Research Paper No.1007241

Real Incomes, Employment, and California Climate Policy

David Roland-Holst

November, 2010

CENTER FOR ENERGY, RESOURCES, AND ECONOMIC SUSTAINABILTY

DEPARTMENT OF AGRICULTURAL AND
RESOURCE ECONOMICS
338 GIANNINI HALL
UNIVERSITY OF CALIFORNIA
BERKELEY, CA 94720
PHONE: (1) 510-643-6362
FAX: (1) 510-642-1099
WEBSITE: www.berkeley.edu/~dwrh/ceres

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.

For this project on Incomes, Employment, and California Climate Policy, financial support from Next 10 is gratefully acknowledged. Thanks are also due for outstanding research assistance by Samuel Heft-Neal, Ian Horton, Fredrich Kahrl, Sam Shaw, and Ryan Triolo.

F. Noel Perry, Sarah Henry, Morrow Cater, Chris Busch, Adam Rose, and many other colleagues offered helpful insights and comments. Opinions expressed remain those of the author, however, and should not be attributed to his affiliated institutions.

Executive Summary

This report provides an economy-wide assessment of how California's Global Warming Solutions Act (AB32) will affect patterns of state economic growth, employment, and income. We used the Berkeley Energy and Resources (BEAR) macro-economic model to simulate AB32 Scoping Plan implementation and consider a variety of alternative schemes for auction/allocation of emissions permits and recycling of revenues accruing from these.

Since its passage in 2006, California's climate initiative, has aroused global attention. Within the state, it is widely acknowledged that GHG policies already implemented and under consideration will have far reaching economic consequences. Both public and private institutions have expressed an urgent interest in better understanding this issue. While no substantive mitigation policy can be without some direct and indirect costs, the benefits from greater energy efficiency, reduced vulnerability to fossil fuel price spikes through greater use of clean energy alternatives and a more diverse energy system, and improved environmental conditions can significantly outweigh these. Thus responsible climate action assessment requires consideration of both the magnitudes and composition of adjustment costs and benefits.

The main goal of this work is 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 pollution rights allocation choices and in particular the efficiency and equity tradeoffs these entail as well are their macroeconomic implications. Seven salient insights emerge from this economic analysis:

Table ES 1: Main Findings

1. ***Aggregate effects of AB32 on the California economy are very modest; amounting to less than three months deferred growth across a decade.***
2. ***Households experience energy efficiency gains that reduce total energy expenses. In other words, the policy as written has a small positive net cost to the overall economy, but a significant negative net cost in terms of energy expenses to households.***
3. ***Scalable permit auctions can facilitate adjustment, without compromising long term climate goals, employment, or equity. In particular:***
   a. ***Auctioning permits and distributing the revenue to households (Cap and Dividend) reduces the aggregate cost of climate policies and can increase statewide employment.***
   b. ***Returning permit revenues to households with tax reductions is better for growth and total employment than equal per capita lump sum transfers.***
4. ***Free allocation of permits might reduce adjustment costs for individual polluting industries, but it increases costs for the population of California.***
5. ***Modest autonomous innovation and efficiency responses to AB32 would deliver significant growth dividends across the state.***
6. ***The estimated risk of "leakage" posed by AB32, either in terms of job losses or pollution transfers, is negligible.***
7. ***AB32 will reduce aggregate criteria pollution, but might change its composition in ways that justify complementary, localized mitigation efforts. In all cases, however, the impacts are very modest.***

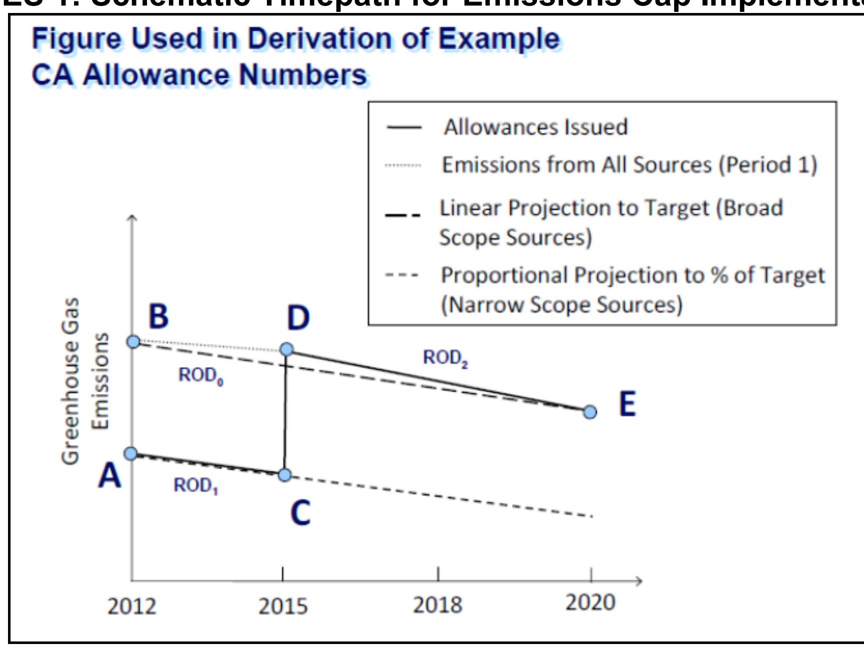
AB32 Assessment

One of the most advanced examples of such independent climate policy research capacity 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. The research summarized below is part of a larger effort to assess the long term implications of AB32 for the California economy.

After its initial contribution to CARB's Scoping Plan (Roland-Holst: 2007a)., the BEAR project was involved for several months in a collaborative model comparison exercise with ARB. This activity entailed comparison of results from BEAR, ARB's own EDRAM model, and the MRN-NEEM model developed by the Electric Power Research Institute (EPRI) and Charles Rivers Associates (EPRI:2007). The point of the exercise was to appraise California climate policy from a variety of perspectives, using the models most closely associated with various stakeholders in the policy process. To facilitate results comparison, ARB set forth a uniform set of policy scenarios, in each case involving a combination of the leading CAT policies and market oriented carbon cap measures that would be designed to make up the difference between CAT mitigation and the state's official goals for GHG reduction.

For the present assessment, we build on this experience to elucidate the revenue management, or fiscal characteristics of AB32, with careful attention to both the timepath of implementation and impacts on income distribution. Figure ES 1 illustrates the path of Cap and Trade implementation, as set forth by CARB. The intertemporal complexity of this rulemaking may create complex incentives and structural adjustments, and for this reason we incorporate it explicitly in the BEAR dynamic analysis.

Figure ES 1: Schematic Timepath for Emissions Cap Implementation



Source: CARB (2009)

To model the implementation of the anticipated Cap and Trade rulemaking explicity, we use annual calculations of scope, permit requirements, allowable offsets, and the cap itself, based on CARB official data and summmarized in Table ES 2. In the recently released draft cap-and-trade regulation, some modest changes have been made to these policy parameters, but these small changes do not affect the fundamental insights provided by this work.

Table ES 2: Estimated Allowance Budgets

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Narrow Scope	197.2	193.4	189.5	185.7					
Fuels Estimate (2015)				235.3					
Broad Scope				421.0	409.8	398.6	387.4	376.2	365.0
Allowances Per Year	197.2	193.4	189.5	421.0	409.8	398.6	387.4	376.2	365.0
Offset Use (CARB)	8.2	8.0	7.9	17.5	17.0	16.5	16.1	15.6	15.2
Cap on Covered Emissions	205.4	201.4	197.4	438.5	426.8	415.2	403.5	391.8	380.2

Source: CARB (2009).

This phased implementation scheme is a necessary acknowledgement of the diversity of California's economic structure, with differing emissions intensities, technological issues, and administrative engagement. On the economic assessment side, an essential feature of diversity is the state's income distribution. It is well known that lower income households face different challenges from higher income ones in nearly every dimension of economic activity, and energy use and emissions are no exception. For this reason, the current analysis takes explicit account of difference in initial conditions, economic behavior, and outcomes across the spectrum of households encompassed by California's tax code. In particular, as detailed in Table ES 3 below, we track seven household groups throughout the analysis, including their detailed linkages to production activities, state government, and the national economy, across income and expenditure chains.

Table ES 3: California Households and Population by Income Tax Bracket (California Department of Finance: 2006, millions of people)

		Households	Cumulative	Population	Cumulative	Percent
1	< $12k	1.220	1.340	3.575	3.926	9.752
2	$12-28k	2.360	3.580	6.915	10.489	18.86
3	$28-40k	1.650	5.230	4.835	15.324	13.19
4	$40-60k	2.110	7.340	6.182	21.506	16.87
5	$60-80k	1.650	8.990	4.835	26.341	13.19

6	$80-200k	3.140	12.130	9.200	35.541	25.10
7	$200k+	0.380	12.510	1.113	36.654	3.04
	Total	12.510		36.654		100

With these distributional considerations in mind, we now specify a set of policy scenarios, based on CARB's reference Case 1, to assess the impacts of AB32 under alternative permit auction and revenue allocation schemes. These five basic scenarios are summarized in Table ES 4, where Case 1 includes both Cap and Trade and all complementary measures.

Table ES 4: Scenarios analyzed in this Assessment

S1. **Cap and Full Dividend** - 100% auction of output based pollution permits in each year
- a. 100% revenue recycling via income tax reduction (equi-proportionate reductions in all baseline tax income tax rates)
- b. 100% recycling via per capita dividend (equal payments to each household)

S2. **Cap and Half Dividend** - 50% free permit allocation to industries, 50% auction
- a. 100% recycling of auction revenue via income tax reduction (equi-proportionate reductions in all baseline tax income tax rates)
- b. 100% recycling of auction revenue via per capita dividend (equal payments to each household)

S3. **Free Pollution** – 100% free permit allocation to industries, based on baseline emissions, annually from 2012 to 2020

S4. **Innovation/Efficiency** - Carb Case 1, inclusive of an additional increase in equivalent to 1% annual Autonomous Energy Efficiency Improvement (AEEI) across the state (2012-2020). Full Auction and Dividend

With these distributional considerations in mind, we now specify a set of policy scenarios, based on CARB's reference Case 1, to assess the impacts of AB32 under alternative permit auction and revenue allocation schemes. These six basic scenarios all use CARB's Case 1 as their starting point, and are summarized in Table 7. Recall that Case 1 includes both Cap and Trade and all complementary measures.

Permit Allocation and Revenue Recycling

Pollution rights and permits for these rights recognize air quality as a public good, but their pricing and allocation of the associated revenues ("recycling") present complex and important policy challenges. To implement AB32 in a socially effective manner, CARB constituted a panel of experts, the Economic Allocation and Advisory Committee (EAAC), to consider these issues carefully and recommend the best approaches. This panel of experts characterized the policy challenge this way:

> "There are two main elements of allocation design. One is to specify the *mechanisms for allowance distribution*, that is, the way that emissions allowances are to be put into circulation. This can be done by free provision to various entities or by auctioning. The other element is to determine the pattern of *provision of allowance value,* that is, how the value of the emissions allowances will be distributed across various parties. If allowances are freely issued, then allowance value goes to the recipients of these free allowances. If allowances are auctioned, allowance value goes to the parties to whom the revenues from the auction are directed." (EAAC: 2010)

As other studies have shown at the national level (e.g. Goulder et al:2009, Burtraw and Palmer:2008), the choices of both allowance distribution and value provision can affect economic efficiency and fairness. If firms pay for the right to pollute in an auction (S1), the resulting cost for industry can be offset for society by returning the permit revenues to society. The net economic impact of this approach, taxing a negative social externality and returning the revenues to households, depends on complex adjustments in industry and extended demand effects in consumption. When permits to pollution are given away (S3), society bears the burden of pollution without compensation, and firms adapt to limits on global warming pollution while reaping windfall profits on tradable permit values. These are the general equilibrium effects that a model like BEAR is designed to elucidate.

Once the scope of auctioning is decided, governments can do many things with permit revenue. In this study, test the implications of the current recommendations of the state's Economic and Allocation Advisory Committee (EAAC) and California Air Resource Board, redistributing or recycling permit revenues to households, an approach popularly known as Cap and Dividend. The actual recycling rule itself is important, and here we consider two basic alternatives, (1) tax reduction and (2) equal per capita transfer payments.

Table ES 5: Level and Composition of Permit Revenue Rebates and Transfers
(based on a permit price of $21/MMT, 2007 millions of dollars)

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Permit Value	4,279	4,195	4,111	9,133	8,890	8,647	8,404	8,161	7,918
Free Allocation	4,279	3,671	3,084	5,708	4,445	3,243	2,101	1,020	-
Per Capita Dividend	-	524	1,028	3,425	4,445	5,404	6,303	7,141	7,918
Total Dividends	-	-	-	-	-	-	-	-	-
< $12k	-	51	100	334	433	527	615	696	772
$12-28k	-	99	194	646	839	1,020	1,189	1,347	1,494
$28-40k	-	69	136	452	586	713	831	942	1,044
$40-60k	-	88	173	578	750	912	1,063	1,204	1,335
$60-80k	-	69	136	452	586	713	831	942	1,044
$80-200k	-	132	258	860	1,116	1,357	1,582	1,792	1,987
$200k+	-	16	31	104	135	164	191	217	241
Total	-	524	1,028	3,425	4,445	5,404	6,303	7,141	7,918
Average/HH	-	42	82	274	355	432	504	571	633

Note: Flows are totals for all households in each tax bracket, not per household amounts.
Source: Author estimates.

In Table ES 5, we present calculations of the flows of estimated permit value, as these would accrue in the recycling scenarios above. To be concise, we use the Scenario 2b scalable auction scheme and per capita transfers as an example. Permits are assumed to be allocated on the basis of baseline emissions, but since we only have one representative firm per industry this is equivalent to output based allocation.[1] Comparing these results to the aggregate household income impacts at the outset of this section, we can see that recycling is an important offset to the cost of the program, even when firms are allowed to more gradually assume the burden of carbon costs.

