's Energy Action Plan (CPUC: 2010), allocating $100M per year to subsidize more efficiency lighting, appliances, and building retrofits for low and middle income households.

4.11.2 Background

According California energy policy, low-income could be defined as any household that spends 17% of its household income on energy costs. At this point, a household qualifies for government programs towards funded energy upgrades to the household such as Low Income Energy Efficiency (LIEE) program, Weatherization Assistance Program (WAP), Low Income Home Energy Assistance Program (LIHEAP), and others. Cap-and-trade policy though continues to benefit the low-income homeowners as revenues from cap-and-trade go on to help finance these low-income programs. This is probably one of the most efficient allocations of cap-and-trade, as low-income households are the least likely to improve energy consumption as they cannot afford these energy upgrades. They will continue to overuse energy until there is government intervention. Here, the results of these programs will be assessed.

The LIEE program installs new lighting (CFL lightbulbs), replaces refrigerators, changes attic insulation, DHW package, which includes low flow showerheads, aerators, pipe insulation and tank wraps (which showerheads and tank wraps have the largest savings) and other upgrades (this list does not have parallel construction). We see that these upgrades reduce the amount of electricity being used, as shown in Figure 1, and the amount of gas used, as shown in Figure 2. (There are multiple Figure 1s)

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[25] For comparison, the reader can find more detailed results in Roland-Holst et al (2010).

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There are a few things that need to be contemplated before continuing the LIEE program in future years. How reliable and accurate are these evaluations? Data is often unreliable at the individual household levels, which is why data has to be taken by sectors. Redesigning the evaluations so that it can be done at the individual household level requires additional costs and may not even increase reliability of the evaluations. What about cost effectiveness? There are programs that have low returns, but also some programs are cost-effective in one area and not so much in the other. It might be worthwhile to research which programs work in some areas and which do not work in others. What about non-energy benefits? It may be worth to keep some programs that are not effective in energy reduction for the other benefits not pertaining to energy, i.e. giving more stability in the homeowner's life financially and socially or property value increases. Where do we draw the line for refrigerator eligibility standards? We could draw the line at pre-1992 refrigerators and obtain more energy savings per refrigerator, or we can draw the line at pre-1994 refrigerators and benefit a larger amount of the population. And are there any additional ways to save in the LIEE program? The LIEE program may find it beneficial to retrofit washing machines or water pumping. (Have there been any studies that address any of these questions?)

WAP also offers energy reduction at low-income households by air sealing, installing attic and wall insulation, refrigerator replacement, resetting temperature on water heaters, and installing programmable thermostats on central heating system. Little information has been given about California savings in the WAP, but Figure 3 shows the energy reductions with a $2,500 weatherization package. A 19 state case study was also done, though it does not include California, we can get a gist of what its effects would be like, states were chosen in all different climates, therefore figure 4 shows a decent cross section of the effects of the WAP (This sentence can be broken up to make it easier to read). We also see air emissions improvement from the WAP, shown in the dollars per tons of gas emissions in figure 5.

Lastly there is very little data on LIHEAP energy savings in the country. LIHEAP encompasses helping to pay for heating or cooling bills, low-cost weathering projects, services needed to reduce need for energy assistance, and assistance with energy-related emergencies. A study done in Minnesota's LIHEAP showed that energy consumption over a distribution of households was 10% higher and lower than the average energy consumption prior to LIHEAP. It was concluded that energy consumption did not change.

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Households under the 17% threshold unfortunately do not benefit to these programs, yet there is some assistance in the form of grants, tax credits, rebates, or loans. Grants and rebates are gained when one makes a retrofit, and both of these require an immediate spending, whereas loans are paid over time. Grants and rebates are also received much faster than tax credits, and loans put the homeowner in debt, while this is not the case for grants, rebates, and tax credits. Because of this, lower income households prefer grants and rebates over loans as they usually want to stay out of debt as much as possible. But as we move up the income ladder, homeowners will start to prefer loans over grants and rebates as high income homeowners will often spend more money on EE investments, and are generally more financially responsible and can take on some debt.

Table 14: Overview of savings in electricity

Measure	Regression Result	Showerhead/ On-site Estimate	DEER/ External Studies	Previous LIEE Evaluations	Source of PY2005 Savings Estimate
Lighting (per CFL)	11 kWh	22 kWh	21 – 60 kWh	22 - 43 kWh	Adjusted to be between regression and on-site estimate, at 90% upper confidence bound of regression result
Refrigerators	755 kWh	None	None	645 - 795 kWh	Electric regression model
Attic Insulation (heating)	257 kWh	None	180 kWh (2005)	35 - 288 kWh	Electric regression model
Attic Insulation (cooling)	70 kWh	None	None	44 - 208 kWh	Electric regression model
DHW Package	Not estimated	171 kWh (showerhead)	78 - 608 kWh (2001)	30 - 240 kWh	Convert savings from gas regression model
Evaporative Coolers	245 kWh	None	333 – 5056 kWh (2001)	98 - 571 kWh	Electric regression model
Efficient Room A/C	97 kWh	None	None	80 - 571 kWh	Electric regression model
Air Sealing/ Envelope measures	Not estimated	None	None	10 - 56 kWh	Convert savings from gas regression model

Table 15: Impact Evaluation of the 2005 California Low Income Energy

Measure	Regression Result (Therms)	Showerhead/ On-site Estimate	DEER/ External Studies	Previous LIEE Evaluations	Source of PY2005 Savings Estimate
Air sealing/envelope	6.1	None	None	3 – 11 therms	Gas regression model
Attic Insulation	47.2	None	41 therms	10 – 59 therms	Gas regression model
Heating System Repair/Replace	2.4	None	None	Increased Use to 147 therms	Gas regression model
DHW Package	13.5	7.3 therms (showerhead)	20 – 26 therms	10 - 20 therms	Gas regression model
DHW Replacement	12.1	None	None	9 – 19 therms	Gas regression model

Impact Evaluation of the 2005 California Low Income Energy Efficiency Program, 2005.

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Table 16: Photo-voltaic (PV) Projects Installed or In Progress
(systems > 50 kw)

	Northeast		South		Midwest		West	
	Typical	High-Energy-Use	Typical	High-Energy-Use	Typical	High-Energy-Use	Typical	High-Energy-Use
$2500 Package								
Weatherization costs	$2,581	$2,732	$2,370	$2,725	$2,388	$2,638	$1,499	$2,311
Energy bill savings	15.5%	18.7%	15.2%	15.9%	20.4%	22.7%	14.3%	20.6%
Site Btu savings	21.8%	24.6%	15.2%	15.9%	25.0%	26.6%	16.9%	24.5%
Source Btu savings	17.1%	20.3%	15.2%	15.9%	21.5%	23.7%	14.8%	21.5%
CO_2 reductions	17.6%	20.9%	15.2%	15.9%	20.1%	22.5%	16.6%	24.1%

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Schweitzer, Martin & Joel F. Eisenberg. "Meeting the Challenge: The Prospect of Achieving 30 Percent Energy Savings Through the Weatherization Assistance Program." *Oak Ridge National Laboratory*, 2002.

Table 17: Average savings in electrically-heated houses, with comparison to national savings estimate for gas-heated dwellings

Fuel/Analysis	Average savings per household (million site BTUs)	Average savings per household as percentage of pre-weatherization consumption for all end uses(%)	Average savings per household as percentage of pre-weatherization consumption for space heating (%)
Electricity/weighted average			
Point estimate	6.6	9.0	19.8
90% confidence interval	3.7 – 9.4	6.6 – 11.5	12.3 – 27.4
Electricity/unweighted average			
Point estimate	7.1	10.3	25.6
90% confidence interval	4.0 – 10.2	6.9 – 13.7	15.3 – 36.0
Natural gas/weighted regression analysis			
Point estimate	30.5	22.9	32.3
90% confidence interval	26.0 – 35.0	19.5 – 26.3	27.5 – 37.1

Schweitzer, Martin. "Estimating the National Effects of the U.S. Department of Energy's Weatherization Assistance Program With State-Level Data: A Metaevaluation Using Studies From 1993-2005." *Oak Ridge National Laboratory*, 2005

Table 18: Environmental benefits of the WAP.

Non-energy benefit	Range of benefits (in 2001 dollars per participating household: net present value)	Point estimate of benefits (in 2001 dollars per participating household: net present value)
Air emissions—natural gas		
Carbon (CO_2)	40–32,189	102
Sulfur oxides (SO_x)	0.02–6015	23
Nitrogen oxides (NO_x)	0.02–2254	48
Carbon monoxide (CO)	0.21–758	46
Methane (CH_4)	0.07–269	92
Particulate matter (PM)	0.01–6983	9
Subtotal	40–49,176	320
Air emissions—electricity		
Carbon (CO_2)	167–97,857	305
Sulfur oxides (SO_x)	31–40,872	92
Nitrogen oxides (NO_x)	11–17,290	523
Carbon monoxide (CO)	36–81	39
Methane (CH_4)	0.68–1.15	0.91
Particulate matter (PM)	0.27–704	14
Subtotal	246–156,805	974
Other benefits		
Heavy metals (air emissions)	1.39–17,205	380
Fish impingement	23.44–23.44	23.44
Waste water and sewage	3.36–657	146
Subtotal	28–17,885	549
Total[a]	68–67,061	869

[a] Uses natural-gas estimates for air emissions.

Schweitzer, Martin & Bruce Tonn. "Non-Energy Benefits of the US Weatherization Assistance Program: a Summary of Their Scope and Magnitude." *Oak Ridge National Laboratory*, 2002.

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4.12 Financing for Industrial GHG Reduction, EE, and Renewables

4.12.1 Scenario

This scenario subsidizes industrial activites to help them adopt technologies for GHG reduction, EE, and renewables. We assume technologies conformal with the AB32 scoping plan for sectors cited as operative participants in Ab32 mitigation schemes. This approach is similar to giving free permits to industry worth $100M/yr.

4.12.2 Background

In addition to the initiatives cited in section 4.8 above, PG&E is currently administering 11 different programs for the industrial sector and tens of other programs for different industries. Other IOUs are also running their own programs to improve EE for their customers. IOUs are required to submit a monthly report to CPUC which can be found on CPUC's website. Following CPUC and PACE estimates for energy cost (savings) recovery, our $100M scenario assumes an annual rate of 1.45 for savings to program cost over 2013-2020.