The Role of Innovation

An important characteristic of most AB32 scenario analyses is technological neutrality.[2] This means that, apart from energy savings embodied in complementary measures (e.g. fuel efficiency mandates), factor productivity, energy use intensities, and other innovation characteristics were held constant across cap and trade scenarios. Energy use and pollution levels might change, but the prospects for innovation to reduce energy intensity and improve productivity were not considered. This perspective

[1] This distinction is quite important to the incentive and efficiency properties of the policy. See e.g. Fischer and Fox: 2004 for discussion.
[2] This includes all estimates by CARB (2010), Charles River Associates (2010), and many others.

is unrealistic and significantly biases results against climate policy. Technological change in favor of energy efficiency has been a hallmark of California's economic growth experience over the last four decades. Over this period California has reduced its aggregate energy intensity by about 1.5% per year, attaining levels that today are 40% below the national average. Structural changes in the economy have played a role, but most observers give a significant amount of credit this technological progress to California's energy/climate policies, combinations of mandated and incentive based efficiency measures from which the Climate Action Team recommendations are direct descendants. Thus, energy innovation has been part of the history of the state's economic growth and at the same time a consequence of its policies.

Macroeconomic Results

For the scenarios discussed above, the BEAR macroeconomic assessment effects are presented in Table ES 6 below. A few salient results are immediately apparent in both tables. Firstly, central tenets of the EAAC advisory report are strongly supported by these findings. In particular:

1. Permit auctions with revenue recycling reduce overall costs to the state economy.

2. For recycling, income tax relief is more efficient (lower cost) from a macroeconomic perspective than lump sum transfers.

3. Free allocation of the right to pollute increases economic costs to society.

The reasons for these three impacts are already widely discussed in the literature on allocation, although this is the first effort to measure them in the context of AB32. Goulder et al (2009) found the same kinds of effects at the national level, and Burtraw and Palmer (2008) have similar findings that are focused on the electric power sector. What is novel about these California results is the magnitude of the demand side impact of revenue recycling.

Table ES 6: Aggregate Adjustments
(percent changes from baseline values in 2020)

	S1a Full-a	S1b Full-b	S2a Half-a	S2b Half-b	S3 Free	S4 AEEI

Total GHG*	-27.58	-27.67	-27.79	-27.83	-27.78	-25.96
Household GHG*	-31.47	-31.50	-31.48	-31.49	-31.48	-31.31
Industry GHG*	-25.33	-25.47	-25.66	-25.73	-25.64	-22.87
Real GSP	-0.23	-0.31	-0.52	-0.56	-0.67	4.44
Real Consumption	0.01	0.39	-0.95	-0.77	-1.97	3.97
Employment*	0.55	0.58	-0.21	-0.19	-0.61	3.10
Permit Price	$21	$19	$31	$28	$43	$18
Jobs Created (1000)	163	177	65	70	47	623
Jobs Lost	-53	-62	-107	-108	-167	-9
Net	109	115	-41	-38	-120	614
Income Per Capita	-103	-137	-231	-248	-296	1,959

Source: Author estimates.
Permit price in 2007 dollars per metric ton of CO2 equivalent carbon, in 2020.

As many authors (e.g. Smith et al: 2002, Smith and Ross: 2002, Stavins: 2007) have already observed, however laudable the goal of climate change mitigation, permit auctions present costs to polluting industries. Goulder et al (2009) make a more subtle point that the resource royalty value of permits, even if received free, still embeds an opportunity cost on firm balance sheets, presenting an opportunity to profit by reducing output. In either case, permits induce an adverse supply side shock on the economy. If they are auctioned and the revenues given to households, however, this creates an offsetting demand side stimulus.

Ultimately, the net macroeconomic impact depends on the magnitude and composition of these two, and the results in Table ES 6 show how complex this can be. For example, when all permits are auctioned and all revenue given to households (S1ab), the demand side stimulus offsets nearly all the supply side shock. Conversely, free allocation of permits reduces the demand side potential of recycling and therefore increases net economic costs.

More dramatically, demand side forces actually increase total California employment, creating over 100,000 additional jobs by 2020. The reason employment can increase while GSP remains essentially constant is because the demand growth from revenue recycling is more employment intensive than are the sectors with lower growth under AB32. Like most OECD economies, California is properly seen as post-industrial in structure, with more than two-thirds of demand, value-added, and employment in service sectors. As the following figure illustrates, these sectors are 10-50 times more job intensive (per million of output value) than the carbon fuel supply chain. For this simple reason, transferring resources from the latter to households (Expenditure Shifting) will create more jobs.[3]

A second robust finding of this analysis is at least as important. The overall growth impact in all four Case 1 versions of this ambitious climate policy package is very modest or even negligible, changing state real GSP by about half of one percent annually by 2020, cumulative GSP about half this much, and real state employment in 2020 by even less. Under our hypothetical induced innovation scenario, whereby energy and emissions policies lead to meaningful gains in energy efficiency over the business-as-usual scenario, employment in the state actually increases significantly, as productivity rises and expenditures shift from imported energy dependence to demand for more labor-intensive in-state goods and services. What this means in practical terms is quite simple. The state can achieve its ambitious climate objectives, unprecedented GHG mitigation, over the next decade with a deferred growth impact of about three months. Since we have taken no account of the environmental cost of doing nothing, this seems like a real bargain.[4]

Permit prices are obviously central to this analysis and to Cap and Trade generally. The BEAR model estimates these prices as the outcome of a market process that, in a competitive auction of pollution rights, would equate permit prices with the economywide private marginal cost of CO2 abatement. As the results in Table ES-6 suggest, BEAR estimates of this cost are comparable to those of CARB (coinciding in the reference case), but lower than many estimates circulated by industry sources.

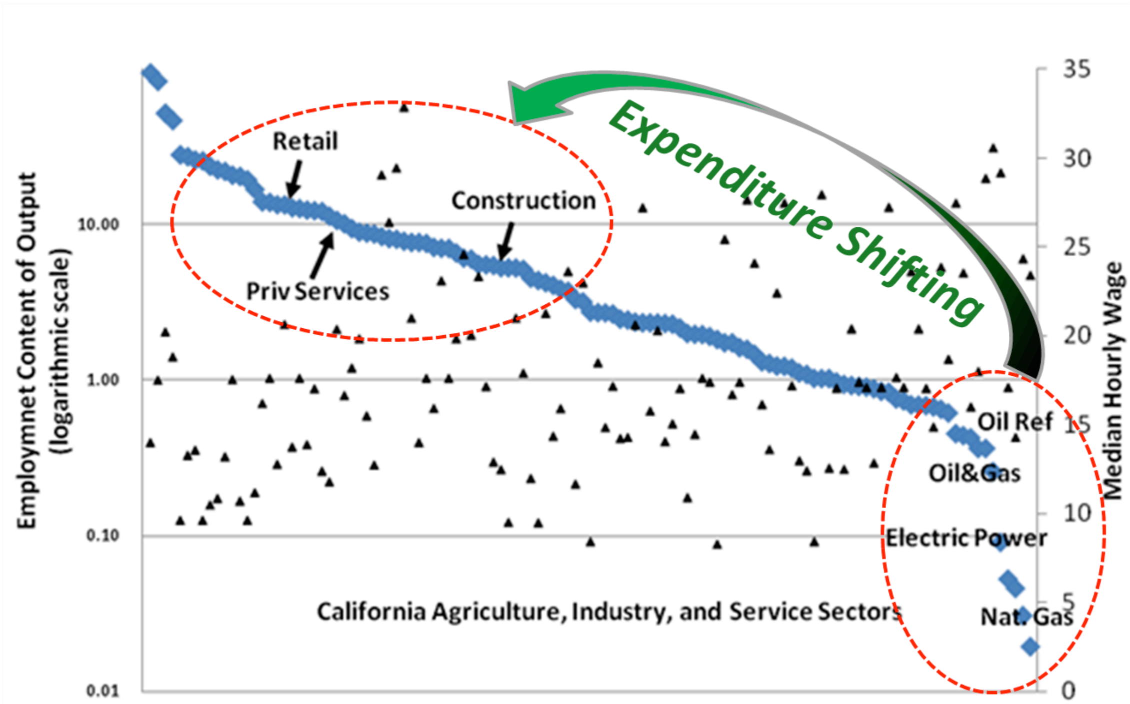
Our estimated permit prices vary somewhat across scenarios, with permit prices rising as with the proportion of free allowance allocation and falling with energy efficiency improvements (S4). When some share of permits are allocated free, the remaining marketable share is constrained and competition for these intensifies. Looked at another way, in a competitive framework lower cost permits will be used to cover lower (abatement) cost emission reductions, so tradable permit prices reflect the higher end of the abatement cost curve. Permit prices are slightly lower in the lump sum redistribution case because changing demand patterns shift economic structure toward tertiary, less pollution intensive activities.

---

[3] Because carbon fuels are also import-intensive, more demand will be directed at in-state goods and services. As others have observed, however, this import reduction will be offset by real exchange rate appreciation, attendant export reductions, and ambiguous net employment effects.
[4] For a detailed review of California climate impacts, see e.g. Kahrl and Roland-Holst: 2008.

On the general issue of job estimates, two important points should be made. Firstly, even in the strongly negative scenario (S3/Free Pollution), there is no reduction in aggregate California employment, Baseline growth far exceeds the estimated downward adjustment by 2020 (about 27%). In none of these results do we see job losses compared to levels today, only slower employment growth. Secondly, although net job changes are small, job turnover as result of AB32 is often much larger. Because the skill required for these jobs can be quite different, this labor market adjustment will be a more complex prospect than suggested by merely adding new and lost job numbers to find the result for net employment.

Figure ES 2: How Revenue Recycling and Energy Efficiency Create Jobs



Source: Roland-Holst, David "Energy Efficiency, Innovation, and Job Creation in California," Next10.org.

Finally, the efficiency and innovation scenario (S4/AEEI), is by far the most pro-growth. The reason for this is productivity growth via technology adoption and more intensive expenditure shifting, i.e. multiplier effects, coming from two sources. A carbon trading system provides a direct and transparent incentive for technology adoption and reduce carbon fuel expenditures, and to change expenditure patterns in ways that promote innovation. If users face the prospect of paying for pollution rights, their expenditures shift toward public goods and services that are more employment intensive than would be higher fuel spending. Those who avoid permit fees by investing in energy efficiency will save money in the long run, spending that on more conventional and generally more job intensive alternatives. This pattern of direct and indirect expenditure shifting has for a generation helped California to ever higher environmental and living standards. The future holds the same promise for positive, innovation based synergy between environmental values and livelihoods, and forward looking policies like AB32 can help to realize this potential, securing prosperity for another generation.

In terms of permit prices, we see some variation across scenarios. In comparison to tax reductions ($21 allowance price, S1a), lump-sum redistribution leads to lower long term demand stimulus and thus achieves emission reduction at a slightly lower price

($18 allowance price in S1b. When pollution is partially or completely free, two forces are at work. Demand side weakness (less recycling resources) makes emission reduction cheaper, but permit discounts reduce the incentive to abate pollution. For the free permit scenarios considered (S2ab, S3), the latter prevails and higher nominal permit prices are needed to offset (average) permit discounting. Finally, the AEEI scenario achieves mitigation by Cap and Trade as well as higher innovation potential, meaning a lower permit price can hit AB32's mitigation targets.

Before moving on to the distributional results, the effects of these policies on energy prices should be considered (Table ES 7). After aggregate growth, the "burden" of energy costs has been the most debated issue surrounding climate action. Imposing a price on carbon emissions will obviously increase the cost of carbon-based energy sources, but the ultimate impact of this on prices depends on both supply and demand. The BEAR results suggest that the demand side of energy markets, under determined policies of climate action, will prevail in many cases and substantially mitigate price increases in others. In contrast to industry estimates of 20% and higher electricity price increases, we see single-digit increases in technology neutral scenarios and price declines in more the historical efficiency/productivity scenario.[5] Meanwhile, natural gas prices actually decline, gasoline prices rise negligibly, and overall energy price indexes for households and all state demand rise only modestly over the decade.

Table ES 7: Energy and Fuel Prices
(percent changes from baseline in 2020)

	S1a Full-a	S1b Full-b	S2a Half-a	S2b Half-b	S3 Free	S4 AEEI
Electricity	2.3%	2.1%	3.3%	3.1%	4.1%	-5.4%
Nat. Gas	-1.2%	-0.9%	-1.3%	-1.0%	-2.4%	-2.7%
Gasoline	2.2%	2.1%	3.3%	3.1%	3.8%	-2.0%
HH Energy	1.6%	1.5%	2.4%	2.3%	2.7%	-3.5%
All Energy	0.9%	0.9%	1.5%	1.5%	1.4%	-3.3%

Source: Author estimates.

[5] It should be emphasized that the present modeling framework assumes electricity prices are market determined, a simplification that may not be too restrictive in the long run, but needs to be interpreted with care.

Household Results

We now examine AB32 impacts from the household perspective. Table ES 8 provides detailed income effects for different tax brackets of household income. As is generally true in economics, beneath the smooth veneer of aggregate growth lies a complex array of adjustments, more diverse outcomes, and even tradeoffs. In the present context, this means that choice of both the permit allocation and revenue recycling scheme is important to income distribution, even with relatively small aggregate stakes. For example, the lowest income group actually benefits in all scenarios, in the first instance because of policy induced energy savings and secondly when the recycling scheme is per capita (S1b and S2b). Conversely, higher income groups lose most because of adverse capital income effects (permit and adoption cost), and even more when recycling is per capita rather than per dollar of prior tax liability.

Table ES 8: Real Income Effects by Household Income Level
(percent changes from baseline in 2020)

	S1a Full-a	S1b Full-b	S2a Half-a	S2b Half-b	S3 Free	S4 AEEI
< $12k	0.3%	1.2%	0.3%	0.8%	0.3%	1.1%
$12-28k	0.1%	0.8%	-0.5%	-0.1%	-0.8%	3.5%
$28-40k	0.2%	0.7%	-0.6%	-0.3%	-0.9%	3.4%
$40-60k	0.5%	1.2%	-0.8%	-0.4%	-1.7%	2.5%
$60-80k	0.2%	0.7%	-0.7%	-0.4%	-1.4%	3.5%
$80-200k	0.0%	-1.2%	-1.2%	-1.7%	-3.2%	4.0%
$200k+	-1.0%	-7.4%	-3.4%	-6.3%	-8.2%	1.6%
Total	0.2%	0.4%	-0.7%	-0.5%	-1.4%	3.1%

Source: Author estimates.

Because of California's progressive tax structure, permit revenue recycling schemes have differing impacts across the income distribution. For lower and middle income households, per capita lump sum recycling is better than tax relief, so it either increases benefits or lowers costs. For the highest income groups, tax breaks would be more attractive because their rates are well above average. Thus their costs under the "a" (tax break) scenarios would be about half those under the per capita rebate scheme. For the economy as a whole, tax relief is better for the macro economy than lump sum transfers, yet some might argue that the latter is more defensible on equity grounds. This point cannot really be adjudicated by economic analysis unless long term growth benefits of tax relief are large and dispersed enough to benefit a significant majority of households, in which case macro efficiency and equity could be reconciled.

In all technology neutral scenarios, however, we see the same small aggregate income effects, deferring about three month's GSP growth in a decade to achieve unprecedented GHG mitigation and enhanced energy security. At the outset of this study, we considered designing targeted energy cost assistance to the poor, in order to address concerns expressed by stakeholder groups and the state itself. The real effect of energy costs on households is detailed in Table ES 9, where we see the interplay of two essential forces, energy prices and energy demand. Simply put, the former are small and mixed while the latter are large and negative. Program efficiency improvements and household incentives to reduce energy use drive demand declines in the same direction, and overall energy expenses are dominated by this effect. In Scenario 4, growth effects offset efficiency gains in terms of energy expenditures. In any case, these results suggest that the issue of energy cost of living adjustments for the poor will be rendered superfluous by a combination of program efficiency gains and market forces, as long as the regulatory apparatus allows energy prices to reflect these.

Table ES 9: Household Overall Energy Expenses

(percent changes from baseline in 2020)

	S1a Full-a	S1b Full-b	S2a Half-a	S2b Half-b	S3 Free	S4 AEEI
< $12k	-10.6%	-10.4%	-10.6%	-10.5%	-10.9%	-14.7%
$12-28k	-8.7%	-8.5%	-8.8%	-8.7%	-9.2%	-12.3%
$28-40k	-9.5%	-9.4%	-9.7%	-9.5%	-10.1%	-13.1%
$40-60k	-10.1%	-9.9%	-10.2%	-10.1%	-10.6%	-13.6%
$60-80k	-13.9%	-13.7%	-14.1%	-13.9%	-14.5%	-17.0%
$80-200k	-13.0%	-13.0%	-13.1%	-13.1%	-13.7%	-16.1%
$200k+	-35.3%	-35.6%	-35.5%	-35.6%	-36.0%	-36.3%
Total	-10.9%	-10.7%	-11.1%	-10.9%	-11.5%	-14.4%

Source: Author estimates.

Transfers and Tax Credits

For auctioned permits, the recycling scenarios we consider allocate permit revenues in two ways. In scenarios 1a, 2a, and 4, we assume that revenues are returned to households with equi-proportional reductions in baseline income taxes. This means that households will receive rebates proportional to their individual contribution to overall tax revenue.[6] In scenarios 1b, and 2b, we assume the total revenue is allocated equally, meaning every household gets the same lump sum transfer payment. The implications

[6] We assume that total (State and Federal) household income tax payments are used to calculate these proportions.

of these approaches for the overall economy have already been discussed. Generally speaking, the proportional approach is more economically efficient, reducing inframarginal taxes and returning more money to households with higher saving rates, which offers more investment stimulus over the long run.

To see the direct household impacts of these approaches, the following two tables give estimates rebates under the two groups of scenarios. For the equal payments, we show annual redistribution, per household, and the cumulative rebate over the policy interval considered (2012-2020). For the proportional approach, we only show results for the final year because households receive different rebates.

Table ES 10: Household Lump-sum Dividends from Auctioning Pollution Rights

(payment per CA household per year, 2007 constant dollars)

/HH	Full-a	Full-b	Half-a	Half-b	Free	AEEI
2012		$300		$221	$0	
2013		$294		$216	$0	
2014		$288		$212	$0	
2015		$639		$471	$0	
2016		$622		$459	$0	
2017		$605		$446	$0	
2018		$588		$434	$0	
2019		$571		$421	$0	
2020		$554		$408	$0	
Total		$4,462		$3,288	$0	
Average		$827		$609	$0	

Source: Author estimates.

Table ES 11: Household Income Tax Dividends from Auctioning Pollution Rights

(income tax remission per CA household in 2020, 2007 constant dollars)

		Full-a	Full-b	Half-a	Half-b	Free	AEEI
1	< $12k	$57		$42			$49
2	$12-28k	$108		$80			$92
3	$28-40k	$172		$127			$148
4	$40-60k	$251		$185			$215
5	$60-80k	$306		$226			$262
6	$80-200k	$1,170		$864			$1,003
7	$200k+	$4,956		$3,658			$4,248
	Wgt Average	$647		$478			$555

Source: Author estimates.

Leakage

One of the most widely debated issues related to California climate policy is the so-called "leakage" effect. This term describes the exodus of business activity from one jurisdiction to another, or growth displacement from a home market to one outside, because of changing regulatory or market conditions. In particular, if one jurisdiction imposes more stringent rules or fees, leading to higher relative costs of operation, firms may be induced to migrate. Conversely, tax incentives, resource discoveries, productivity growth, and other conditions that reduce relative costs can attract enterprise migrants. Sometimes, activities may be fully financed (e.g. public goods and services) or forbidden by government, but in most cases firms exercising free will to choose their production venue by weighing local relative costs against advantages of market proximity. Thus the issue leakage ultimately becomes an empirical question.

Leakage presents both private and public challenges. Leakage will limit local economic opportunities for workers and some supporting economic activities, although it may also alleviate high costs and improve conditions for other enterprises and competitors. From a public sector perspective, leakage might be seen as an adverse investment climate indicator, undermining public efforts to attract and retain new business. Again, however, leakage of one industry may simply be a symptom of industrial transition that makes way for new patterns of business activity. In any, case leakage remains a policy priority for consideration in the context of AB32, where it is considered primarily in terms of emissions, i.e. a transfer of emissions from inside to outside California. This perspective suggests that leakage not only represents foregone economic activity in the state, but also an adverse environmental spillover from California. The panel explicitly recognized its importance in its main advisory recommendations to CARB:

> "The ARB should rely on free allocation as a distribution mechanism only where necessary to address "emissions leakage," i.e., increases in out-of-state GHG emissions generated by California's climate policy." (EAAC: 2010)

This means that EAAC's general finding in favor of permit auctions might exempt cases where permit costs transfer emission activity out of state. Because of process/technology differences and very heterogeneous market conditions outside California, it is nearly impossible to assess leakage in terms of exact emissions creation and diversion. Instead, here we attempt to infer leakage risk on the basis of conjoint adjustments of in-state and out-of-state economic activity.

It has been argued by industry advocates that AB32 will impose adjustment costs on California enterprises that are high enough to trigger significant leakage form the state economy. Counterarguments to this are many, including the observation that most historical environmental compliance represents only a few percentage points of total cost, high relocation costs, and strong historical evidence of firm retention in the Golden State. The latter evidence is perhaps most compelling, as California has enjoyed a long history of net enterprise immigration despite ever-escalating property prices, wages, and many other attendant local cost premia.

In addition to weak evidence supporting threat of leakage, this issue is difficult to adjudicate empirically because the deciding factors are so heterogeneous, varying from facility to facility, firm to firm, market to market, and across time. The BEAR model does not track enterprise dynamics at this level of resolution, neither are their data to support such analysis. Having said this, however, it is possible to infer the potential for leakage indirectly using BEAR's external trade linkages. In the present case, we examine sectors that experience output declines under AB32, combined with increases in the same sector's imports from outside California. Such combinations suggest potential substitution between in-state and out-of-state goods and services, although this is a weaker condition than firm exit. Other explanations for this include demand side factors like changes in tastes (product variety) and other changes in competitive conditions.

Even by this relatively expansive definition, however, the results in the following table suggest that leakage risks from AB32 are isolated and small in terms of employment vulnerability. The first four columns of this table display import changes (increases) as a percent of in-state output changes (decreases).[7] This coincidence only occurs in only 18 of 50 sectors, and on average import penetration only represents less that 25% of the output decline in question. In other words, the vast majority of sector contractions is a result of low carbon structural adjustment, not leakage or other strategic substitution of imports for in-state products and/or services.

The last four columns of the table show the number of jobs associated with leakage potential, or the number of jobs embodied in imports that coincide with declining in-state output. Across the state's labor markets, and especially in the context of aggregate job creation and destruction (in both the Baseline and scenarios), these numbers are small enough (less than 5% of job creation or losses) to suggest that leakage can be easily and economically addressed with re-employment and re-training policies. Surely this

[7] Scenario S4 is omitted from the table because it has no cases of potential leakage.

adjustment is operating on a far different scale from momentous issues like climate mitigation and adaptation, which implicate trillions of dollars in real California assets.[8]

More generally, our results strongly support EAAC in qualifying the commitment to addressing leakage with policy exceptions. In particular, we find strong evidence to support the following assertion:

"The need for free allocation to address emissions leakage is likely to be small, for two reasons. First, as a share of total allowance value, the share needed to deal with potential leakage is small. Second, other mechanisms such as border adjustments sometimes offer a more cost-effective way to address leakage." (EAAC: 2010)

[8] Throughout this assessment, we examine climate action against a business as usual scenario, taking no account of the costs of doing nothing. As a number of detailed and rigorous studies have shown, however, the cost of adaptation for California could easily dwarf the AB32 adjustment costs we are estimating.

Table ES 12: Leakage Potential
(percent change from Baseline in 2020; jobs in absolute terms)

	% Import/Output Changes					Jobs Vulnerable to Leakage				
	S1a	S1b	S2a	S2b	S3	S1a	S1b	S2a	S2b	S3
Agriculture	-40	-36	-5	-8		-756	-1,055	-332	-540	
Cattle										
Dairy										
Forestry, Fishery										
Oil and Gas Extraction										
Other Primary										
Electricity										
Natural Gas Dist.										
Water, Sewage, Steam										
Residential Construction										
Non-Res Construction										
Other Construction		-64					-67			
Food Processing										
Textiles and Apparel										
Wood, Pulp, and Paper										
Printing and Publishing		-20					-6			
Oil and Gas Refineries										
Chemicals										
Pharmaceuticals										
Cement										
Metal Products										
Aluminium Prod										
Machinery										
Air Con, Refridge Prod										
Semiconductors										
Electrical Appliances	-264	-28				-230	-38			
Autos and Light Trucks										
Other Vehicles										
Aeroplane and Aerospace										
Other Industry										
Wholesale Trade										
Vehicle Sales/Service										
Air Transport										
Ground Transport	-162	-151	-33	-40		-2,739	-3,159	-727	-976	
Water Transport										
Truck Transport	-18	-11	-2	-3		-58	-86	-36	-49	
Public Transport										
Retail Appliance										
General Retail										
InfoComm Services										
Financial Services										
Other Prof Services										
Business Services										
Waste Services			-2	-3	-1			-12	-20	-7
Landfill			-15	-15	-19			-19	-20	-38
Educational Services										
Medical Services										
Recreation and Cultural										
Hotel and Restaurant										
Other Private Services										
Total						-3,782	-4,400	-1,126	-1,604	-45

Criteria Pollution Impacts

Simulation results of the last section apply to CARB's primary climate objective, reducing global warming pollution. While GHG emissions are the primary focus of AB32, however, it also represents an important landmark for all environmental policy. While achieving dramatic gains in reduction of global warming pollution, AB32's effects on other categories of emissions will be indirect and depend on collateral details of policy implementation. From a toxics and public health perspective, however, criteria pollutants remain an important environmental category. Since AB 32 has not directly targeted at these, the effects of its approach to GHG reduction may have unintended consequences.

The EAAC explicitly recognize such collateral environmental risk and included criteria pollutant mitigation explicitly in its advisory recommendations:

> "In keeping with the stipulated objectives of AB 32, sufficient allowance value should be earmarked for the purposes of (1) addressing emissions leakage (when other mechanisms cannot easily or effectively be engaged for this purpose), (2) avoiding disproportionate adverse economic impact of AB 32 on low income households, and (3) creating a contingency fund to be devoted to any communities eventually found to be experiencing increased exposure to co-pollutants as a result of possible fossil-fuel burning stemming from AB 32 implementation. It is anticipated that a relatively small share of the state's total allowance value would be needed for these purposes."

We used the BEAR model to provide estimates of such collateral impacts, focusing on three representative scenarios (S1a, S3, and S4). These results show (Figures ES 3 and 4) that, in both relative and absolute terms, AB32 achieves a modest amount of collateral mitigation in criteria pollutants. When pollution permits are auctioned (S1a), the resulting demand side economic stimulus reduces this mitigation, but the amounts are very small in both cases. Finally, recall that the efficiency/innovation scenario (S4) achieved the same overall GHG reductions, yet criteria pollution changes in this "green growth" scenario are significantly positive. Thus we are reminded that growth oriented climate action requires a more determined approach to complementary measures. In all cases, however, our findings bear out the insight of EAAC above, that criteria impacts of AB32 are quite negligible in the aggregate.