To promote greater renewable deployment, the Solar Energy Industries Association(SEIA) is arguing for a percentage of auction revenues to be allocated to the a renewable energy and efficiency program like CSI in order to help meet the goal of 33% energy production from renewable systems by 2020 specified in the state's scoping plan. SEIA argues that in order to meet this goal, more investment is needed in these projects in order to meet these goals. The Joint Investor Owned Utilities(IOUs) argue that they already contribute a large amount of money to these programs and that further investment into these projects would be duplicative and would not benefit the consumers which would violate one of the stipulations in AB 32. SEIA responded to the Joint IOUs by saying that although there is already a large amount of money in the programs, more money will be need not for solar and other renewable energy installations, but that the revenue would be needed to connect the private producers to the power grid for distributed generation, a program that SEIA feels is paramount to meeting the goal of 33% energy production by renewable energy. The connection of private energy producers for distributed generation can be costly and all distributed generation connections are currently funded exclusively by the developer which can make the venture unprofitable. SEIA recognized the problem and proposed to have 10% of auction revenues go to EE programs and 5% to the connection of renewable energy installations to the power system grid.

SEIA also argues that both EE and renewable energy production can shield from direct energy price increases and can act as a hedge for low income households, which would also apply to small businesses especially those that are energy intensive. Energy efficiency programs in conjunction with renewable energy installation and distributed generation programs could help stop leakage from businesses due to the direct and indirect effects of increasing energy costs. SEIA also argues that funding EE and renewable energy programs is in keeping with the goals of AB 32, that the auction revenues should contribute to the further reduction of GHG emissions.

The Natural Resources Defense Council (NRDC) (This is the first reference to the NRDC so you don't have to spell out the full name) and affiliates agree with the position of SEIA and advocate the spending of a portion of revenues on renewable energy and EE programs but also acknowledge the importance of the effect of energy cost increases on low income communities because of the low elasticity of demand for energy. This means that energy consumption will not decrease by a substantial amount for the low income communities and the cost of energy consumption will represent a much large portion of their income. The NRDC and affiliates say that consumer preferences will change over time if they are prompted by appropriate price signals and alternatives to high priced energy such as EE or renewable, self-generated systems. These points were made about residential preferences, but commercial preferences should behavior in a similar fashion.

4.13 Advanced Technology Vehicle Deployment

4.13.1 Scenario

Both California and the Federal government have in recent years enunciated policies to improve the fuel efficiency the light vehicle fleet. In this scenario, we assume that the state strives for improvements of 5%/yr in miles per gallon, using $100M/yr to subsidize new cars in proportion to their efficiency over last year's new car average. Thus a car that gets 5% better mileage would be eligible for a 5% subsidy until the funds are exhausted. A recent CARB initiative is also intended to accelerate electric vehicle adoption. We do not evaluate this program, but it is the subject of a separate economic assessment.

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4.13.2 Background

Transport, as a fast-growing energy intense sector, relies heavily on the fossil fuel petroleum and largely contributes to global GHG emission as well. These two factors add up making transport a great hazard to environment and therefore calling for accelerated deployment of sustainable transport and energy system. In this assessment, I will elaborate on the automobile transition, government's responsibility in propelling the deployment of AFV, consumer responses as well as problems that might be encountered during transition from internal combustion engines (ICE) to AFV.

From the "integrated modeling framework" investigation conducted by H. Turton, a key finding is that "sustainable energy system can emerge over the long term at relatively little cost overt the century (roughly 2% of GDP by 2100)." There's also an underlying implication that "the higher per unit energy costs under a sustainable transport system may result in a shift from air transport towards additional automobile transport compared to an equivalent scenario where sustainable development objectives are pursued". The indicated increasing proportion of automobile transport stresses the importance of deployment of advanced tech vehicle. The scenario introduces the transition process from "internal combustion engine vehicles to hybrid-electric vehicles, and eventually a shift towards hydrogen fuel cell vehicles". The question lies on "whether current market drives alone will be sufficient to promote a complete transition to these vehicles over the next 50 years or so." The current high cost of fuel cells requests public support which highlights "government rebates, subsidies or procurement programs to create additional confidence in this technology".

Besides developments in transport technology, "two complementary fuel production trends" also emerge: "biomass as a primary feedstock" and "development of a hydrogen and alcohol-based energy system". Alcohol is easier to deal with than hydrogen which requires intense investment in "production and transportation infrastructure". This again points out the role of public financial support. Moreover, "given the likely monopoly nature of a hydrogen distribution network, there exits an important role for government in overall strategic co-ordination of investment to guarantee an efficient network". In this scenario, "both alcohols and hydrogen are synthesized predominantly from biomass" which is economically and ecologically competitive. Accelerated request for biomass may "promote smaller-scale decentralized alcohol and hydrogen synthesis close to the feedstock sources" which excels today's centralized oil industry in terms of

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the needs of long-distance transportation. However, bulk biomass production demands sufficient land which might compete with the "increasing human needs for food and fiber and at very least maintain environmental amenity". This "biomass-based energy system underlines "the need for innovative approaches to investment, including public-private partnerships" and once again "a role for governments in providing the strategic framework in which private sector expertise can be exploited to realize long-term social goals, while ensuring other aspects of sustainability are addresses."

Having the recognition of the demands for large investment in "infrastructure for vehicle and fuel production, and an expansion of the network of refueling facilities", an understanding on the factors that "encourage households to adopt AFVs would help to inform industry stakeholders and to develop policy interventions". Results show that "reduced monetary costs, purchase tax relieves and low emissions rates would encourage households to adopt a cleaner vehicle. On the other hand, incentives such as free parking and permission to drive on high occupancy vehicle lanes with one person in the car were not significant. Furthermore, limited fuel availability is a concern when households considered the adoption of an alternative fuelled vehicle." Also, willingness to pay varies based on different parameters including "gender, age, education level and household size".

There are some obstacles that can hinder the accelerated deployment of AFV. First, the "awareness and adoption of AFV must exceed the threshold to become self-sustaining" which puts great pressure on "social exposure, learning and other positive feedbacks". Second, the long vehicle lives means that "share of AFVs in the installed base will increase slowly even if AFVs capture a large share of new vehicle sales." As a result, policies should be aiming at "removing old ICE vehicles form the installed" and "feebate programs or subsidies offered to vehicle owners who not only buy an AFV but have their ICE vehicle shredded rather than sold into the used car market. Also, "a successful transition to AFVs will require policies that raise the real price of gasoline to levels that reflect its fully internalized cost, thus providing the persistent incentive favoring AFVs".

4.14 Low Carbon Goods Movement

4.14.1 Scenario

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In this, the first of our fiscal experiments, we assume that $100M of emission permit revenue is returned directly to households, on an equal per capita basis. This is done equally across the state population, without regard to income or tax status. Results for this experiment are discussed in the preceding section.[26]

4.14.2 Background

Part of the California AB 32 scoping plan includes reductions in GHGs by implementing a number of regulations on goods movement activities throughout the state. The California Air Resources Board (ARB) has set a target of reducing carbon emissions by 0.2 million metric tons from ship electrification at ports, by 3.5 million metric tons by goods movement efficiency measures, by 0.5 million metric tons by medium- and heavy-duty vehicle hybridization, and by 1 million metric ton from the implementation of the California High Speed Rail (HSR) (California Air Resources Board, 2008). Other policies for GHGemission reduction include Heavy-Duty Vehicle emission reduction.

There are several policies aimed toward reducing GHG emissions from ocean-going vessels. The ship electrification policy requires vessels visiting any California Port to reduce diesel emissions by either turning off auxiliary engines and connect the vehicle to some other source of power, or to use an alternative control technique that achieve equivalent emission reductions. This policy has already been approved by the board in December 2007 and became effective January 2009 (California Air Resources Board, 2010). The ARB has calculated that this policy will reduce carbon emissions by 136,000 to 269,000 metric tons by 2020 (California Air Resources Board, 2007).

Another ship vessel-related regulation is to reduce vessel speeds within a certain distance along the California coast. A study by CE Delft suggests that reductions in vessel speeds can reduce emissions by as much as 30% (Faber, Freund, Kopke, & Nelissen, 2010). Although this program has not taken effect, there have been voluntary VSR programs at the Ports of Los Angeles and Long Beach (California Air Resources Board, 2008).

Also included in the scoping plan are reduced carbon emissions from vehicles used for goods movement by land. One would be of port drayage trucks,

[26] For comparison, the reader can find more detailed results in Roland-Holst et al (2010).

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which are diesel-fueled and have harmful emissions. Port drayage truck regulation comes in two phases. In the first phase (ending December 2009), all pre-1994 drayage truck engines must be retired or replaced with newer models, and all trucks with 1994-2003 model year engines must meet certain standards set by the ARB. In phase 2, all truck engines must meet or exceed the 2007 California and Federal Emission Standards by December 31, 2013. The ARB estimates that the diesel fuel savings from this policy (estimated to be 11 million gallons per year) will reduce carbon dioxide emissions by 7%, and that the capital investment costs to comply with the drayage truck regulation would range from $1.1 to $1.5 billion (2006 dollars) (California Air Resources Board, Stationary Source Division Project Assessment Branch, 2007). Currently, phase 2 is underway.

In January 2010, the state also approved regulation to improve fuel efficiency of heavy duty tractors that pull 53-foot or longer trailers by improving tractor and trailer aerodynamics and by the usage of low rolling resistance tires. This regulation sets standards that must have 100% compliance for all such trucks circulating in California by the year 2014 (California Air Resources Board, 2011). The California ARB estimates that this policy will reduce greenhouse gas emissions by roughly 0.93 million metric tons by 2020 statewide, and that truckers and trucking companies will save $8.6 billion dollars over the years of 2009 to 2020 when diesel fuel consumption reduces by an estimated 750 million gallons in California (California Air Resources Board, 2012). This policy is estimated to cost $521 million in capital investment.

Other proposals in the scoping plan include clean/green ships, reduction of idling of cargo equipment (such as cranes and other machines), and reduction of emissions from locomotives. Such proposals are either currently undergoing research or have been stalled (Coalition for Clean Air, 2011).

4.15 High Speed Rail Bookends

4.15.1 Scenario

In this experiment, we assume that the permit auction system contributes $100M/yr to this large transportation infrastructure, and receives credit for that compoent of the project's growth and emissions dividends. The finances of high speed rail are set forth below, but a high degree of uncertaintly prevails.

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4.15.2 Background

Governor Brown has suggested using Cap and Trade revenues toward the funding of the High Speed Rail (HSR) project, which in its latest proposal has a price tag of $68.4 billion (California High-Speed Rail Authority, 2012), and according to the AB 32 scoping plan, can reduce carbon emissions by 1 million metric tons (California Air Resources Board, 2008). The latest business plan estimates that the implementation of HSR can save travel time, reduce traffic congestion, and create hundreds of thousands of jobs in the economy (see table XX) (California High-Speed Rail Authority, 2012). Unfortunately, the project still remains uncertain, as it has only secured $9 billion in voter approved bond funds, and $3.5 billion in federal funds. In addition, there may be some legal concerns regarding the usage of cap and trade revenues on HSR. Under the current proposal, construction would not be completed until 2021, which cannot be made applicable to AB 32's goal of reducing GHG emissions by 2020 (Legislative Analyst's Office, 2012). In addition, if there is insufficient ridership on HSR, then the pollution from constructing HSR might outweigh than any reduction in carbon emissions (Westin & Kageson, 2012). The Legislative Analyst's Office also suggests that other GHG reduction strategies are likely to be more cost-effective (Legislative Analyst's Office, 2012).

Table 19: California High Speed Rail Budget

High–Speed Rail Construction

Phase/Stage	Description	Length in Miles[a]	Completion Year	Cost in Billions[b]
Phase 1 Blended				
Initial Operating Segment (IOS), first construction	Madera to Bakersfield	130	2017	$6.0
Remainder of IOS	Merced to San Fernando Valley	170	2021	25.3
Bay to Basin	San Jose to San Fernando Valley	110	2026	19.9
Blended	San Francisco to Los Angeles	110	2028	17.2
Subtotals		520		$68.4
Phase 2	Extend to other regions[c]	280	Unknown	Unknown
Total		**800**		

[a] Length of construction segments are approximate.
[b] Estimated dollar amounts are in the year of expenditure.
[c] Other regions include East Bay, Sacramento, San Diego, Inland Empire, and Orange County.

Source: (California High-Speed Rail Authority, 2012)

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Although the specific projects to be constructed under the terms of these agreements have not been fully identified, plans include electrifying the Caltrain corridor. Projects in Southern California will be smaller improvements around the region that improve safety or increase capacity and could include, for example, grade separations or double–tracking along the high–speed rail corridor.

Because of the high overall cost and uncertainties associated with this system, more recent proposals have decomposed it into localized ("blended bookends") upgrades of local transit, followed by connecting components (see the figure below). The 2012 revised business plan proposes to direct $1.1 billion in Proposition 1A funds to make investments in regional rail projects in the San Francisco Bay and the Los Angeles metropolitan areas—referred to as the bookends of the high–speed rail system. The HSRA has signed memoranda of understanding (MOUs) with regional transit agencies in these areas to coordinate efforts to obtain additional funding for projects that can immediately improve passenger rail service in those regions.

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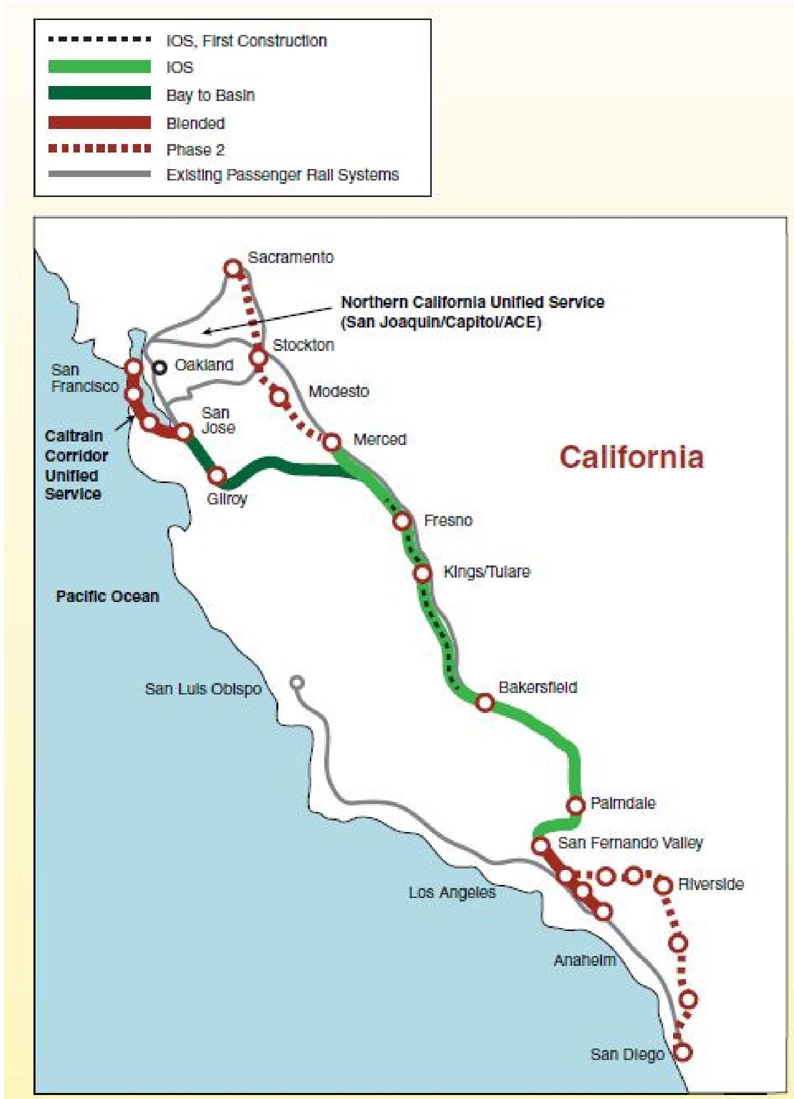
Figure 10: Map of the Proposed HSR System



Source: Legislative Analysts' Office: 2012.

If this approach were taken, early investments in the system would yield local savings in travel time, cost, energy fuel, and emissions. For our scenario in this context, we assume a $100M/yr auction revenue contribution to the project over the period 2013-2020, with a savings recovery rate comparable to those estimated for other local public transit investments (see the table XX below), with a low value of 1.5.

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Table 20: Summary of the Short-term Economic Impact per Billion Dollars of National Investment in Public Transportation (includes indirect and induced effects)

Economic Impact	Per $ Billion of Capital Spending	Per $ Billion of Operations Spending	Per $ Billion of Average Spending[B]
Jobs (Employment. thousands)	23.8	41.1	36.1
Output (Business Sales, $ billions)	$ 3.0	$ 3.8	$ 3.6
GDP (Value Added, $ billions)	$ 1.5	$ 2.0	$ 1.8
Labor Income ($ billions)	$ 1.1	$ 1.8	$ 1.6
Tax Revenue ($ millions, rounded)	$ 350	$ 530	$ 490

A indirect and induced effects include impacts on additional industries; they provide multiplier impacts on job creation only to the extent that there is sufficient unemployment to absorb additional jobs without displacement of other existing jobs.

B The US average impact reflects a mix of 29% capital and 71% operations spending. The study finds that the FTA federal aid impact is 30,000 jobs per billion of spending, due to a mix of 69% capital and 31% maintenance (operations). See full report for further explanation.

Source: Weisbrod and Reno: 2009.

4.16 Water Supply Energy Efficiency

4.16.1 Scenario

In this experiment, we assume that the states contributes $100M/yr to improving EE in large scale water storach and conveyance.

4.16.2 Background

Water supply and conveyance is extremely important in California and will only become more important as time goes on. Auction revenues could be used for this project without much risk of violating the Sinclair Paint ruling because of the great amount of energy that is used to move water in California. The water sector is the largest consumer of energy in California, estimated to account for 19 percent of total electricity and 32 percent of total natural gas consumed in the state. In the past, snow packs would hold for the summer, slowing melting, providing an even flow of runoff over the summer months. With global warming the snow packs have been melting early causing erratic water conditions with dry summers and flooding in the winter. In order to hold the melted snowpack for the

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summer months, dams and reservoirs have become more prevalent which disrupt native animal populations and increased the need for pumps in order to move water. By replacing these pumps with more energy efficient pumps, a significant reduction in GHG emissions would take place.

Other goals the scoping plan has for improving the water supply are water use efficiency, water recycling, urban runoff reuse, and increasing renewable energy production. GHGs are planned to be offset by the planting and maintaining of forests and riparian areas, which provide carbon sequestration as well as watershed protection. This is a natural way of storing water and protecting from severe floods or droughts. Improving water supply helps achieve the goals of AB 32 by providing a more secure and abundant water supply to low-income families as well as further decreasing GHG emissions from both energy efficient pumps and carbon sequestration while keeping food prices from rising by maintaining or improving water supplies for farmers. Water use efficiency in agriculture should be invested in reducing the net water use and improving the drainage water from farms and orchards.

Auction revenues can be used on a state level to remodel the systems of reservoirs, canals and levees in order to increase water supply while simultaneously responding to climate change factors. The remodeling of these systems and the installation of flood management programs should also coincide with natural habitat reclamation in order to re-establish forests to help prevent sediment accumulation and erosion. It will also be important to improve management of surface and groundwater, expanding the amount of storage in both to provide as reserves during a drought. A very important part of the water supply improvement program would be multi-faceted planning from rural regional planning and inter-regional planning as well as urban planning to ensure efficient storage, use and reuse of water in each stage. The planning would in part consist of improving data collection and analysis in order to implement water saving strategies as soon as possible and continue to improve the practices over time.

Jerry Brown endorses water supply improvement in his projected funding from Cap and Trade revenues by reducing GHG emissions from water use as well as protecting and managing natural resources and funding sustainable agriculture. No real objections have come up to Jerry Brown's proposal to fund these projects as California's water supply is an important issue in many places in California. There does not appear to be a high likelihood of groups challenging the water supply but it could be possible that some would argue that the

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conservation of natural resources and the funding of sustainable agriculture programs do not directly benefit those hurt by the increase in energy costs due to the implementation of Cap and Trade.