Figure ES 3: Criteria Pollution Impacts
(percent change from Baseline in 2020)

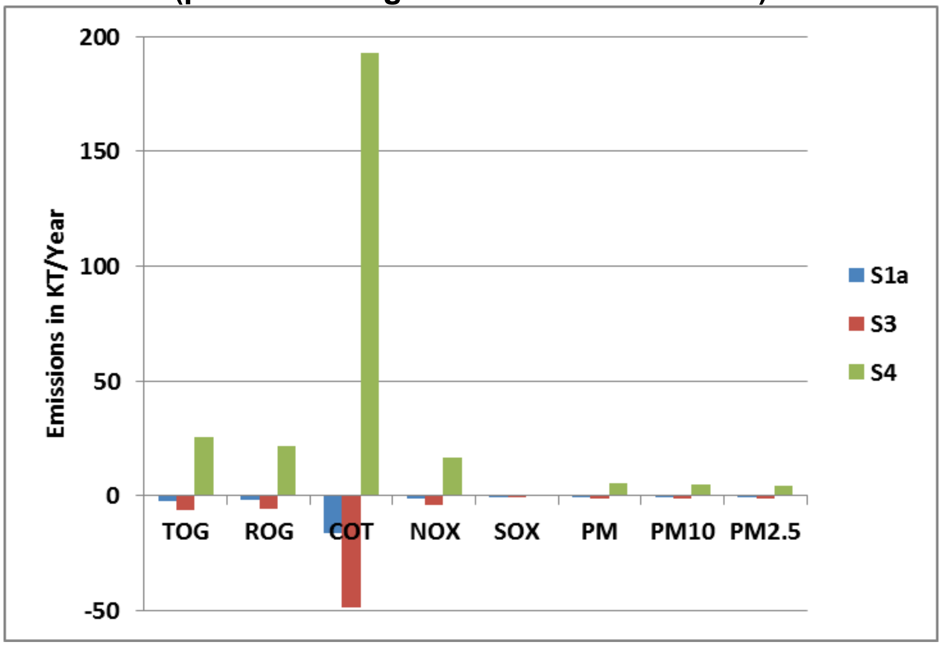
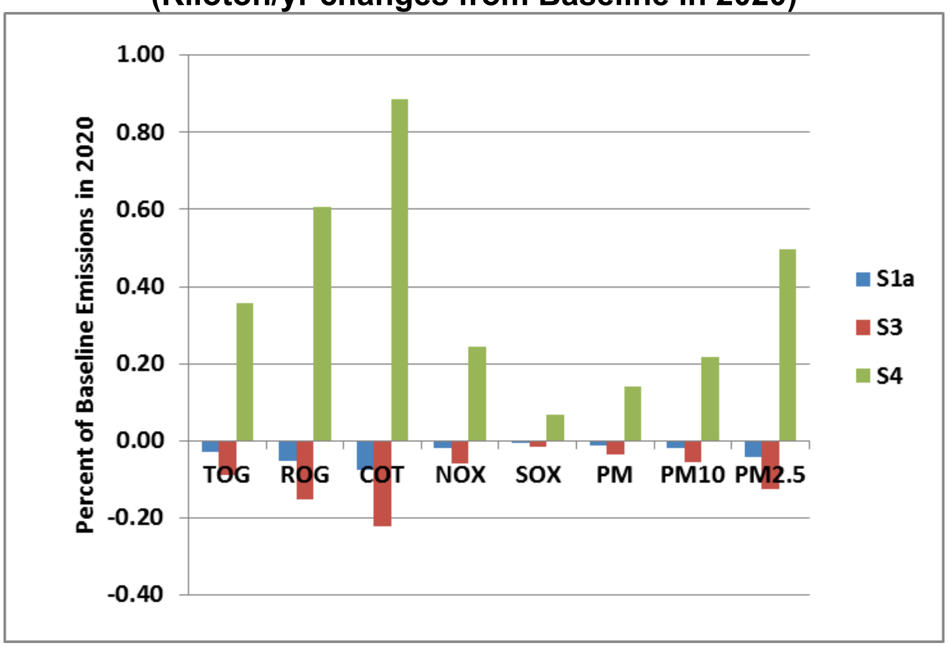


Figure ES 4: Criteria Pollution Impacts
(Kiloton/yr changes from Baseline in 2020)



CONTENTS

EXECUTIVE SUMMARY iii

AB32 Assessment iv

Permit Allocation and Revenue Recycling viii

The Role of Innovation ix

Macroeconomic Results x

Household Results xvi

Leakage xix

Criteria Pollution Impacts xxiii

1 Introduction 27

2 Background and Scenario Description 30

Permit Allocation and Revenue Recycling 39

The Role of Innovation 40

Macroeconomic Results 44

Household Results 50

Sectoral Adjustments 54

Leakage 56

Criteria Pollution Impacts 60

Other Observations 62

3 Conclusions 64

4 Background Annexes 66

Structure of the CGE Model 66

Production 67

Consumption and Closure Rule 68

Trade 69

Dynamic Features and Calibration 69

Capital accumulation 70

The putty/semi-putty specification 70

Profits, Adjustment Costs, and Expectations 70

Dynamic calibration 72

Modelling Emissions 72

Emissions Data 77

Renewable Energy Cost Estimates 77
5 References 85

`

Real Incomes, Employment, and California Climate Policy

David Roland-Holst

November, 2010

1 Introduction

Since its passage in 2006, California's path breaking Global Warming Solutions Act (AB32), has drawn the world's eighth largest economy into a global policy dialogue that will influence energy and environmental decisions for generations. Within the state, it is widely acknowledged that GHG policies already implemented and under consideration will have far reaching economic consequences. Both public and private institutions have expressed an urgent interest in strengthening the basis of evidence on this issue.

In response, economists are developing assessment tools to support more effective policy design, implementation, and assessment. One of the most advanced examples of this policy research capacity 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. This paper reports on efforts to build out BEAR's capacity and address a central issue in the state's climate policy formulation: How will the livelihoods of California households be affected by this legislation? In particular, because a market-oriented approach to emissions regulation could generate significant fiscal revenues for the state, it would be useful to know if these resources be channeled in ways that both facilitate a lower carbon future and improve economic welfare.

`

The last round of BEAR analysis was broadly in accord with the state's findings and buttressed the public interest in legislative discussion of Assembly Bill 32 (Roland-Holst, 200?). In the next phase of climate action dialogue, more specific policy design features and impacts will be subjected to intensive public and private scrutiny. Rules for allocating emissions permits, as well as those governing the revenues obtained from permit auction programs, remain to be fixed, yet the potential magnitude of these transactions has aroused substantial 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.

An additional dimension of the AB32 dialog involves criteria pollutants. As it is currently envisioned, AB32 objectives focus on cost-effective reductions in GHG emissions, without explicit standards for mitigation or measurement of emissions of other types of pollution. Several categories of criteria pollutants are collateral to GHG production, while others will be affected indirectly by GHG policies, as the latter induce structural change in production and consumption patterns. Thus GHG mitigation measures could either decrease or increase net criteria pollution, and the level itself is a complex empirical question. In this study, we explicitly estimate criteria pollution effects.

Finally, this assessment is the first to fully map out this policy and the intertemporal adjustments of state economic structure that follow it. As it is presently framed, the Scoping Plan for AB32 calls for phased implementation, including two tiers of coverage and a changing time path for the total emissions cap and concurrent carbon market activity. Using BEAR's dynamic framework, we follow this process over the period 2010-2020 and produce detailed estimates of annual impacts.

For the package of GHG mitigation policies that comprise AB32, macroeconomic effects will arise from structural linkages that transmit economic impacts across the state economy. A consistent feature of such complex processes is the economic 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 which can only be assessed with methods like the one used here.

`

The main goal of this work is 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 pollution rights allocation choices and in particular the efficiency and equity tradeoffs these entail as well are their macroeconomic implications. Seven salient insights emerge from the BEAR economic analysis:

Main Findings

1. ***Aggregate effects of AB32 on the California economy are very modest; amounting to less than three months deferred growth across a decade.***
2. ***Households experience energy efficiency gains that reduce total energy expenses. In other words, the policy as written has a small positive net cost to the overall economy, but a negative net cost in terms of energy expenses to households.***
3. ***Scalable permit auctions can facilitate adjustment, without compromising long term climate goals, employment, or equity. In particular:***
    a. ***Auctioning permits and distributing the revenue to households (Cap and Dividend) reduces the aggregate cost of climate policies and can increase statewide employment.***
    b. ***Returning permit revenues to households with tax reductions is better for growth and total employment than equal per capita lump sum transfers.***
4. ***Free allocation of permits might reduce adjustment costs for individual polluting industries, but it increases costs for the population of California.***
5. ***Modest autonomous innovation and efficiency responses to AB32 would deliver significant growth dividends across the state.***
6. ***The estimated risk of "leakage" posed by AB32, either in terms of job losses or pollution transfers, is negligible.***
7. ***AB32 will reduce aggregate criteria pollution, but might change its composition in ways that justify complementary, localized mitigation efforts. In all cases, however, the impacts are very modest.***

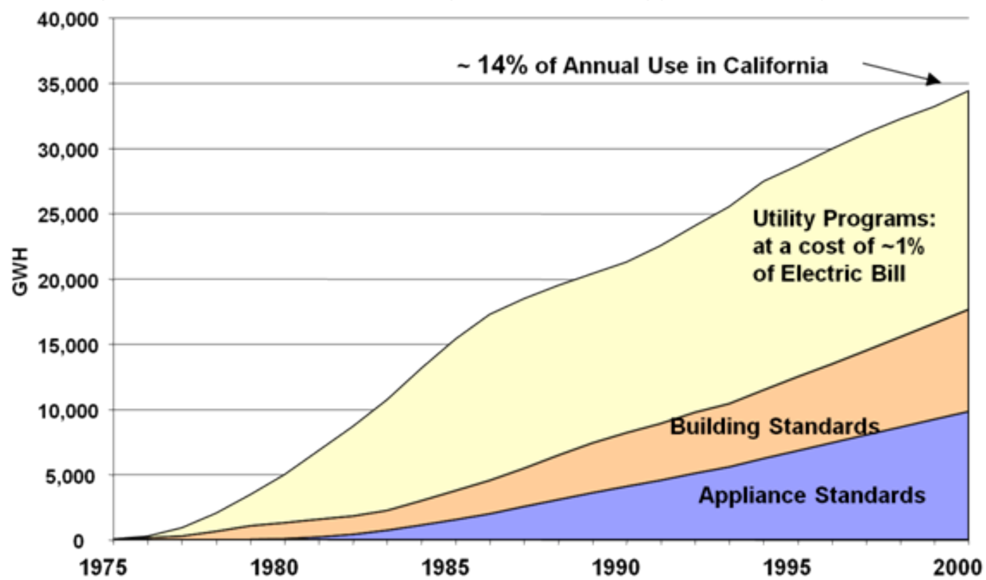
`

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 Background and Scenario Description

California has over thirty years of direct experience with policies related to climate change, including a broad spectrum of energy and emissions initiatives that have set national standards for economic growth through innovation and efficiency. These policies have targeted energy efficiency and air pollution from many different angles, including vehicle, appliance, and building standards, tax credits, and now economywide emissions targets. While the approaches are diverse, most of these policies share the important objective of seeking to influence economic behavior in ways that limit adverse environmental consequences. Thus climate action policies seek to change behavior, which in turn alters economic structure by inducing agents to choose different technologies, goods and services, and other modalities of economic behavior.

Figure: Household Savings from Energy Efficiency Measures

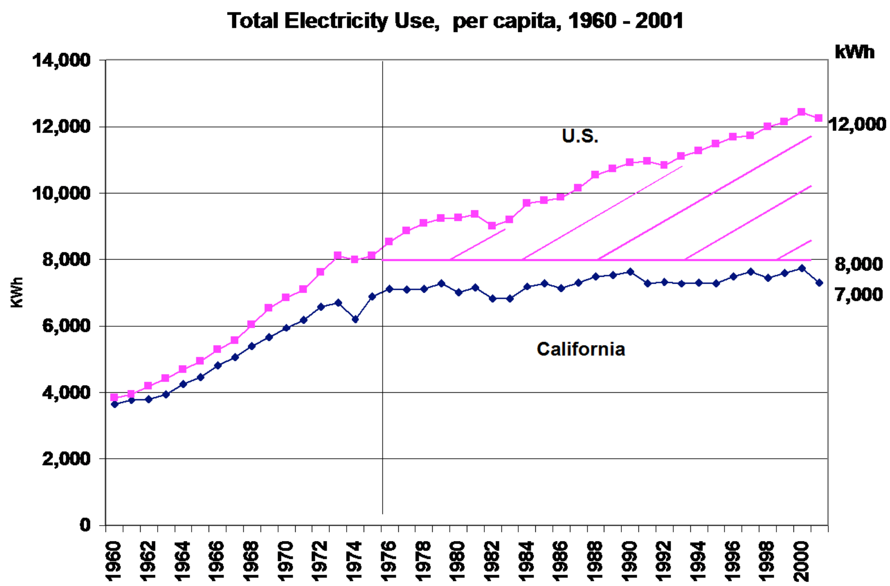


Source: Rosenfeld (2008)

`

A prime example of the state's positive experience with regulation at the energy/climate nexus is illustrated in the above figure. Since the early 1970's California households have saved billions from a combination of standards for appliances, efficiency oriented building codes, and incentive programs to decouple utility profits from conventional energy sales. These savings were in turn redirected to more employment-intensive consumption patterns, generating over 1.4 million additional jobs in the state as its per capita electricity consumption declined from parity to 40% below the national average (Figure 1).

Figure 1



More recently, during the legislative discussions prior to AB32's passage, the California Climate Action Team proposed a set of over 40 component policies (Table 1 below) to realize the state's goal of a lower carbon future. This is an extremely diverse set of initiatives, reflecting the complexity of the California economy and the sophistication of the initiatives themselves. The policies also vary greatly in their scale, and some will affect nearly every energy consumer while others are targeted a very narrowly defined economic activities. Most are now included in a group referred to as "complementary" to other free standing climate policies and to Cap and Trade, yet they represent many essential components of the state's GHG challenges. For the scenario work with BEAR, we relied then and continue to rely on policy definitions assembled by the

`

California Air Resources Board (ARB). These are then implemented in our economic modeling framework in conjunction with a wide variety of data sources discussed below.

Table 1: Recommended AB32 Complementary Policies

Policy	Description
Pavley II Vehicle Standards	The marginal vehicle efficiency for passenger cars and light trucks is incrementally increased beginning in 2017 to reach a new vehicle fleet of 42.5 mpg by 2020.
Low Carbon Fuel Standard	The ethanol share of passenger ground transportation fuels is increased to approximately 18% for light vehicles and the biodiesel share of freight ground transportation is increased to approximately 15% to represent a 10% reduction in the carbon intensity of fuels by 2020.
VMT Reduction Measure	Vehicle miles travelled per year in California were assumed to be reduced by 4% by 2020.
33 Percent Renewable Portfolio Standard	The sales share of renewable electricity is increased to 33 percent by 2020. Renewable sources are not required to be in-state. The type of renewable generation built to meet the requirement was based on resource mix projections by the California Public Utilities commission.[9]
Residential and Commercial Energy Efficiency	Building and Device efficiency standards and programs reduce electricity sales by 22,000 GWh and natural gas sales by 800 million therms reduction by 2020. The costs of actual equipment upgrades associated with these efficiency gains are captured in the model, however, program and administration costs are not captured.
Combined Heat and Power	The electricity output from CHP facilities was increase by 30,000 GWh by 2020. It was assumed that the heat output of these facilities is used to serve existing or new heating loads.
Heavy Duty Vehicle and Marine Efficiency	Increases in freight end use efficiency to reflect Smart Way Truck Efficiency and the use of on-shore electricity to ships in port.