In-state hydroelectric power generation in 2004 accounted for approximately

(this is an incomplete sentence)

The Agricultural Peak Load Reduction Program (APLRP) was developed by the California Energy Commission (CEC) in early June 2001, under the authority of Section 5(b) of California Senate Bill 5x. This legislation arose from the blackouts and brownouts that hit the state of California during the 2000-2001 winter, caused by a severe imbalance in electricity supply. The primary goal of SB 5x was to reduce peak period electric demand throughout California.

ITRC was contracted by CEC to administer the agricultural water agency portion of the APLRP. ITRC was entrusted with all technical aspects of the program, including reviewing and approving all water agency APLRP applications, technical support, and verification of project completion and peak load reduction. Because everything went through ITRC, massive amounts of red tape were eliminated and the program was able to run smoothly, quickly, and efficiently.

Table 21: The Agricultural Peak Load Reduction Program

Category	Description	Examples of Projects
1	High Efficiency Electrical Equipment/ Other Overall Electricity Conservation Efforts	• Expanding buffer reservoirs to supply water users during the peak period (12 p.m.-6 p.m. M-F) • Installing variable frequency drives (VFDs) • Replacing well casings • Other innovative solutions
2	Pump Efficiency Testing and Retrofit/Repair	• Rebates for pump testing and retrofitting/repairs • Five ITRC-developed pump test training courses

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3	Advanced Metering and Telemetry	• Installation of advanced metering and/or telemetry • Grants for participating in California ISO Demand Relief Program

(source?)

The ITRC-administered APLRP was extremely successful. The program incorporated over 50 Megawatts of peak load reduction into Categories 1 and 3 of the program, and an additional estimated 16 million kilowatt-hours of energy will be saved per year through Category 2, for a $6.5 million total investment from the State of California.

4.17 SB 375 Compliance through VMT Reductions

4.17.1 Scenario

In this case we assume that $100M/yr is contributed to SB 375 compliance at the local level, and this in turn reduces VMT by 2%/yr.

4.17.2 Background

The transportation sector is the largest contributor of GHG emissions (40%) in California, with automobiles and light trucks alone contributing nearly 30%[27]. It is widely understood[28] that there are three main approaches to reducing vehicle GHG emissions: (1) developing fuel efficient vehicles (2) reducing carbon contents of fuels (3) reducing the overall vehicle miles traveled (VMT) through more efficient land use and transportation development. California's Senate Bill 375 tackles exactly this third prong by commissioning CARB to set regional GHG reduction targets (only those resulting from changes in land and transportation plans) and mandating each of California's 18 Metropolitan Planning Organizations (MPOs) to create its own "Sustainable Community Strategy" (SCS) through efficient land use planning and transportation development to meet these emission reduction targets. Upon approval, SCSs will be incorporated into the federally mandated Regional Transportation Planning (RTP) as part of a

[27] California Air Resources Board California Air Resources Board

[28] UCLA School of Public Affairs *Measuring Vehicle Greenhouse Gas Emission for SB 375 Implementation*

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comprehensive long-term plan to reduce GHG emissions and to develop sustainable communities and transportation systems.

In September 2010, CARB assigned the final reduction targets for each of 18 MPOs for the years 2020 and 2035. Figure 1 (There is already a Figure 1) presents the reduction targets (% per capita) for the four largest MPOs, which "contain 83% of California's population and contribute over 80% of passenger vehicle GHG emissions generated in the state." [29] Thus the success of emission reductions in these four MPOs is crucial. However, SCAG, which produces about half of CA's GHG emissions, initially had rejected CARB's recommendation largely due to reasons related to funding.

Table 22: CARB's Proposed GHG Reduction Targets (%per capita) [30]

	2020	2035
Metropolitan Transit Commission (MTC "Bay Area")	7%	15%
Sacramento Area Council of Governments (SACOG)	7%	16%
San Diego Association of Governments (SANDAG)	7%	13%
Southern California Association of Governments (SCAG)	8%	13%

4.17.3 The Funding Problem

SCAG set forth 11 conditions necessary for them to accept the proposed targets, the majority of which were regarding getting more state funds for various programs that would be required to meet SB 375 goals including funds for SCS planning. The conditions included: "Restoration of previous levels of state funding for transportation, transit in particular", "Targeted increase in funding

[29] Mitchelle B. Menzer and Ryan Trahan *The CARB Sets Ambitious Greenhouse Gas Emissions Reduction Targets Under SB 375*

[30] Mitchelle B. Menzer and Ryan Trahan *The CARB Sets Ambitious Greenhouse Gas Emissions Reduction Targets Under SB 375*

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commitments for transportation", and "continued leadership by the regional partners to increase availability of state funds for the region."[31]

The problem with lack of funding was brought up throughout the regional MPO workshops and also by the Regional Targets Advisory Committee (RTAC), an advisory body mandated under SB 375 and created by CARB to recommend and advice in setting emission reduction targets and related methods for the target setting process. In a summary[32] written by the League of California cities, the funding issue was discussed as following:

"The most frequently cited implementation barriers were cuts to transit funding and redevelopment, and the lack of funds for new community-based plans, zoning changes, and programmatic environmental reviews. The State should fund the programs necessary for local and regional governments to actually implement the developed set of regional strategies."

Many experts argue that allocating adequate funding as the most important factor for meeting the target reduction. With lack of funding, MPOs will be discouraged from taking bold steps to bring about changes that are necessary to make their SCSs successful.

4.17.4 Organizations Recommend Using the C&T Revenue to Fund SB 375 Activities

In its 2009 Recommendations, RTAC recommended the Cap and Trade auction revenue to be used to fund SB 375 activities in two ways (The list needs to be reformatted to include 2 bullet points, not 4):

1. Providing incentives for exceeding target as a way to reward and encourage MPOs to meet their SCS targets.

2. RTAC recommended that "the state could set aside a portion of future Cap and Trade program revenues exclusively for grants to regions that

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[31] Orange County Transportation Authority *Adopted SB 375 Regional Greenhouse Gas Reduction Targets: Staff Report* (2010)
[32] League of California Cities *12 Point Summary of the RTAC Report (2009)*

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exceed targets, or local jurisdictions that meet specified standards related to SB 375 implementation."[33]

3. Transportation Planning

4. RTAC recommended that "Some portion of funds generated from the auction of carbon emissions allowances from any future Cap and Trade system be set aside to fund regional transportation planning that reduces greenhouse gas emissions."[34]

Most important is the recommendation by the Economic and Allocation Advisory Committee (EAAC). In its 2010 report to CARB, it argued that "the *most urgent need* is to fund regional and local governments to update their plans and zoning codes to meet the goals of the SB 375 (Steinberg, 2008) regional Sustainable Communities Strategies (SCS) requirement."[35] Without sufficient funding, local and regional governments will be discouraged from committing to long-term plans with long-term returns. EAAC finds efficient land developments to be highly cost-effective in reducing GHG reduction, which comes from reduction in VMT. It also believes that transportation developments through broadening accessibility, developing alternate transit, and expanding existing systems benefits the overall California's Climate agenda.

A non-profit environmental and climate organization based in Bay Area called TransForm also voiced their endorsement to use Cap and Trade revenues for implementing the goals of SB 375. They wanted the revenues be invested in the following activities as part of meeting the emission reduction targets:

1. "Expanded and improved transit, vanpool, bicycle and pedestrian facilities within developed areas, especially in highly-congested areas and those heavily-exposed to GHG emissions."

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[33] California Air Resources Board *Recommendations of the Regional Targets Advisory Committee Pursuant to Senate Bill 375: A Report to the California Air Resources Board* (2009)
[34] California Air Resources Board *Recommendations of the Regional Targets Advisory Committee Pursuant to Senate Bill 375: A Report to the California Air Resources Board* (2009)
[35] Economic and Allocation Advisory Committee. "Allocating Emissions Allowances Under a California Cap-and-Trade Program: Recommendations to the California Air Resources Board and California Environmental Protection Agency" (2010).

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2. “Compact, multi- and single-family homes affordable to lower-income households and located near frequent public transit and job centers.”[36]

Although there are currently no formal proposals for C&T revenue allocation to SB 375 projects, there is a general consensus that the local and regional governments have urgent funding needs to implement the goals of SB 375 and that a part of C&T can be used to mitigate these needs. RTP/SCSs are long-term plans and are also in line with California’s SB 32 goals to reduce GHG emissions thus C&T revenue, which could provide continuous funds, can substantially help small governments in planning their long-term strategies. For our scenario we assume that $100M in permit revenue is allocated to local government for programs that reduce vehicle miles travelled. Moreover, we assume that these programs achieve VMT reductions of 20% statewide by 2020 (see SCAG/UCLA: 2005 for estimates).

4.18 Loan Guarantees for Energy Efficiency and Renewables

4.18.1 Scenario

As in the above EE scenarios, we follow the state’s Energy Action Plan (CPUC: 2010), but this time put the $100M revolving fund for 5-year credit to finance technology adoption. We assume that the funds are used by representative household and small enterprise agents in equal measure to finance efficiency measures. Annual repayments comprising 20% of outstanding principal and 3% interest are recycled to new loans annually.

4.18.2 Background

Several states, including California, Vermont, Nebraska, Kansas, and Hawaii have established a variety of incentive loan programs to promote private EE and renewable adoption. Generally speaking these programs are intended to overcome the primary hurdles for households and smaller enterprise who contemplate adoption these technologies: initial cost and cost of capital. Because these fixed costs may be large and not eligible for mortgage-related finance, it can be difficult for smaller enterprises and families to borrow for these investments and, when they can, interest rates may be quite high. For this

[36] TransForm *Using Cap-and-Trade Revenue to Equitably Advance AB 32 and SB 375 Goals*

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reason, the core of most state incentive programs is expanded credit eligibility and subsidized interest.

Even though these programs are committing public funds at sub-market rates, repayment rates are very high and established programs are profitable. This means benefits can be “recycled” to future borrowers, yielding multiples of the intiial financing benefits. For our auction revenue allocation experiment, we examine a case of lending at subsidized interest for five year credit on small scale solar and energy efficient appliances.

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5 Conclusions

This report provides an economy-wide assessment of alternative strategies for allocation auction revenues from California's Cap and Trade program for greenhouse gas emissions reduction. The state's AB32 legislation is expected to generate billions of dollars in revenue from auctioning the "right to pollute." This new revenue source can be used for a broad array of fiscal purposes, such as "recycling" rebates to taxpayers, public investments in sustainable growth, further emission reduction, etc. How the revenues are allocated will have important consequences, but also differential impacts on the composition of economic activity and employment.