Source: California Air Resources Board
http://www.arb.ca.gov/cc/scopingplan/sp_measures_implementation_timeline.pdf

[9] http://www.cpuc.ca.gov/PUC/energy/Renewables/hot/33implementation.htm

`

After its empirical assessment of the CAT policies was included in CARB's initial Scoping Plan[10], the BEAR project was involved for several months in a collaborative model comparison exercise with ARB. This activity entailed comparison of results from BEAR, ARB's own EDRAM model, and the MRN-NEEM model developed by the Electric Power Research Institute (EPRI) and Charles Rivers Associates (EPRI:2007). The point of the exercise was to appraise California climate policy from a variety of perspectives, using the models most closely associated with various stakeholders in the policy process. To facilitate results comparison, ARB set forth a uniform set of policy scenarios, in each case reflecting the mix of performance standards and market-oriented carbon cap measures designed to achieve the AB32 mandate, and varying assumptions about the effectiveness of complementary policies (whether or not anticipated reductions are fully achieved or not) and whether or not offsets are allowed in the cap-and-trade program. These combinations are indicated in the first five scenarios defined in Table 2 below.

Table 2: Scenarios Analyzed for the ARB Comparison Project

	Offsets	LCFS	Pavley II	VMT Reduction	EE Standards	33% RES	CHP	Annual EE Response
ARB1	4%	Full	Full	Full	Full	Full	Full	None
ARB2	No	Full	Full	Full	Full	Full	Full	None
ARB3	4%	Half	Half	Excluded	Full	Full	Full	None
ARB4	4%	Full	Full	Full	Half	Excluded	Half	None
ARB5	4%	Half	Half	Excluded	Half	Excluded	Half	None
ARB_Cap	4%	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	None
EE1	4%	Full	Full	Full	Full	Full	Full	0.40%
WM1	Full	Full	Full	Full	Full	Full	Full	None

For the present assessment, we build on this experience to elucidate the revenue management, or fiscal characteristics of AB32, with careful attention to both the timepath of implementation and impacts on income distribution and effects on

---

[10] Roland-Holst (2007a).

`

leakage. The former is important because the current version of implementation plans calls for a complex phase in plan. As currently set forth, Cap and Trade will begin in 2012 with coverage of an initial set of emissions intensive industrial activities (Group 1, in Annex 1 below). Table 3 illustrates the diversity of emission intensity across generic economic activities and energy sources.

Table 3: Historical California Emissions Inventory

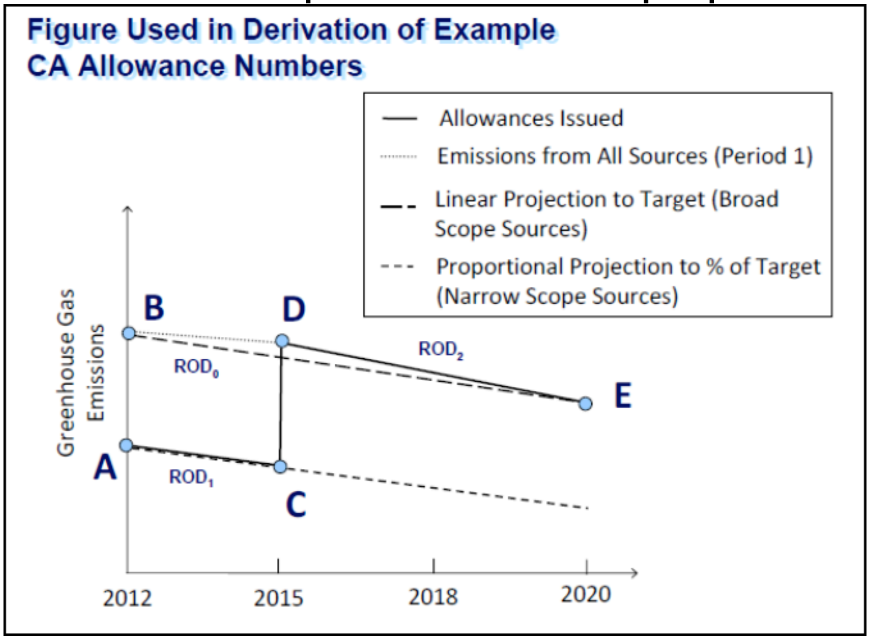
		2000	2001	2002	2003	2004	2005	2006
Electricity	Imports	43.0	52.4	50.6	56.3	58.6	54.9	49.9
	In-State	60.8	64.7	51.6	49.8	58.1	52.4	57.0
	Total	103.7	117.0	102.2	106.1	116.7	107.4	106.9
Industrial	Other	34.3	32.0	34.1	30.1	25.4	23.9	24.7
	Refining	34.6	34.6	35.1	36.3	35.4	36.8	37.8
	Oil and Gas	17.9	17.7	16.8	18.9	19.1	17.8	17.9
	Cement	9.5	9.6	9.7	9.8	9.9	10.1	9.9
	Total	96.3	94.0	95.8	95.1	89.9	88.6	90.3
	Narrow Scope	200.1	211.1	197.9	201.2	206.6	195.9	197.2
Fuels	Other	10.6	9.8	9.0	10.2	11.9	13.3	13.1
	Diesel	35.7	36.6	37.1	36.5	39.0	41.3	42.0
	Natural Gas	41.0	39.4	42.3	39.2	39.9	38.1	39.4
	Gasoline	133.7	135.7	142.0	140.1	141.3	141.5	140.8
	Total	220.9	221.5	230.4	226.1	232.2	234.3	235.3
	Broad Scope	421.0	432.5	428.3	427.2	438.8	430.3	432.6

Source: CARB (2008).

In 2015, the current plan calls for coverage to be stepped up to nearly all GHG sources (i.e. fuels), with a higher cap that will continue to be reduced linearly through 2020 (see Figure 2). By covering fuels directly at their production or distribution origins, the Cap and Trade system can more effectively cover mobile and residential emissions. The intertemporal complexity of this rulemaking may create complex incentives and structural adjustments, and for this reason we incorporate it explicitly in the BEAR dynamic analysis.

`

Figure 2: Schematic Timepath for Emissions Cap Implementation



Source: CARB (2009)

To implement the anticipated Cap and Trade rulemaking explicity, we use annual calculations of scope, permit requirements, allowable offsets, and the cap itself, based on CARB official data and summmarized in Table 4. . In the recently released draft cap-and-trade regulation, some modest changes have been made to these policy parameters, but these small changes do not affect the fundamental insights provided by this work.

Table 4: Estimated Allowance Budgets

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Narrow Scope	197.2	193.4	189.5	185.7					
Fuels Estimate (2015)				235.3					
Broad Scope				421.0	409.8	398.6	387.4	376.2	365.0
Allowances Per Year	197.2	193.4	189.5	421.0	409.8	398.6	387.4	376.2	365.0
Offset Use (CARB)	8.2	8.0	7.9	17.5	17.0	16.5	16.1	15.6	15.2
Cap on Covered Emissions	205.4	201.4	197.4	438.5	426.8	415.2	403.5	391.8	380.2

Source: CARB (2009).

`

This phased implementation scheme is a necessary acknowledgement of the diversity of California's economic structure, with differing emissions intensities, technological issues, and administrative engagement. On the economic assessment side, an essential feature of diversity is the state's income distribution. It is well known that lower income households face different challenges from higher income ones in nearly every dimension of economic activity, and energy use and emissions are no exception. For this reason, the current analysis takes explicit account of difference in initial conditions, economic behavior, and outcomes across the spectrum of households encompassed by California's tax code. In particular, as detailed in Table 5 below, we track seven household groups throughout the analysis, including their detailed linkages to production activities, state government, and the national economy, across income and expenditure chains.

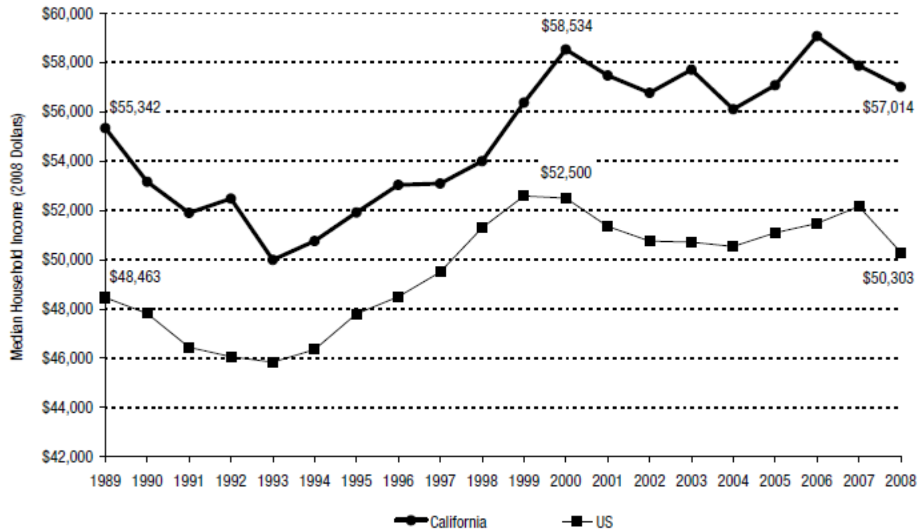
Table 5: California Households and Population by Income Tax Bracket (California Department of Finance: 2006, millions of people)

		Households	Cumulative	Population	Cumulative	Percent
1	< $12k	1.220	1.340	3.575	3.926	9.752
2	$12-28k	2.360	3.580	6.915	10.489	18.86
3	$28-40k	1.650	5.230	4.835	15.324	13.19
4	$40-60k	2.110	7.340	6.182	21.506	16.87
5	$60-80k	1.650	8.990	4.835	26.341	13.19
6	$80-200k	3.140	12.130	9.200	35.541	25.10
7	$200k+	0.380	12.510	1.113	36.654	3.04
	Total	12.510		36.654		100

While the assessment considers all California households, particular attention has been given to low income groups because of their economic vulnerability. Despite a well-deserved reputation for prosperity (Figure 3), poverty rates in California are high relative to the nation as a whole and they have risen sharply in recent years (Figure 4). To focus our assessment on lower income groups, we use Federal poverty lines (Table 6), adjusted for California cost of living, and consider household groups 1 and 2 above to be economically vulnerable.

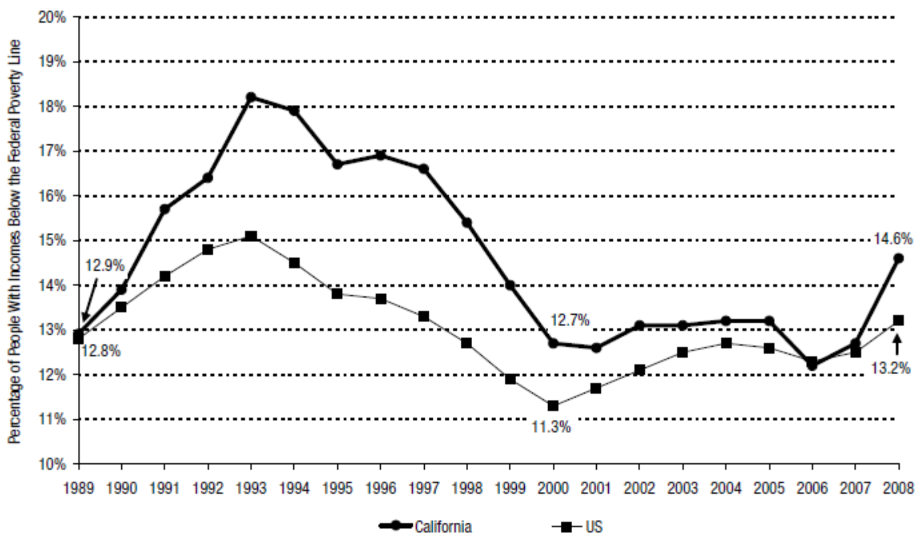
`

Figure 3: Median Household Income Rates in the United States and California



Source: US Census Bureau

Figure 4: Poverty Rates in the United States and California



Source: US Census Bureau

`

Table 6: Federal Poverty Lines (2008)

Persons in Family Unit	48 Contiguous States and D.C.	Alaska	Hawaii
1	$10,830	$13,530	$12,460
2	$14,570	$18,210	$16,760
3	$18,310	$22,890	$21,060
4	$22,050	$27,570	$25,360
5	$25,790	$32,250	$29,660
6	$29,530	$36,930	$33,960
7	$33,270	$41,610	$38,260
8	$37,010	$46,290	$42,560
For each additional person, add	$3,740	$4,680	$4,300

Source: U.S. Department of Health and Human Services (2009).

With these distributional considerations in mind, we now specify a set of policy scenarios, based on CARB's reference Case 1, to assess the impacts of AB32 under alternative permit auction and revenue allocation schemes. These five basic scenarios are summarized in Table ES 4, where Case 1 includes both Cap and Trade and all complementary measures.

Table 7: Scenarios analyzed in this Assessment

S1. **Cap and Full Dividend** - 100% auction of permits in each year
   a. 100% revenue recycling of auction revenue via income tax reduction (equi-proportionate reductions in all baseline tax income tax rates)
   b. 100% recycling of auction revenue via per capita dividend (equal payments to each household)

S2. **Cap and Half Dividend** - 50% free permit allocation to industries, 50% auction
   a. 100% recycling of auction revenue via income tax reduction (equi-proportionate reductions in all baseline tax income tax rates)
   b. 100% recycling of auction revenue via per capita dividend (equal payments to each household)

S3. **Free Pollution** – 100% free permit allocation to industries, based on baseline emissions, annually from 2012 to 2020

S4. **Innovation/Efficiency** - Carb Case 1, inclusive of an additional increase in equivalent to 1% annual Autonomous Energy Efficiency Improvement (AEEI) across the state (2012-2020). Full Auction and Dividend

`

With these distributional considerations in mind, we now specify a set of policy scenarios, based on CARB's reference Case 1, to assess the impacts of AB32 under alternative permit auction and revenue allocation schemes. These six basic scenarios all use CARB's Case 1 as their starting point, and are summarized in Table 7. Recall that Case 1 includes both Cap and Trade and all complementary measures.