Using a dynamic economic forecasting model, we have evaluated a set of eighteen generic alternatives for auction revenue allocation. These were derived from a series of expert consultations to represent the leading alternatives being considered in the current AB32 policy dialog, and represent the interest of a broad spectrum of leading stakeholders. Five salient insights emerge from the economic analysis:

1. *California has a wide array of options for recycling revenues from auctions for GHG emission permits, each of which can contribute to long-term economic growth and job creation.*

2. *Most of the allocation options considered return more to economic growth than their cost, and in the process increase state revenue, but net benefits differ significantly.*

3. *The most pro-growth options invest auction revenue in expanded household-level EE and renewable technology diffusion, and these generate more new state revenue than their initial cost.*

4. *Allocations that merely offset existing fiscal commitments, while still fostering some growth, do not yield benefits comparable to committing new revenues to efficiency measures.*

5. *New employment benefits generally increase with GDP, but vary depending on the demand patterns affected by the policy. Again household efficiency promotion is the most employment-intensive allocation strategy.*

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California's leadership in climate policy will not only benefit the state's economy and the quality of life for those who live there, it offers a unique opportunity to broaden public awareness of these complex issues, to design more sophisticated and forward looking policies, and to set global standards for a new generation of integrated environmental policies. Although the present results are best interpreted as indicative, they demonstrate that informed policy innovation and determined commitments to EE can translate into higher economic growth and job creation.

Many studies emphasize the costs of policies that deal with climate change because they emphasize narrowly focused direct adjustment costs and do not take account of extensive indirect policy benefits. Technical details about the scope of market failures and the scope for effective government policy can support extensive future research, but we need general guidance regarding macroeconomic impacts to choose policies that support growth and job creation for California as a whole. To date, relatively little has been done in terms of analyzing the results of different allocation choices within macroeconomic modeling of AB 32. In fact, the only studies to look at this question have been sponsored by Next 10, which has commissioned a strand of research that looks at variation across the options of government investment/spending, tax reductions, and equal dividends to citizens.

This study finds that policies promoting environmental quality and energy conservation *save money* and *increase employment* overall because their *indirect and incentive effects* propagate efficiency benefits across the economy. These overall benefits only become apparent when the economywide implications and innovation potential of the policies are taken into account. For example, we shall see below that energy savings allow consumers to increase other spending, largely on in-state goods and services, and this stimulates California growth and employment. Industry-specific and bottom-up studies of GHG polices fail to capture these indirect benefits, giving disproportionate emphasis to direct costs. An economywide perspective reveals that the supposed tradeoff between higher environmental quality and economc growth is a fallacy, and with careful and determined policy innovation, California can have both.

A number of next steps would productively build on the findings of this work. A next step in the research dimension would be more detailed analysis of the costs and benefits across an array of options. The Economic and Technology

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Advancement Advisory Committee developed the concept of maximizing net social benefit to help guide the development of packages. Then packages of investment options could be developed. Developing such packages helps solve the problem of nearly infinite combinations of options, and will produce results that are more easily digested by policymakers and the public. These investment packages could be compared against each other, as well as against spending on dividends or tax reductions.

7 Appendix 1 – Expert Survey Responses and Comments

For the sake of transparency, we reproduce here the results of our online survey of revenue allocation priorities. (These results are difficult to read in the current form. The results would be more accessible if reformatted for the paper.)

Question 3: allocation priorities.

3. In FY 2012-2013, how would you most prefer to use auction revenue?	Response Percent	Response Count
Dividend to each taxpayer (avg. amount $50)	21.1%	4
Fund education, health care and other public services	31.6%	6
Greenhouse gas reductions	47.4%	9
	answered question	19
	skipped question	3

5. Please mark your top three options among those that help achieve clean and efficient energy:		
		Rating (lower is better)
1	Industrial and manufacturing facilities to reduce greenhouse gas emissions by investment in EE, energy storage, and clean and renewable energy projects	1.7
2	Public universities, schools, water agencies, and other public facilities and fleets to reduce GHG emissions by investment in energy and water use efficiency, energy storage, and clean and	1.7

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	renewable energy and fuel projects	
3	Residential EE and distributed generation programs that serve to reduce GHG emissions	2.0
4	Commercial EE and distributed generation programs that serve to reduce GHG emissions	2.4
5	Energy efficiency actions to upgrade residential lighting and appliance efficiency upgrades and replacements	1.0
6	Programs that provide financing for, or directly fund conservation and EE upgrades in low-income and middle-income dwellings	2.1
7	Financing programs for renewable energy installations at commercial, industrial and manufacturing facilities	2.0
8	Financing program for renewable energy installations at residential properties	1.0
9	Financing programs for distributed generation installation in vulnerable communities	2.5
10	What top priorities are we missing?	0.0

4. Please rank the following funding criteria in order of priority:		
		Rating (lower is better)
1	Cost effectiveness ($ per ton)	2.0
2	Equity	2.5
3	Mitigation of cost of compliance for covered entities	4.6
4	Mitigation of indirect cost increases for end users	3.6
5	Minimize leakage	3.4
6	Research, development and deployment of high risk/high reward GHG reductions	2.8

6. Please mark your top two options among those that help promote low-carbon transportation:		
		Rating (lower is better)
1	Funding for California's high speed rail project	2.0
2	Investments in alternative fueling infrastructure for zero-emissions vehicles, including hydrogen fuel cell	1.8

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	vehicles	
3	Advanced biofuels standards and deployment	2.0
4	Accelerated deployment of advanced technology vehicles	1.3
5	Low-carbon public transportation and sustainable transportation and infrastructure development	1.2
6	Low-carbon goods movement and freight vehicle technologies and infrastructure	1.6
7	What top priorities are we missing?	0.0

Items 2 and 4 are incorporated in this study. Item 5 would have to be more clearly defined as a public sector project. Item 6 is also included according to CARB standards for this policy.

7. Please mark your top two options that help achieve natural resource protection:		
		Rating (lower is better)
1	Improve water supply through more efficient storage, conveyance, and management infrastructure	1.4
2	Policies and incentives for land and natural resource management, conservation and restoration	1.3
3	Promote beneficial farming practices to reduce GHG emissions	2.0
4	Development and implementation of sustainable agriculture, forestry, and related water, land, and resource management practices	1.5

8. On a scale of 1 (most important) to 3 (less important) please let us know how important the following option is to help achieve sustainable infrastructure development:

Other suggestions:

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1	While this is a worthwhile initiative, it seems unlikely to provide significant emissions reductions by 2020.
2	This may be one of the most important (and cheapest) of them all and could have a significant impact on land preservation due to more compact growth. However I would recast the sentence to say "Planning grants and incentives for regions and local governments to implement resource-efficient land use and transportation systems and exceed the goals of SB375"
3	integrate mitigation of impacts from greenhouse gas emissions into SB 375 implementation
4	focused strategy and funding pool for MUSH-- municipal, university, schools and hospitals and other publicly owned facilities

A study of state infrastructure priorities would be an ambitious project in its own right, but of course worthwhile, probably on a case by case basis.

9. Please mark your top two options that were not included in the above objectives:

		Rating (lower is better)
1	Adaptation strategies	1.1
2	Dividends to all Californians	1.4
3	Energy efficiency job training	1.7
4	Community benefits corporation	1.6
5	Affordable housing	0.0

Adaptation strategies is a very large area of policy and public interest, and deserves extensive research in its own right.

10. Please let us know if there are any other alternatives for allocating revenues that should be considered in our research:

1	You should at least consider using some of the revenues to fund tax cuts. It would also be good to consider not allocating the revenue to any particular use, but simply treating it as general revenue (the way the revenues from a lot of taxes are handled)

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2	Reducing taxes - see above. Some of these questions were hard to answer because the mechanism was not clear. For example, in Q4 i answered as my top priority "Mitigation of indirect cost increases for end users" but I might put this last depending on how it's administered.

Again the revenue rebate idea gets support. Even though this was addressed this in a previous study, updating that analysis might be advisable since it is central to the public interest in C&T.

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8 Annex 2: Summary of the BEAR Model

The Berkeley Energy and Resources (BEAR) model is in reality a constellation of research tools designed to elucidate economy-environment linkages in California. The schematics in **Error! Reference source not found.** reference missing) and **Error! Reference source not found.** (reference missing) describe the four generic components of the modeling facility and their interactions. This section provides a brief summary of the formal structure of the BEAR model.[37] For the purposes of this report, the 2003 California Social Accounting Matrix (SAM), was aggregated along certain dimensions. The current version of the model includes 50 activity sectors and ten households aggregated from the original California SAM. The equations of the model are completely documented elsewhere (Roland-Holst: 2005), and for the present we only discuss its salient structural components.

8.1 Structure of the CGE Model

Technically, a CGE model is a system of simultaneous equations that simulate price-directed interactions between firms and households in commodity and factor markets. The role of government, capital markets, and other trading partners are also specified, with varying degrees of detail and passivity, to close the model and account for economywide resource allocation, production, and income determination.

The role of markets is to mediate exchange, usually with a flexible system of prices, the most important endogenous variables in a typical CGE model. As in a real market economy, commodity and factor price changes induce changes in the level and composition of supply and demand, production and income, and the remaining endogenous variables in the system. In CGE models, an equation system is solved for prices that correspond to equilibrium in markets and satisfy the accounting identities governing economic behavior. If such a system is precisely specified, equilibrium always exists and such a consistent model can be calibrated to a base period data set. The resulting calibrated general equilibrium model is then used to simulate the economywide (and regional) effects of alternative policies or external events.

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[37] See Roland-Holst (2005) for a complete model description.

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The distinguishing feature of a general equilibrium model, applied or theoretical, is its closed-form specification of all activities in the economic system under study. This can be contrasted with more traditional partial equilibrium analysis, where linkages to other domestic markets and agents are deliberately excluded from consideration. A large and growing body of evidence suggests that indirect effects (e.g., upstream and downstream production linkages) arising from policy changes are not only substantial, but may in some cases even outweigh direct effects. Only a model that consistently specifies economywide interactions can fully assess the implications of economic policies or business strategies. In a multi-country model like the one used in this study, indirect effects include the trade linkages between countries and regions which themselves can have policy implications.