Permit Allocation and Revenue Recycling

Pollution rights and permits for these rights recognize air quality as a public good, but their pricing and allocation of the associated revenues ("recycling") present complex and important policy challenges. To implement AB32 in a socially effective manner, CARB constituted a panel of experts, the Economic Allocation and Advisory Committee (EAAC), to consider these issues carefully and recommend the best approaches. This panel of experts characterized the policy challenge this way:

> "There are two main elements of allocation design. One is to specify the *mechanisms for allowance distribution*, that is, the way that emissions allowances are to be put into circulation. This can be done by free provision to various entities or by auctioning. The other element is to determine the pattern of *provision of allowance value,* that is, how the value of the emissions allowances will be distributed across various parties. If allowances are freely issued, then allowance value goes to the recipients of these free allowances. If allowances are auctioned, allowance value goes to the parties to whom the revenues from the auction are directed." (EAAC: 2010)

As other studies have shown at the national level (e.g. Goulder et al:2009, Burtraw and Palmer:2008), the choices of both allowance distribution and value provision can affect economic efficiency and fairness. If firms pay for the right to pollute in an auction (S1), the resulting cost for industry can be offset for society by returning the permit revenues to society. The net economic impact of this approach, taxing a negative social externality and returning the revenues to households, depends on complex adjustments in industry and extended demand effects in consumption. When permits to pollution are given away (S3), society bears the burden of pollution without compensation, and firms adapt to limits on global warming pollution while reaping windfall profits on tradable permit values. These are the general equilibrium effects that a model like BEAR is designed to elucidate.

`

Once the scope of auctioning is decided, governments can do many things with permit revenue. In this study, test the implications of the current recommendations of the state's Economic and Allocation Advisory Committee (EAAC) and California Air Resource Board, redistributing or recycling permit revenues to households, an approach popularly known as Cap and Dividend. The actual recycling rule itself is important, and here we consider two basic alternatives, (1) tax reduction and (2) equal per capita transfer payments.

Table 8: Level and Composition of Permit Revenue Rebates and Transfers
(based on a permit price of $21/MMT, 2007 millions of dollars)

	2012	2013	2014	2015	2016	2017	2018	2019	2020
Permit Value	4,279	4,195	4,111	9,133	8,890	8,647	8,404	8,161	7,918
Free Allocation	4,279	3,671	3,084	5,708	4,445	3,243	2,101	1,020	-
Per Capita Dividend	-	524	1,028	3,425	4,445	5,404	6,303	7,141	7,918
Total Dividends	-	-	-	-	-	-	-	-	-
< $12k	-	51	100	334	433	527	615	696	772
$12-28k	-	99	194	646	839	1,020	1,189	1,347	1,494
$28-40k	-	69	136	452	586	713	831	942	1,044
$40-60k	-	88	173	578	750	912	1,063	1,204	1,335
$60-80k	-	69	136	452	586	713	831	942	1,044
$80-200k	-	132	258	860	1,116	1,357	1,582	1,792	1,987
$200k+	-	16	31	104	135	164	191	217	241
Total	-	524	1,028	3,425	4,445	5,404	6,303	7,141	7,918
Average/HH	-	42	82	274	355	432	504	571	633

Note: Flows are totals for all households in each tax bracket, not per household amounts.
Source: Author estimates.

In Table 8, we present calculations of the flows of estimated value for a sample permit price of $21/MT, as these would accrue in the recycling scenarios above. To be concise, we use the Scenario 2b scalable auction scheme and per capita transfers as an example. Comparing these results to the aggregate household income impacts at the outset of this section, we can see that recycling is an important offset to the cost of the program, even when firms are allowed to more gradually assume the burden of carbon costs.

The Role of Innovation

An important characteristic of most AB32 scenario analysis is technological neutrality.[11] This means that, apart from energy savings embodied in

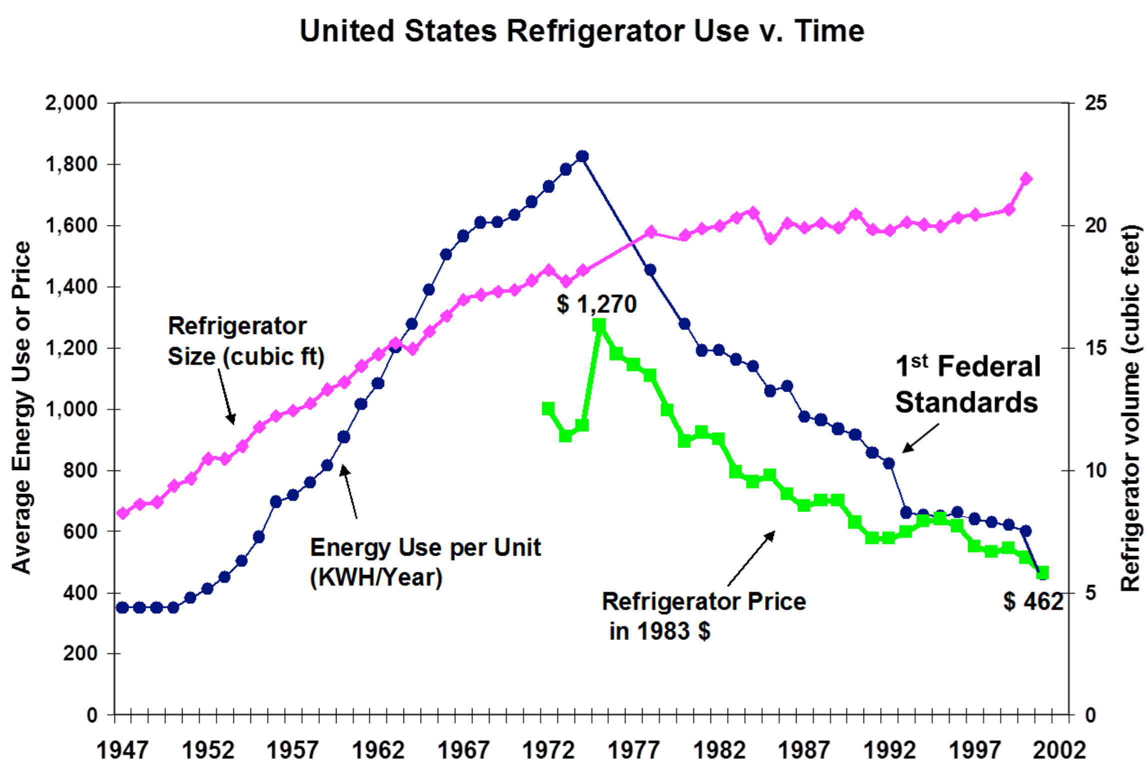
---

[11] This includes all estimates by CARB (2010), Charles River Associates (2010), and many others.

`

complementary measures (e.g. fuel efficiency mandates), factor productivity, energy use intensities, and other innovation characteristics were held constant across cap and trade scenarios. Energy use and pollution levels might change, but the prospects for innovation to reduce energy intensity and improve productivity were not considered. This perspective is unrealistic and significantly biases results against climate policy. Technological change in favor of energy efficiency has been a hallmark of California's economic growth experience over the last four decades. Over this period California has reduced its aggregate energy intensity by about 1.5% per year, attaining levels that today are 40% below the national average. Structural changes in the economy have played a role, but most observers give a significant amount of credit this technological progress to California's energy/climate policies, combinations of mandated and incentive based efficiency measures from which the Climate Action Team recommendations are direct descendants. Thus, energy innovation has been part of the history of the state's economic growth and at the same time a consequence of its policies.

Figure 5: Induced Innovation in Refrigerator Technology



Source: Rosenfeld (2008)

`

Induced innovation was a strong private sector response to the state's historic efficiency standards. This is typified by appliances general and refrigerators in particular. As Figure 5 clearly illustrates, not only did energy efficiency sharply increase with standards, but capacity remained high and prices fell nearly continuously. Just as importantly, because of economic prominence, California also set the de facto national standard for appliance producers, and the later application of national appliance efficiency standards had a small incremental effect because manufacturers already met or exceeded California standards, a precedence benefit often overlooked in the AB32 dialog.

For these reasons, it is important to consider the potential contribution of continued innovation to the economic effects of California climate policy. For illustrative purposes, we used the BEAR model for one comparison case to illustrate what innovation could contribute to the economic impact estimates already discussed. In particular, we assume in Scenario 4 that California extends baseline and AB32 aggregate energy efficiency improvements by exactly 1% per annum over 2012-2020. This amount is intended to be indicative only, and would be on top an estimated 1.1% annual average achieved by AB32 policies. Over three decades from the early 1970s until 2002, the state averaged 1.5% improvements. With the much more determined policy commitments embodied in AB32, it is reasonable to expect significant increases in Autonomous Energy Efficiency Improvements (AEEI).

Before proceeding to the results discussion, it is worth reminding the reader that forecasting models are not crystal balls that magically foresee the future against all uncertainty, but empirical tools based on best available evidence, analytical tools, and assumptions about residual uncertainties. The data are discussed throughout this report, the model summarized in Annex 1 and fully documented elsewhere (Roland-Holst: 2009). For convenience, in the following table we summarize the main residual assumptions about AB32 implementation.

`

Table 9: Assumptions

	Component	Assumption
1	GHG Pollutants	CO_2, CH_4, N_2O, SF_6, PFC, and HFC
2	2020 Goal	15% below 2005 emissions
3	Covered Sectors	
	2012-2014	Electricity and Large Industrials
	2015-2020	Electricity and Large Industrial, transportation fuels, commercial and residential fuels and small industrial
4	Banking	Banking is not modelled
5	Cap Trajectory	Stepwise and Linear phase-in
6	Allocation	As in scenarios
7	Offsets	Offsets estimated to 49% of C&T reducton
8	EE: Energy Efficiency	Assume California sustains its historical 1.5% EE improvement per year to 2020
9	Criteria Pollutants	TOG, ROG, COT, NOX, SOX, PM, PM10, PM25

`

Macroeconomic Results

For the scenarios discussed above, the BEAR macroeconomic assessment effects are presented in Table 10 below. A few salient results are immediately apparent in both tables. Firstly, central tenets of the EAAC advisory report are strongly supported by these findings. In particular:

1. Permit auctions with revenue recycling reduce overall costs to the state economy.
2. For recycling, income tax relief is more efficient (lower cost) from a macroeconomic perspective than lump sum transfers.
3. Free allocation of the right to pollute increases economic costs to society.

Table 10: Aggregate Adjustments
(percent changes from baseline values in 2020)

	S1a Full-a	S1b Full-b	S2a Half-a	S2b Half-b	S3 Free	S4 AEEI
Total GHG*	-27.58	-27.67	-27.79	-27.83	-27.78	-25.96
Household GHG*	-31.47	-31.50	-31.48	-31.49	-31.48	-31.31
Industry GHG*	-25.33	-25.47	-25.66	-25.73	-25.64	-22.87
Real GSP	-0.23	-0.31	-0.52	-0.56	-0.67	4.44
Real Consumption	0.01	0.39	-0.95	-0.77	-1.97	3.97
Employment*	0.55	0.58	-0.21	-0.19	-0.61	3.10
Permit Price	$21	$19	$31	$28	$43	$18
Jobs Created (1000)	163	177	65	70	47	623
Jobs Lost	-53	-62	-107	-108	-167	-9
Net	109	115	-41	-38	-120	614
Income Per Capita	-103	-137	-231	-248	-296	1,959

Source: Author estimates.

NB: *Permit price in 2007 dollars per metric ton of CO2 equivalent carbon, in 2020.*

The reasons for these three impacts are already widely discussed in the literature on allocation, although this is the first effort to measure them in the context of AB32. Goulder et al (2009) found the same kinds of effects at the national level, and Burtraw and Palmer (2008) have similar findings that are

`

focused on the electric power sector. What is novel about these California results is the magnitude of the demand side impact of revenue recycling.

As a number authors (e.g. Smith et al: 2002, Smith and Ross: 2002, Stavins: 2007) have already observed, however laudable the goal of climate change mitigation, permit auctions present costs to polluting industries. Goulder et al (2009) make a more subtle point that the resource royalty value of permits, even if received free, still embeds an opportunity cost on firm balance sheets, presenting an opportunity to profits by reducing output. In either case, permits induce an adverse supply side shock on the economy. If they are auctioned and the revenues given to households, however, this creates an offsetting demand side stimulus.

Ultimately, the net macroeconomic impact depends on the magnitude and composition of these two, and the results in Table 10 show how complex this can be. For example, when all permits are auctioned and all revenue given to households (S1ab), the demand side stimulus offsets nearly all the supply side shock. Conversely, free allocation of permits reduces the demand side potential of recycling and therefore increases net economic costs.

More dramatically, demand side forces actually increase total California employment, creating over 100,000 additional jobs by 2020. The reason employment can increase while GSP remains essentially constant is because the demand growth from revenue recycling is more employment intensive than are the sectors with lower growth under AB32. Like most OECD economies, California is properly seen as post-industrial in structure, with more than two-thirds of demand, value-added, and employment in service sectors. As the following figure illustrates, these sectors are 10-50 times more job intensive (per million of output value) than the carbon fuel supply chain. For this simple reason, transferring resources from the latter to households (Expenditure Shifting) will create more jobs.[12]

A second robust finding of this analysis is at least as important. The overall growth impact in all four Case 1 versions of this ambitious climate policy package is very modest or even negligible, changing state real GSP by about half of one

[12] Because carbon fuels are also import-intensive, more demand will be directed at in-state goods and services. As others have observed, however, this import reduction will be offset by real exchange rate appreciation, attendant export reductions, and ambiguous net employment effects.

`

percent annually by 2020, cumulative GSP about half this much, and real state employment in 2020 by even less. Under our hypothetical induced innovation scenario, whereby energy and emissions policies lead to meaningful gains in energy efficiency over the business-as-usual scenario, employment in the state actually increases significantly, as productivity rises and expenditures shift from imported energy dependence to demand for more labor-intensive in-state goods and services. What this means in practical terms is quite simple. The state can achieve its ambitious climate objectives, unprecedented GHG mitigation, over the next decade with a deferred growth impact of about three months. Since we have taken no account of the environmental cost of doing nothing, this seems like a bargain.[13]

Permit prices are obviously central to this analysis and to Cap and Trade generally. The BEAR model estimates these prices as the outcome of a market process that, in a competitive auction of pollution rights, would equate permit prices with the economywide private marginal cost of CO2 abatement. As the results in Table ES-6 suggest, BEAR estimates of this cost are comparable to those of CARB (coinciding in the reference case), but lower than many estimates circulated by industry sources.