The model we use for this work has been constructed according to generally accepted specification standards, implemented in the GAMS programming language, and calibrated to the new California SAM estimated for the year 2003.[38] The result is a single economy model calibrated over the fifteen-year time path from 2005 to 2020.[39] Using the very detailed accounts of the California SAM, we include the following in the present model:

8.2 Production

All sectors are assumed to operate under constant returns to scale and cost optimization. Production technology is modeled by a nesting of constant-elasticity-of-substitution (CES) function.

In each period, the supply of primary factors — capital, land, and labor — is usually predetermined.[40] The model includes adjustment rigidities. An important feature is the distinction between old and new capital goods. In addition, capital is assumed to be partially mobile, reflecting differences in the marketability of capital goods across sectors.[41] Once the optimal combination of inputs is

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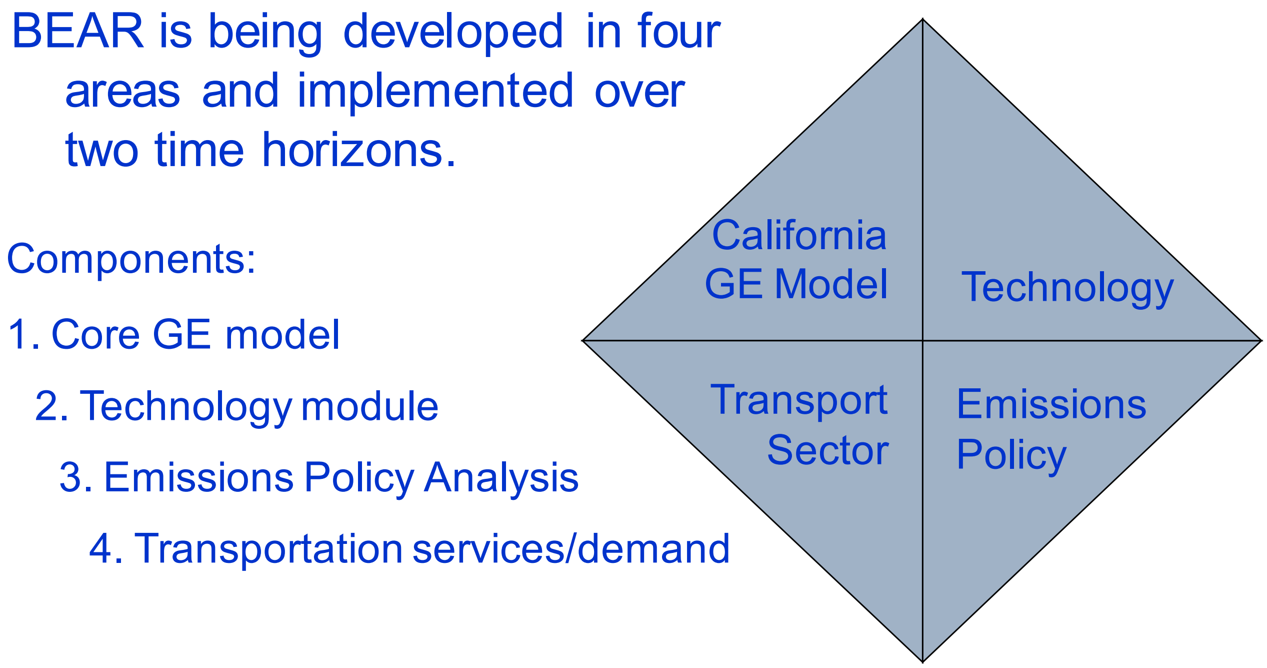
[38] See e.g. Meeraus et al (1992) for GAMS. Berck et al (2004) for discussion of the California SAM.
[39] The present specification is one of the most advanced examples of this empirical method, already applied to over 50 individual countries or combinations thereof.
[40] Capital supply is to some extent influenced by the current period's level of investment.
[41] For simplicity, it is assumed that old capital goods supplied in second-hand markets and new capital goods are homogeneous. This formulation makes it possible to introduce downward

determined, sectoral output prices are calculated assuming competitive supply conditions in all markets.

Figure A1.1: Component Structure of the Modeling Facility



8.3 Consumption and Closure Rule

All income generated by economic activity is assumed to be distributed to consumers. Each representative consumer allocates optimally his/her disposable income among the different commodities and saving. The consumption/saving decision is completely static: saving is treated as a "good" and its amount is determined simultaneously with the demand for the other commodities, the price of saving being set arbitrarily equal to the average price of consumer goods.

The government collects income taxes, indirect taxes on intermediate inputs, outputs and consumer expenditures. The default closure of the model assumes that the government deficit/saving is exogenously specified.[42] The indirect tax

rigidities in the adjustment of capital without increasing excessively the number of equilibrium prices to be determined by the model.

[42] In the reference simulation, the real government fiscal balance converges (linearly) towards 0 by the final period of the simulation.

schedule will shift to accommodate any changes in the balance between government revenues and government expenditures.

The current account surplus (deficit) is fixed in nominal terms. The counterpart of this imbalance is a net outflow (inflow) of capital, which is subtracted (added to) the domestic flow of saving. In each period, the model equates gross investment to net saving (equal to the sum of saving by households, the net budget position of the government and foreign capital inflows). This particular closure rule implies that investment is driven by saving.

8.4 Trade

Goods are assumed to be differentiated by region of origin. In other words, goods classified in the same sector are different according to whether they are produced domestically or imported. This assumption is frequently known as the *Armington* assumption. The degree of substitutability, as well as the import penetration shares are allowed to vary across commodities. The model assumes a single Armington agent. This strong assumption implies that the propensity to import and the degree of substitutability between domestic and imported goods is uniform across economic agents. This assumption reduces tremendously the dimensionality of the model. In many cases this assumption is imposed by the data. A symmetric assumption is made on the export side where domestic producers are assumed to differentiate the domestic market and the export market. This is modeled using a *Constant-Elasticity-of-Transformation* (CET) function.

8.5 Dynamic Features and Calibration

The current version of the model has a simple recursive dynamic structure as agents are assumed to be myopic and to base their decisions on static expectations about prices and quantities. Dynamics in the model originate in three sources: i) accumulation of productive capital and labor growth; ii) shifts in production technology; and iii) the putty/semi-putty specification of technology.

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8.6 Capital accumulation

In the aggregate, the basic capital accumulation function equates the current capital stock to the depreciated stock inherited from the previous period plus gross investment. However, at the sectoral level, the specific accumulation functions may differ because the demand for (old and new) capital can be less than the depreciated stock of old capital. In this case, the sector contracts over time by releasing old capital goods. Consequently, in each period, the new capital vintage available to expanding industries is equal to the sum of disinvested capital in contracting industries plus total saving generated by the economy, consistent with the closure rule of the model.

8.7 The putty/semi-putty specification

The substitution possibilities among production factors are assumed to be higher with the new than the old capital vintages — technology has a putty/semi-putty specification. Hence, when a shock to relative prices occurs (e.g. the imposition of an emissions fee), the demands for production factors adjust gradually to the long-run optimum because the substitution effects are delayed over time. The adjustment path depends on the values of the short-run elasticities of substitution and the replacement rate of capital. As the latter determines the pace at which new vintages are installed, the larger is the volume of new investment, the greater the possibility to achieve the long-run total amount of substitution among production factors.

8.8 Profits, Adjustment Costs, and Expectations

Firms output and investment decisions are modeled in accordance with the innovative approach of Goulder and co-authors (see e.g. Goulder et al: 2009 for technical details). In particular, we allow for the possibility that firms reap windfall profits from events such as free permit distribution. Absent more detailed information on ownership patterns, we assume that these profits accrue to US and foreign residents in proportion to equity shares of publically traded US corporations (16% in 2009, Swartz and Tillman:2010). Between California and other US residents, the shares are assumed to be proportional to GSP in GDP (11% in 2009).

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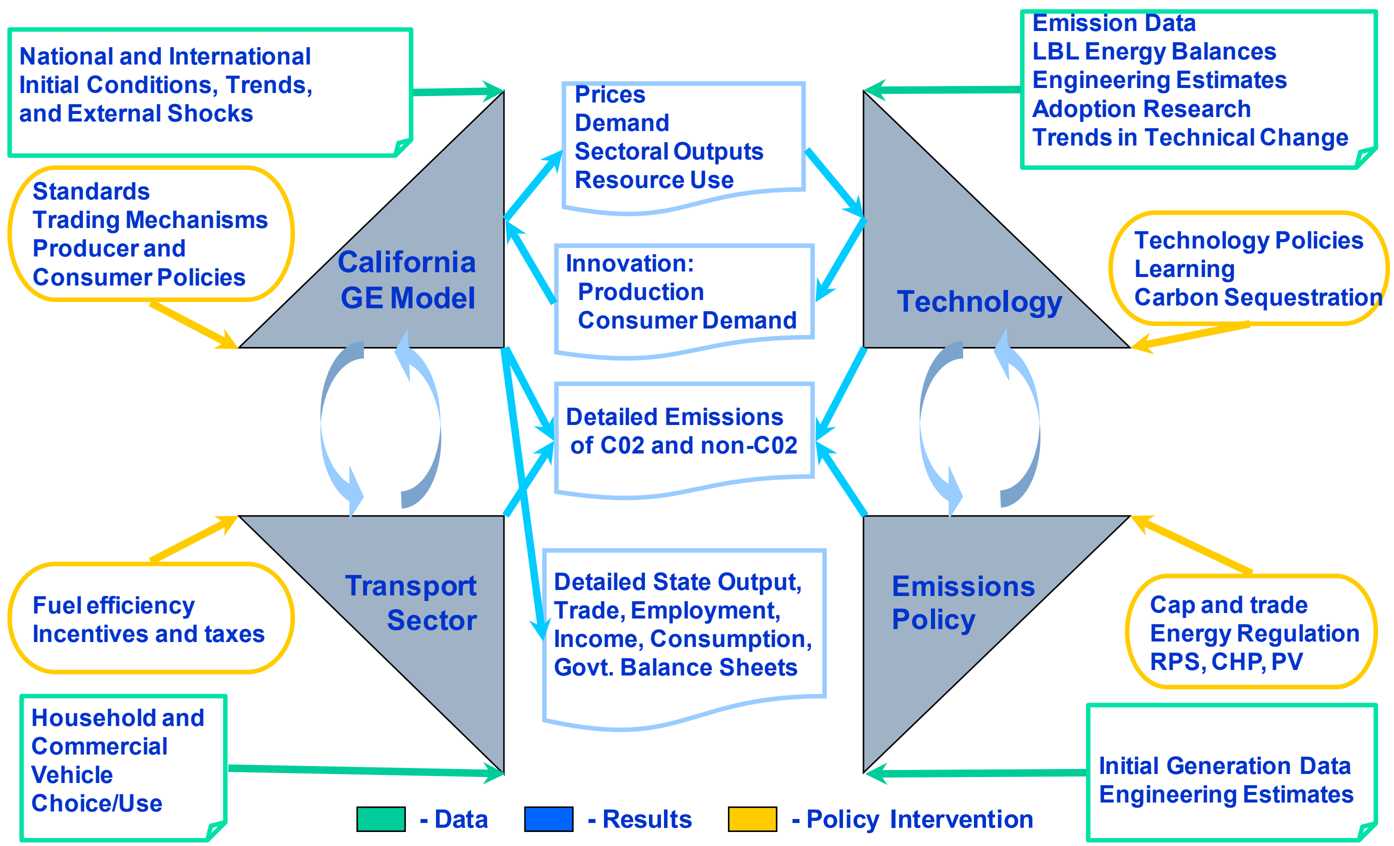
Figure A1.2: Schematic Linkage between Model Components