Our estimated permit prices vary somewhat across scenarios, with permit prices rising as with the proportion of free allowance allocation and falling with energy efficiency improvements (S4). When some share of permits are allocated free, the remaining marketable share is constrained and competition for these intensifies. Looked at another way, in a competitive framework lower cost permits will be used to cover lower (abatement) cost emission reductions, so tradable permit prices reflect the higher end of the abatement cost curve. Permit prices are slightly lower in the lump sum redistribution case because changing demand patterns shift economic structure toward tertiary, less pollution intensive activities.

On the general issue of job estimates, two important points should be made. Firstly, even in the strongly negative scenario (S3/Free Pollution), there is no reduction in aggregate California employment, Baseline growth far exceeds the estimated downward adjustment by 2020 (about 27%). In none of these results do we see job losses compared to levels today, only slower employment growth.

---

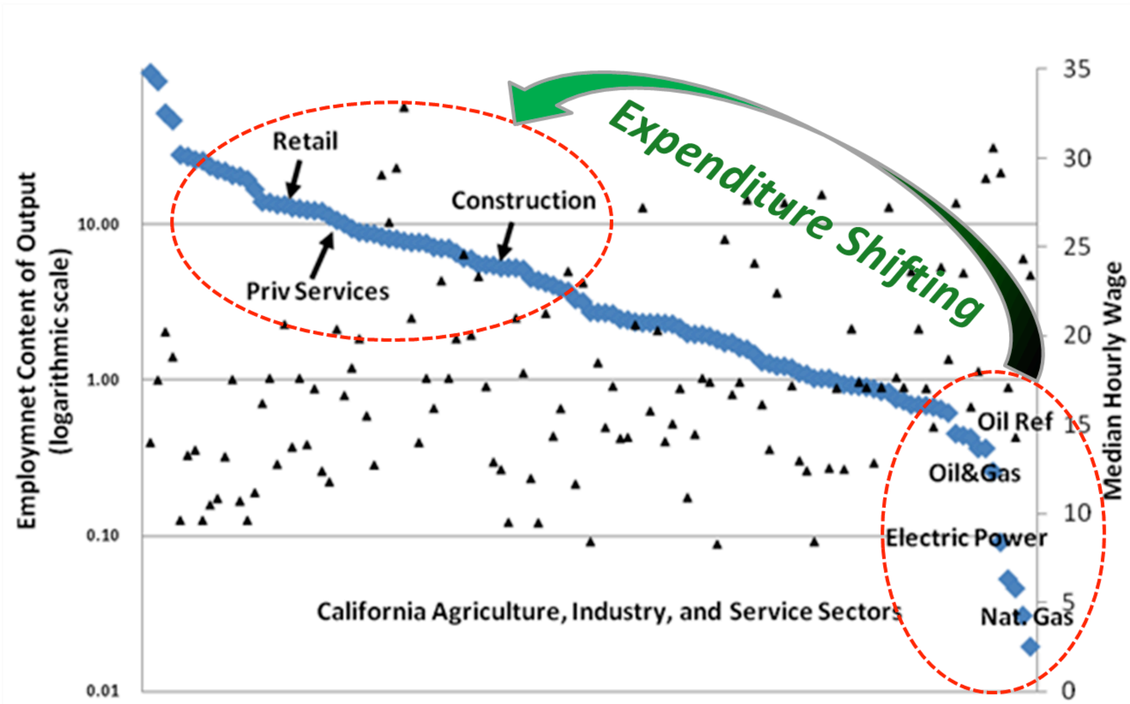
[13] For a detailed review of California climate impacts, see e.g. Kahrl and Roland-Holst: 2008.

`

Secondly, although net job changes are small, job turnover as result of AB32 is often much larger. Because the skills required for these jobs can be quite different, this labor market adjustment will be a more complex prospect than suggested by merely adding new and lost job numbers to find the result for net employment.

`

Figure 6: How Revenue Recycling and Energy Efficiency Create Jobs



Source: Roland-Holst, David "Energy Efficiency, Innovation, and Job Creation in California," Next10.org.

Finally, the efficiency and innovation scenario (S4/AEEI), is by far the most pro-growth. The reason for this is productivity growth via technology adoption and more intensive expenditure shifting, i.e. multiplier effects, coming from two sources. A carbon trading system provides a direct and transparent incentive for technology adoption and reduce carbon fuel expenditures, and to change expenditure patterns in ways that promote innovation. If users face the prospect of paying for pollution rights, their expenditures shift toward public goods and services that are more employment intensive than would be higher fuel spending. Those who avoid permit fees by investing in energy efficiency will save money in the long run, spending that on more conventional and generally more job intensive alternatives. This pattern of direct and indirect expenditure shifting has for a generation helped California to ever higher environmental and living standards. The future holds the same promise for positive, innovation based synergy between environmental values and livelihoods, and forward looking policies like AB32 can help to realize this potential, securing prosperity for another generation.

`

In terms of permit prices, we see some variation across scenarios. In comparison to tax reductions ($21 allowance price, S1a), lump-sum redistribution leads to lower long term demand stimulus and thus achieves emission reduction at a slightly lower price. When pollution is partially or completely free, two forces are at work. Demand side weakness (less recycling resources) makes emission reduction cheaper, but permit discounts reduce the incentive to abate pollution. For the free permit scenarios considered (S2ab, S3), the latter prevails and higher nominal permit prices are needed to offset (average) permit discounting. Finally, the AEEI scenario achieves mitigation by Cap and Trade as well as higher innovation potential, meaning a lower permit price can hit AB32's mitigation targets.

Before moving on to the distributional results, the effects of these policies on energy prices should be considered (Table 11). After aggregate growth, the "burden" of energy costs has been the most debated issue surrounding climate action. Imposing a price on carbon emissions will obviously increase the cost of carbon-based energy sources, but the ultimate impact of this on prices depends on both supply and demand. The BEAR results suggest that the demand side of energy markets, under determined policies of climate action, will prevail in many cases and substantially mitigate price increases in others. In contrast to industry estimates of 20% and higher electricity price increases, we see single-digit increases in technology neutral scenarios and price declines in more the historical efficiency/productivity scenario.[14] Meanwhile, natural gas prices actually decline, gasoline prices rise negligibly, and overall energy price indexes for households and all state demand rise only modestly over the decade.

Table 11: Energy and Fuel Prices
(percent changes from baseline in 2020)

	S1a Full-a	S1b Full-b	S2a Half-a	S2b Half-b	S3 Free	S4 AEEI
Electricity	**2.3%**	**2.1%**	**3.3%**	**3.1%**	**4.1%**	**-5.4%**
Nat. Gas	**-1.2%**	**-0.9%**	**-1.3%**	**-1.0%**	**-2.4%**	**-2.7%**
Gasoline	**2.2%**	**2.1%**	**3.3%**	**3.1%**	**3.8%**	**-2.0%**
HH Energy	**1.6%**	**1.5%**	**2.4%**	**2.3%**	**2.7%**	**-3.5%**
All Energy	**0.9%**	**0.9%**	**1.5%**	**1.5%**	**1.4%**	**-3.3%**

Source: Author estimates.

[14] It should be emphasized that the present modeling framework assumes electricity prices are market determined, a simplification that may not be too restrictive in the long run, but needs to be interpreted with care.

`

Household Results

We now examine AB32 impacts from the household perspective. Table 12 provides detailed income effects for different tax brackets of household income. As is generally true in economics, beneath the smooth veneer of aggregate growth lies a complex array of adjustments, more diverse outcomes, and even tradeoffs. In the present context, this means that choice of both the permit allocation and revenue recycling scheme is important to income distribution, even with relatively small aggregate stakes. For example, the lowest income group actually benefits in all scenarios, in the first instance because of policy induced energy savings and secondly when the recycling scheme is per capita (S1b and S2b). Conversely, higher income groups lose most because of adverse capital income effects (permit and adoption cost), and even more when recycling is per capita rather than per dollar of prior tax liability.

Because of California's progressive tax structure, permit revenue recycling schemes have differing impacts across the income distribution. For lower and middle income households, per capita lump sum recycling is better than tax relief, so it either increases benefits or lowers costs. For the highest income groups, tax breaks would be more attractive because their rates are well above average. Thus their costs under the "a" (tax break) scenarios would be about half those under the per capita rebate scheme. For the economy as a whole, tax relief is better for the macro economy than lump sum transfers, yet some might argue that the latter is more defensible on equity grounds. This point cannot really be adjudicated by economic analysis unless long term growth benefits of tax relief are large and dispersed enough to benefit a significant majority of households, in which case macro efficiency and equity could be reconciled.

`

Table 12: Real Income Effects by Household Income Level
(percent changes from baseline in 2020)

	S1a Full-a	S1b Full-b	S2a Half-a	S2b Half-b	S3 Free	S4 AEEI
< $12k	0.3%	1.2%	0.3%	0.8%	0.3%	1.1%
$12-28k	0.1%	0.8%	-0.5%	-0.1%	-0.8%	3.5%
$28-40k	0.2%	0.7%	-0.6%	-0.3%	-0.9%	3.4%
$40-60k	0.5%	1.2%	-0.8%	-0.4%	-1.7%	2.5%
$60-80k	0.2%	0.7%	-0.7%	-0.4%	-1.4%	3.5%
$80-200k	0.0%	-1.2%	-1.2%	-1.7%	-3.2%	4.0%
$200k+	-1.0%	-7.4%	-3.4%	-6.3%	-8.2%	1.6%
Total	0.2%	0.4%	-0.7%	-0.5%	-1.4%	3.1%

Source: Author estimates.

In all technology neutral scenarios, however, we see the same small aggregate income effects, deferring about three month's GSP growth in a decade to achieve unprecedented GHG mitigation and enhanced energy security. At the outset of this study, we considered designing targeted energy cost assistance to the poor, in order to address concerns expressed by stakeholder groups and the state itself. The real effect of energy costs on households is detailed in Table 13, where we see the interplay of two essential forces, energy prices and energy demand. Simply put, the former are small and mixed while the latter are large and negative. Program efficiency improvements and household incentives to reduce energy use drive demand declines in the same direction, and overall energy expenses are dominated by this effect. In Scenario 4, growth effects offset efficiency gains in terms of energy expenditures. In any case, these results suggest that the issue of energy cost of living adjustments for the poor will be rendered superfluous by a combination of program efficiency gains and market forces, as long as the regulatory apparatus allows energy prices to reflect these.

Table 13: Household Overall Energy Expenses
(percent changes from baseline in 2020)

	S1a Full-a	S1b Full-b	S2a Half-a	S2b Half-b	S3 Free	S4 AEEI
< $12k	-10.6%	-10.4%	-10.6%	-10.5%	-10.9%	-14.7%
$12-28k	-8.7%	-8.5%	-8.8%	-8.7%	-9.2%	-12.3%
$28-40k	-9.5%	-9.4%	-9.7%	-9.5%	-10.1%	-13.1%
$40-60k	-10.1%	-9.9%	-10.2%	-10.1%	-10.6%	-13.6%
$60-80k	-13.9%	-13.7%	-14.1%	-13.9%	-14.5%	-17.0%
$80-200k	-13.0%	-13.0%	-13.1%	-13.1%	-13.7%	-16.1%
$200k+	-35.3%	-35.6%	-35.5%	-35.6%	-36.0%	-36.3%
Total	-10.9%	-10.7%	-11.1%	-10.9%	-11.5%	-14.4%

Source: Author estimates.

`

Transfers and Tax Credits

For auctioned permits, the recycling scenarios we consider allocate permit revenues in two ways. In scenarios 1a, 2a, and 4, we assume that revenues are returned to households with equi-proportional reductions in baseline income taxes. This means that households will receive rebates proportional to their individual contribution to overall tax revenue.[15] In scenarios 1b, and 2b, we assume the total revenue is allocated equally, meaning every household gets the same lump sum transfer payment. The implications of these approaches for the overall economy have already been discussed. Generally speaking, the proportional approach is more economically efficient, reducing inframarginal taxes and returning more money to households with higher saving rates, which offers more investment stimulus over the long run.

To see the direct household impacts of these approaches, the following two tables give estimates rebates under the two groups of scenarios. For the equal payments, we show annual redistribution, per household, and the cumulative rebate over the policy interval considered (2012-2020). For the proportional approach, we only show results for the final year because households receive different rebates.

Table 14: Household Lump-sum Dividends from Auctioning Pollution Rights
(payment per CA household per year, 2007 constant dollars)

/HH	Full-a	Full-b	Half-a	Half-b	Free	AEEI
2012		$300		$221	$0	
2013		$294		$216	$0	
2014		$288		$212	$0	
2015		$639		$471	$0	
2016		$622		$459	$0	
2017		$605		$446	$0	
2018		$588		$434	$0	
2019		$571		$421	$0	
2020		$554		$408	$0	
Total		$4,462		$3,288	$0	
Average		$827		$609	$0	

Source: Author estimates.

[15] We assume that total (State and Federal) household income tax payments are used to calculate these proportions.

`

Table 15: Household Income Tax Dividends from Auctioning Pollution Rights

(income tax remission per CA household in 2020, 2007 constant dollars)

		Full-a	Full-b	Half-a	Half-b	Free	AEEI
1	< $12k	$57		$42			$49
2	$12-28k	$108		$80			$92
3	$28-40k	$172		$127			$148
4	$40-60k	$251		$185			$215
5	$60-80k	$306		$226			$262
6	$80-200k	$1,170		$864			$1,003
7	$200k+	$4,956		$3,658			$4,248
	Wgt Average	$647		$478			$555

Source: Author estimates.

`

Sector Adjustments

While the macroeconomic impact of AB32 on the California appears to be quite small, there are concerns that the smooth aggregate veneer of the economy masks dramatic adjustments across sectors. We have already seen diversity of outcomes across household groups, although these again are not large. Intuition does support the idea, however, that transition to a low carbon future has bigger implications for energy sectors and energy intensive activities than for others.