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8.9 Dynamic calibration

The model is calibrated on exogenous growth rates of population, labor force, and GDP. In the so-called Baseline scenario, the dynamics are calibrated in each region by imposing the assumption of a balanced growth path. This implies that the ratio between labor and capital (in efficiency units) is held constant over time.[43] When alternative scenarios around the baseline are simulated, the technical efficiency parameter is held constant, and the growth of capital is endogenously determined by the saving/investment relation.

8.10 Modelling Emissions

The BEAR model captures emissions from production activities in agriculture, industry, and services, as well as in final demand and use of final goods (e.g. appliances and autos). This is done by calibrating emission functions to each of these activities that vary depending upon the emission intensity of the inputs used for the activity in question. We model both CO2 and the other primary greenhouse gases, which are converted to CO2 equivalent. Following standards set in the research literature, emissions in production are modeled as factors inputs. The base version of the model does not have a full representation of emission reduction or abatement. Emissions abatement occurs by substituting additional labor or capital for emissions when an emissions tax is applied. This is an accepted modeling practice, although in specific instances it may either understate or overstate actual emissions reduction potential.[44] In this framework, mission levels have an underlying monotone relationship with production levels, but can be reduced by increasing use of other, productive factors such as capital and labor. The latter represent investments in lower intensity technologies, process cleaning activities, etc. An overall calibration procedure fits observed intensity levels to baseline activity and other factor/resource use levels. In some of the policy simulations we evaluate sectoral emission reduction scenarios, using specific cost and emission reduction factors, based on our earlier analysis (Hanemann and Farrell: 2006).

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[43]This involves computing in each period a measure of Harrod-neutral technical progress in the capital-labor bundle as a residual. This is a standard calibration procedure in dynamic CGE modeling.

[44] See e.g. Babiker et al (2001) for details on a standard implementation of this approach.

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The model has the capacity to track 13 categories of individual pollutants and consolidated emission indexes, each of which is listed in

below. Our focus in the current study is the emission of CO2 and other greenhouse gases, but the other effluents are of relevance to a variety of environmental policy issues. For more detail, please consult the full model documentation.

An essential characteristic of the BEAR approach to emissions modeling is endogeniety. Contrary to assertions made elsewhere (Stavins et al:2007), the BEAR model permits emission rates by sector and input to be exogenous or endogenous, and in either case the level of emissions from the sector in question is endogenous unless a cap is imposed. This feature is essential to capture structural adjustments arising from market based climate policies, as well as the effects of technological change.

Table A1.1: Emission Categories

Air Pollutants		
1.	Suspended particulates	PART
2.	Sulfur dioxide (SO_2)	SO2
3.	Nitrogen dioxide (NO_2)	NO2
4.	Volatile organic compounds	VOC
5.	Carbon monoxide (CO)	CO
6.	Toxic air index	TOXAIR
7.	Biological air index	BIOAIR
Water Pollutants		
8.	Biochemical oxygen demand	BOD
9.	Total suspended solids	TSS
10.	Toxic water index	TOXWAT
11.	Biological water index	BIOWAT
Land Pollutants		
12.	Toxic land index	TOXSOL
13.	Biological land index	BIOSOL

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Table A1.2 California SAM for 2006 – Structural Characteristics

1.	124 production activities
2.	124 commodities (includes trade and transport margins)
3.	3 factors of production
4.	2 labor categories
5.	Capital
6.	Land
7.	10 Household types, defined by income tax bracket
8.	Enterprises
9.	Federal Government (7 fiscal accounts)
10.	State Government (27 fiscal accounts)
11.	Local Government (11 fiscal accounts)
12.	Consolidated capital account
13.	External Trade Account

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Table A1.3: Aggregate Accounts for the Prototype California CGE

1) 50 Production Sectors and Commodity Groups

Sectoring Scheme for the BEAR Model

The following sectors are aggregated from a new, 199 sector California SAM

	Label	Description
1	A01Agric	Agriculture
2	A02Cattle	Cattle and Feedlots
3	A03Dairy	Dairy Cattle and Milk Production
4	A04Forest	Forestry, Fishery, Mining, Quarrying
5	A05OilGas	Oil and Gas Extraction
6	A06OthPrim	Other Primary Products
7	A07DistElec	Generation and Distribution of Electricity
8	A08DistGas	Natural Gas Distribution
9	A09DistOth	Water, Sewage, Steam
10	A10ConRes	Residential Construction
11	A11ConNRes	Non-Residential Construction
12	A12Constr	Construction
13	A13FoodPrc	Food Processing
14	A14TxtAprl	Textiles and Apparel
15	A15WoodPlp	Wood, Pulp, and Paper
16	A16PapPrnt	Printing and Publishing
17	A17OilRef	Oil Refining
18	A18Chemicl	Chemicals
19	A19Pharma	Pharmaceutical Manufacturing
20	A20Cement	Cement
21	A21Metal	Metal Manufacture and Fabrication
22	A22Aluminm	Aliminium
23	A23Machnry	General Machinery
24	A24AirCon	Air Conditioning and Refridgeration
25	A25SemiCon	Semi-conductor and Other Computer Manufacturing
26	A26ElecApp	Electrical Appliances
27	A27Autos	Automobiles and Light Trucks
28	A28OthVeh	Vehicle Manufacturing
29	A29AeroMfg	Aeroplane and Aerospace Manufacturing
30	A30OthInd	Other Industry
31	A31WhlTrad	Wholesale Trade
32	A32RetVeh	Retail Vehicle Sales and Service
33	A33AirTrns	Air Transport Services
34	A34GndTrns	Ground Transport Services
35	A35WatTrns	Water Transport Services
36	A36TrkTrns	Truck Transport Services
37	A37PubTrns	Public Transport Services
38	A38RetAppl	Retail Electronics
39	A39RetGen	Retail General Merchandise
40	A40InfCom	Information and Communication Services
41	A41FinServ	Financial Services
42	A42OthProf	Other Professional Services
43	A43BusServ	Business Services
44	A44WstServ	Waste Services
45	A45LandFill	Landfill Services
46	A46Educatn	Educational Services
47	A47Medicin	Medical Services
48	A48Recratn	Recreation Services
49	A49HotRest	Hotel and Restaurant Services
50	A50OthPrSv	Other Private Services

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2) Labor Categories
   a) Skilled
   b) Unskilled
3) Capital
4) Land
5) Natural Resources
6) 8 Household Groups (by income
   a) HOUS0 (<$0k)
   b) HOUS1 ($0-12k)
   c) HOUS2 ($12-28k)
   d) HOUS4 ($28-40k)
   e) HOUS6 ($40-60k)
   f) HOUS8 ($60-80k)
   g) HOUS9 ($80-200k)
   h) HOUSH ($200+k)
7) Enterprises
8) External Trading Partners
   a) ROUS Rest of United States
   b) ROW Rest of the World

These data enable us to trace the effects of responses to climate change and other policies at unprecedented levels of detail, tracing linkages across the economy and clearly indicating the indirect benefits and tradeoffs that might result from comprehensive policies pollution taxes or trading systems. As we shall see in the results section, the effects of climate policy can be quite complex. In particular, cumulative indirect effects often outweigh direct consequences, and affected groups are often far from the policy target group. For these reasons, it is essential for policy makers to anticipate linkage effects like those revealed in a general equilibrium model and dataset like the ones used here.

It should be noted that the SAM used with BEAR departs in a few substantive respects from the original 2003 California SAM. The two main differences have to do with the structure of production, as reflected in the input-output accounts, and with consumption good aggregation. To specify production technology in the BEAR model, we rely on both activity and commodity accounting, while the original SAM has consolidated activity accounts. We chose to maintain separate activity and commodity accounts to maintain transparency in the technology of emissions and patterns of tax incidence. The difference is non-trivial and considerable additional effort was needed to reconcile use and make tables separately. This also facilitated the second SAM extension, however, where we

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maintained final demand at the full 119 commodity level of aggregation, rather than adopting six aggregate commodities like the original SAM.

Emissions Data

Emissions data at a country and detailed level have rarely been collated. An extensive data set exists for the United States that includes thirteen types of emissions.[45] The emission data for the United States has been collated for a set of over 400 industrial sectors. In most of the primary pollution databases, measured emissions are directly associated with the volume of output. This has several consequences. First, from a behavioral perspective, the only way to reduce emissions, with a given technology, is to reduce output. This obviously biases results by exaggerating the abatement-growth tradeoff and sends a misleading and unwelcome message to policy makers.

More intrinsically, output based pollution modeling imperfectly to capture the observed pattern of abatement behavior. Generally, firms respond to abatement incentives and penalties in much more complex and sophisticated ways by varying internal conditions of production. These responses include varying the sources, quality, and composition of inputs, choice of technology, etc. The third shortcoming of the output approach is that it give us no guidance about other important pollution sources outside the production process, especially pollution in use of final goods. The most important example of this category is household consumption.

8.11 Renewable Energy Cost Estimates

To impute costs to the renewable technologies being considered in our RPS scenarios, we combined data from multiple sources. The relevant information is summarized in the following

[45] See Martin et. al. (1991).

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Table A1.4: Data and Assumptions for Renewable Cost

Technology	Capacity		Unit Costs				
	kW	Capital Cost ($/kW)	O&M ($/kW-year)	Fuel Cost	Capacity Factor	Capacity Discount	Incentive Percent
Central PV	100,000	$4,823	$10		25%	10%	46%
Commercial PV	75	$5,649	$11		25%	10%	46%
Residential PV	4	$7,200	$35		25%	0%	28%
Central CSP	100,000	$3,744	$55		40%	10%	46%
Central Wind	100,000	$1,434	$29		30%	50%	
Central Wind Offshore	100,000	$2,872	$87		30%	28%	
NGCC 2009	500,000	$706	$11	$4.50	70%		
NGCC 2020 DOE	500,000	$706	$11	$9.00	70%		
NGCC 2020 IEA	500,000	$706	$11	$14.50	70%		
Finance							
Discount Rate	4%						
Comparable Lifetime	25						
Capital Recovery Factor	0.064						

Sources: Wiser et al (2009), RETI (2009abc), CPUC (2009), Milligan and Porter (2005).

Levelized costs provide a means for comparing technologies with different design lifetimes and cost characteristics. For electricity generating technologies, there are generally four costs that are included in levelized cost calculations:

1. Capital costs, which are generally financed
2. Fixed annual costs
3. Operations and maintenance (O&M) costs

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4. Fuel costs, if any

Cost	Units	Description
Capital costs	$/kW	Capital costs are often expressed in unit (per kW) terms. For instance, a 100 MW wind farm with a total capital cost of $300 million has a unit capital cost of $3,000/kW (1 MW = 1,000 kW).
Fixed annual costs	$/kW-yr	Fixed annual costs are expressed in terms of $/kW-yr, reflecting the fact that these costs are paid annually irrespective of output. Insurance and licensing, for instance, are fixed annual costs.
O&M costs	$/kWh	O&M costs are typical variable costs, and are expressed in terms of output ($ per kWh generated).
Fuel costs	$/kWh	Fuel costs also depend on output, and are expressed in kWh terms.

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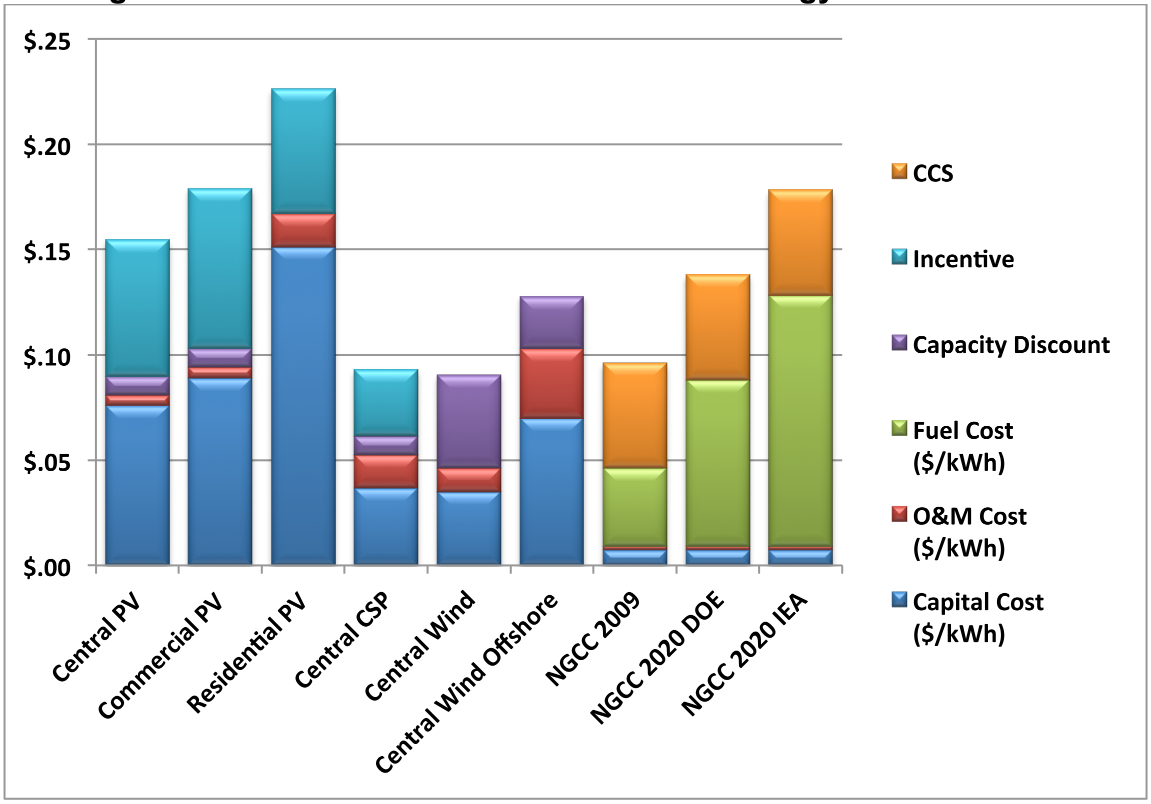
Figure A1.3: Renewable and Conventional Energy Cost Estimates



Source: Roland-Holst, David "Energy Prices and California's Economic Security," Next10.org, October, 2009.See the Annex below for estimation details.

The most common approach to converting these costs into equivalent units is to annualize capital costs, and convert both capital and fixed costs to variable units by normalizing them by total operating hours.

Capital costs (CC) are annualized using a capital recovery factor (CRF)

$$CRF = \frac{r}{(1-(1+r)^{-t})}$$

where r and t can either reflect financing terms or, more frequently, a discount rate and a design lifetime.

Annualized capital costs (ACC) are thus

$$ACC = CC \times CRF$$

`

Annualized capital costs and fixed costs, now both in units of \$/kW-yr, can be converted into variable costs by normalizing both by the number of annual hours that a given technology operates. Operating hours for different technologies are typically calculated using a rule of thumb capacity factor, defined as

$$CF = \frac{Annual\ Operating\ Hours}{Total\ Hours\ per\ Year}$$

Baseload coal- and natural gas-fired power plants, for instance, operate most of the year and have high capacity factors (~0.8), whereas intermittent resources like solar and wind are only available for a limited number of hours per year and have lower capacity factors (~0.2-0.4).

Total levelized costs (LVC, in \$/kWh) can then be calculated as

$$LVC = \frac{ACC + FXC}{(CF \times 8760)} + OMC + FLC$$

where FXC is an annual fixed cost, OMC is an O&M cost, and FLC is a fuel cost.

Fuel costs can be calculated with the following formula:

$$\frac{\left(\frac{1}{\text{Efficiency}} \times 3.6\right)}{\text{Heating Value}_{\text{Fuel}}} \times \text{Price}_{\text{Fuel}}$$

where the efficiency is the thermal efficiency of the generating facility, 3.6 is a conversion factor between kWh and MJ, heating value is the higher heating value (energy content) of the fuel, and price is the price of the fuel in physical (mass or volume) units.

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Annex 2: Emission Categories

For the present research, we developed estimates of sector pollution intensities from official California data. The most detailed information comes from the emissions inventory (http://www.arb.ca.gov/cc/inventory/inventory.htm), of the Air Resources Board was aggregated to conform to BEAR's 50 sector structure, with the resulting initial year sector inventory in Table 4.1 above. Using real output values, these were then converted to emission factors by pollutant and sector. From this point, a dynamic baseline was created by stepping down some criteria intensities based on independent information regarding standards and other mitigation measures outside of AB 32, such as NOx regulations for future truck and rail transport. These have been synthesized to avoid double counting. A summary of the measures taken into account is given in the following table:

Table A2.1: Concurrent Emissions Reduction Measures

Measure	Implementing Agency	Pollutants	Affected Sectors
Diesel Risk Reduction Plan (DRRP) - Statewide Diesel Truck and Bus Regulation	ARB	NOx, PM	Trucking, Ground Transport, Construction
Clean Air Act - National Ambient Air Quality Standards (NAAQS)	US EPA – SIP from ARB	PM 2.5	Trucking, Ground Transport, Construction
Statewide Railroad Agreement (2005)	ARB	PM	Rail
U.S. EPA Locomotive Emission Standards (CAA)	US EPA	NOx and PM	Rail
Goods Movement Emission Reduction Plan (GMERP) (2006)	ARB	NOx and PM	Trucking, Ground, Rail
Cargo Handling Equipment Regulations (2007)	ARB	NOx and PM	Trucking, Ground, Rail
Diesel Fuel Regulations Extended to Intrastate Locomotives (2007)	ARB	NOx and PM	Rail

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The BEAR model has the capacity to track several categories of individual pollutants and consolidated emission indexes, each of which is listed in Table A2.2 below. Our focus in the current study is the effect of offsets policies on the emission of gases other than greenhouse gases. Generally speaking, criteria pollutant emissions are much more heterogeneous than global warming emissions, and a sector-level emission factor cannot capture the different emission rates at different facilities under different conditions (i.e. with variation in maintenance regimes or post- combustion controls). Further, we do not take into account interactions with the RECLAIM program for controlling NOx. To the extent that reductions in NOx occur at facilities covered by RECLAIM, these could free up RECLAIM allowances that would result in increased pollution at facilities not directly covered by a cap-and-trade program aiming to reduce global warming measures. At the same time, while acknowledging that this analysis is imperfect, we use statewide average emission rates and believe these can usefully inform the policy dialogue. The only real restriction on this assumption for the electric power industry is the capacity of the north-south grid. We have calculated emission rates for southern California electric power, including RECLAIM, and northern California power, including significant hydro resources. The emission rates for these two regions differ by less than 2 percent.

An essential characteristic of the BEAR approach to emissions modeling is endogeneity. Contrary to assertions made elsewhere (Stavins et al:2007), the BEAR model permits emission rates by sector and input to be exogenous or endogenous, and in either case the level of emissions from the sector in question is endogenous unless a cap is imposed. This feature is essential to capture structural adjustments arising from market based climate policies, as well as the effects of technological change.

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