To elucidate these adjustments, Table 16 presents detailed output impacts for each scenario and all 50 sectors of the BEAR model, expressed percentage changes from baseline values in 2020. The salient features of these results are consistent both with intuition and related estimates by others (e.g. Goulder et al: 2009, CARB: 2010, Smith and Ross: 2002, etc.). Firstly, most sectors exhibit relatively small output changes, in line with the macroeconomic impacts. Second, large negative impacts are concentrated in a small number of energy and carbon intensive activities, precisely the objective of transition to a lower carbon future. Lastly, a number of sectors are specific beneficiaries of complementary policies. Building standards, for example, have a very tonic effect on all aspects of the state's important construction sector, while Pavley and related transport fuel efficiency standards stimulate the new vehicle sales.

Among sectors specializing in energy fuels and energy carriers (electricity), adjustment again accord with intuition regarding low carbon transition. Carbon intensive energy sources experience slower growth, but not declining overall output to 2020, but natural gas enjoys growth because of fuel substitution. and electricity demand declines. Meanwhile, electricity use grows more slowly than baseline trends because of fuel efficiency, but not as fast as carbon fuels because of renewable deployment.

Table 16: Output Changes by Sector and Scenario (cumulative 2010-20 percent change form Baseline)

	S1a	S1b	S2a	S2b	S3	S4	2010-20 Baseline
Agriculture	-0.4	-0.7	-0.8	-0.9	-0.7	3.2	30.8
Cattle	4.7	4.3	0.5	0.4	-0.6	5.6	31.2
Dairy	1.5	1.1	-0.4	-0.5	-0.6	4.4	34.3
Forestry, Fishery	4.1	3.8	0.6	0.5	-0.2	5.6	38.6
Oil and Gas Extraction	-16.4	-16.7	-16.2	-16.3	-15.7	-13.1	25.8
Other Primary	0.2	-0.1	-0.2	-0.4	0.0	2.3	20.1
Electricity	1.6	1.5	1.3	1.3	1.3	7.4	5.4
Natural Gas Dist.	8.5	8.5	8.1	8.1	8.0	10.6	9.0
Water, Sewage, Steam	5.6	5.6	0.7	0.8	-1.1	6.3	33.7
Residential Construction	-0.9	-1.5	-0.9	-1.2	-0.6	1.8	27.7
Non-Res Construction	3.1	3.1	2.8	2.8	2.7	5.5	27.1
Other Construction	-0.1	-0.5	0.2	0.1	0.9	2.3	22.3
Food Processing	0.3	0.3	-0.6	-0.4	-1.0	2.8	22.3
Textiles and Apparel	0.9	0.9	0.3	0.2	0.2	2.3	17.5
Wood, Pulp, and Paper	0.9	0.7	-0.1	-0.2	-0.2	3.5	33.7
Printing and Publishing	0.0	-0.1	-0.2	-0.2	-0.2	2.3	25.4
Oil and Gas Refineries	-6.5	-6.6	-6.8	-6.8	-6.7	-4.0	27.0
Chemicals	-0.4	-0.7	-0.6	-0.7	-0.3	2.9	32.3
Pharmaceuticals	0.6	0.6	0.3	0.3	0.3	3.6	27.9
Cement	0.2	0.0	-0.3	-0.4	-0.1	2.5	25.8
Metal Products	0.0	-0.2	-0.1	-0.3	0.4	3.2	37.0
Aluminium Prod	1.9	1.6	0.1	-0.1	0.0	3.5	33.2
Machinery	0.7	0.5	0.5	0.4	0.9	2.2	18.0
Air Con, Refridge Prod	7.5	7.2	3.2	3.0	2.0	6.3	20.7
Semiconductors	-0.6	-1.0	-0.7	-0.8	-0.6	1.3	19.8
Electrical Appliances	0.7	0.7	-0.1	-0.2	-0.1	0.3	8.5
Autos and Light Trucks	8.7	9.1	6.1	6.4	4.6	7.3	9.1
Other Vehicles	2.3	2.2	1.1	1.0	0.9	3.6	22.8
Aeroplane and Aerospace	0.1	0.0	0.0	0.0	0.1	0.7	27.2
Other Industry	0.2	0.0	0.0	-0.1	0.1	2.8	27.9
Wholesale Trade	0.0	0.0	-0.2	-0.2	-0.2	3.2	29.8
Vehicle Sales/Service	0.5	0.5	-0.1	0.0	-0.4	3.7	30.3
Air Transport	-0.4	-0.7	-0.9	-0.9	-0.9	2.4	25.9
Ground Transport	-0.5	-0.8	-0.8	-0.9	-0.6	3.8	38.9
Water Transport	1.1	0.8	0.1	-0.1	0.2	3.0	24.8
Truck Transport	-0.1	-0.4	-0.6	-0.7	-0.4	2.8	29.1
Public Transport	9.1	8.8	1.6	1.6	-0.3	6.9	31.8
Retail Appliance	0.8	0.6	0.5	0.4	0.9	3.4	30.2
General Retail	0.2	0.3	-0.4	-0.3	-0.9	3.2	24.7
InfoComm Services	0.3	0.3	0.1	0.1	0.0	3.2	28.3
Financial Services	-0.5	-0.5	-0.7	-0.7	-0.9	3.0	30.4
Other Prof Services	0.0	0.0	-0.3	-0.3	-0.4	2.6	26.0
Business Services	-0.2	-0.2	-0.6	-0.6	-0.8	2.4	25.7
Waste Services	0.4	0.0	-0.8	-0.9	-1.0	3.2	33.5
Landfill	2.5	2.2	-0.8	-0.9	-1.6	3.5	33.2
Educational Services	2.1	2.3	0.7	0.9	-0.1	4.6	25.1
Medical Services	0.5	0.7	-0.3	-0.1	-1.0	2.7	18.5
Recreation and Cultural	0.8	0.8	0.3	0.4	0.2	4.1	31.5
Hotel and Restaurant	-0.1	-0.1	-0.1	-0.1	0.1	3.1	28.7
Other Private Services	0.4	0.4	0.1	0.1	0.0	3.6	30.5
Grand Total	-0.2	-0.3	-0.5	-0.6	-0.7	2.7	27.0

`

Leakage

One of the most widely debated issues related to California climate policy is the so-called “leakage” effect. This term describes the exodus of business activity from one jurisdiction to another, or growth displacement from a home market to one outside, because of changing regulatory or market conditions. In particular, if one jurisdiction imposes more stringent rules or fees, leading to higher relative costs of operation, firms may be induced to migrate. Conversely, tax incentives, resource discoveries, productivity growth, and other conditions that reduce relative costs can attract enterprise migrants. Sometimes, activities may be fully financed (e.g. public goods and services) or forbidden by government, but in most cases firms exercising free will to choose their production venue by weighing local relative costs against advantages of market proximity. Thus the issue leakage ultimately becomes an empirical question.

Leakage presents both private and public challenges. Leakage will limit local economic opportunities for workers and some supporting economic activities, although it may also alleviate high costs and improve conditions for other enterprises and competitors. From a public sector perspective, leakage might be seen as an adverse investment climate indicator, undermining public efforts to attract and retain new business. Again, however, leakage of one industry may simply be a symptom of industrial transition that makes way for new patterns of business activity. In any, case leakage remains a policy priority for consideration in the context of AB32, where it is considered primarily in terms of emissions, i.e. a transfer of emissions from inside to outside California. This perspective suggests that leakage not only represents foregone economic activity in the state, but also an adverse environmental spillover from California. The panel explicitly recognized its importance in its main advisory recommendations to CARB:

> “The ARB should rely on free allocation as a distribution mechanism only where necessary to address “emissions leakage,” i.e., increases in out-of-state GHG emissions generated by California’s climate policy.” (EAAC: 2010)

This means that EAAC’s general finding in favor of permit auctions might exempt cases where permit costs transfer emission activity out of state. Because of process/technology differences and very heterogeneous market conditions outside California, it is nearly impossible to assess leakage in terms of exact emissions creation and diversion. Instead, here we attempt to infer leakage risk

`

on the basis of conjoint adjustments of in-state and out-of-state economic activity.

It has been argued by industry advocates that AB32 will impose adjustment costs on California enterprises that are high enough to trigger significant leakage form the state economy. Counterarguments to this are many, including the observation that most historical environmental compliance represents only a few percentage points of total cost, high relocation costs, and strong historical evidence of firm retention in the Golden State. The latter evidence is perhaps most compelling, as California has enjoyed a long history of net enterprise immigration despite ever-escalating property prices, wages, and many other attendant local cost premia.

In addition to weak evidence supporting threat of leakage, this issue is difficult to adjudicate empirically because the deciding factors are so heterogeneous, varying from facility to facility, firm to firm, market to market, and across time. The BEAR model does not track enterprise dynamics at this level of resolution, neither are their data to support such analysis. Having said this, however, it is possible to infer the potential for leakage indirectly using BEAR's external trade linkages. In the present case, we examine sectors that experience output declines under AB32, combined with increases in the same sector's imports from outside California. Such combinations suggest potential substitution between in-state and out-of-state goods and services, although this is a weaker condition than firm exit. Other explanations for this include demand side factors like changes in tastes (product variety) and other changes in competitive conditions.

Even by this relatively expansive definition, however, the results in the following table suggest that leakage risks from AB32 are isolated and small in terms of employment vulnerability. The first four columns of this table display import changes (increases) as a percent of in-state output changes (decreases).[16] This coincidence only occurs in only 18 of 50 sectors, and on average import penetration only represents less that 25% of the output decline in question. In other words, the vast majority of sector contractions is a result of low carbon structural adjustment, not leakage or other strategic substitution of imports for in-state products and/or services.

[16] Scenario S4 is omitted from the table because it has no cases of potential leakage.

`

The last four columns of the table show the number of jobs associated with leakage potential, or the number of jobs embodied in imports that coincide with declining in-state output. Across the state's labor markets, and especially in the context of aggregate job creation and destruction (in both the Baseline and scenarios), these numbers are small enough (less than 5% of job creation or losses) to suggest that leakage can be easily and economically addressed with re-employment and re-training policies. Surely this adjustment is operating on a far different scale from momentous issues like climate mitigation and adaptation, which implicate trillions of dollars in real California assets.[17]

More generally, our results strongly support EAAC in qualifying the commitment to addressing leakage with policy exceptions. In particular, we find strong evidence to support the following assertion:

"The need for free allocation to address emissions leakage is likely to be small, for two reasons. First, as a share of total allowance value, the share needed to deal with potential leakage is small. Second, other mechanisms such as border adjustments sometimes offer a more cost-effective way to address leakage." (EAAC: 2010)

[17] Throughout this assessment, we examine climate action against a business as usual scenario, taking no account of the costs of doing nothing. As a number of detailed and rigorous studies have shown, however, the cost of adaptation for California could easily dwarf the AB32 adjustment costs we are estimating.

Table 17: Leakage Potential
(percent change from Baseline in 2020; jobs in absolute terms)

	% Import/Output Changes					Jobs Vulnerable to Leakage				
	S1a	S1b	S2a	S2b	S3	S1a	S1b	S2a	S2b	S3
Agriculture	-40	-36	-5	-8		-756	-1,055	-332	-540	
Cattle										
Dairy										
Forestry, Fishery										
Oil and Gas Extraction										
Other Primary										
Electricity										
Natural Gas Dist.										
Water, Sewage, Steam										
Residential Construction										
Non-Res Construction										
Other Construction		-64					-67			
Food Processing										
Textiles and Apparel										
Wood, Pulp, and Paper										
Printing and Publishing		-20					-6			
Oil and Gas Refineries										
Chemicals										
Pharmaceuticals										
Cement										
Metal Products										
Aluminium Prod										
Machinery										
Air Con, Refridge Prod										
Semiconductors										
Electrical Appliances	-264	-28				-230	-38			
Autos and Light Trucks										
Other Vehicles										
Aeroplane and Aerospace										
Other Industry										
Wholesale Trade										
Vehicle Sales/Service										
Air Transport										
Ground Transport	-162	-151	-33	-40		-2,739	-3,159	-727	-976	
Water Transport										
Truck Transport	-18	-11	-2	-3		-58	-86	-36	-49	
Public Transport										
Retail Appliance										
General Retail										
InfoComm Services										
Financial Services										
Other Prof Services										
Business Services										
Waste Services			-2	-3	-1			-12	-20	-7
Landfill			-15	-15	-19			-19	-20	-38
Educational Services										
Medical Services										
Recreation and Cultural										
Hotel and Restaurant										
Other Private Services										
Total						-3,782	-4,400	-1,126	-1,604	-45

`

Criteria Pollution Impacts

Simulation results of the last section apply to CARB's primary climate objective, reducing global warming pollution. While GHG emissions are the primary focus of AB32, however, it also represents an important landmark for all environmental policy. While achieving dramatic gains in reduction of global warming pollution, AB32's effects on other categories of emissions will be indirect and depend on collateral details of policy implementation. From a toxics and public health perspective, however, criteria pollutants remain an important environmental category. Since AB 32 has not directly targeted at these, the effects of its approach to GHG reduction may have unintended consequences.

The EAAC explicitly recognize such collateral environmental risk and included criteria pollutant mitigation explicitly in its advisory recommendations:

> "In keeping with the stipulated objectives of AB 32, sufficient allowance value should be earmarked for the purposes of (1) addressing emissions leakage (when other mechanisms cannot easily or effectively be engaged for this purpose), (2) avoiding disproportionate adverse economic impact of AB 32 on low income households, and (3) creating a contingency fund to be devoted to any communities eventually found to be experiencing increased exposure to co-pollutants as a result of possible fossil-fuel burning stemming from AB 32 implementation. It is anticipated that a relatively small share of the state's total allowance value would be needed for these purposes."

We used the BEAR model to provide estimates of such collateral impacts, focusing on three representative scenarios (S1a, S3, and S4). These results show (Figures 6 and 7) that, in both relative and absolute terms, AB32 achieves a modest amount of collateral mitigation in criteria pollutants. When pollution permits are auctioned (S1a), the resulting demand side economic stimulus reduces this mitigation, but the amounts are very small in both cases. Finally, recall that the efficiency/innovation scenario (S4) achieved the same overall GHG reductions, yet criteria pollution changes in this "green growth" scenario are significantly positive. Thus we are reminded that growth oriented climate action requires a more determined approach to complementary measures. In all cases, however, our findings bear out the insight of EAAC above, that criteria impacts of AB32 are quite negligible in the aggregate.

`

Figure 6: Criteria Pollution Impacts (percent change from Baseline in 2020)

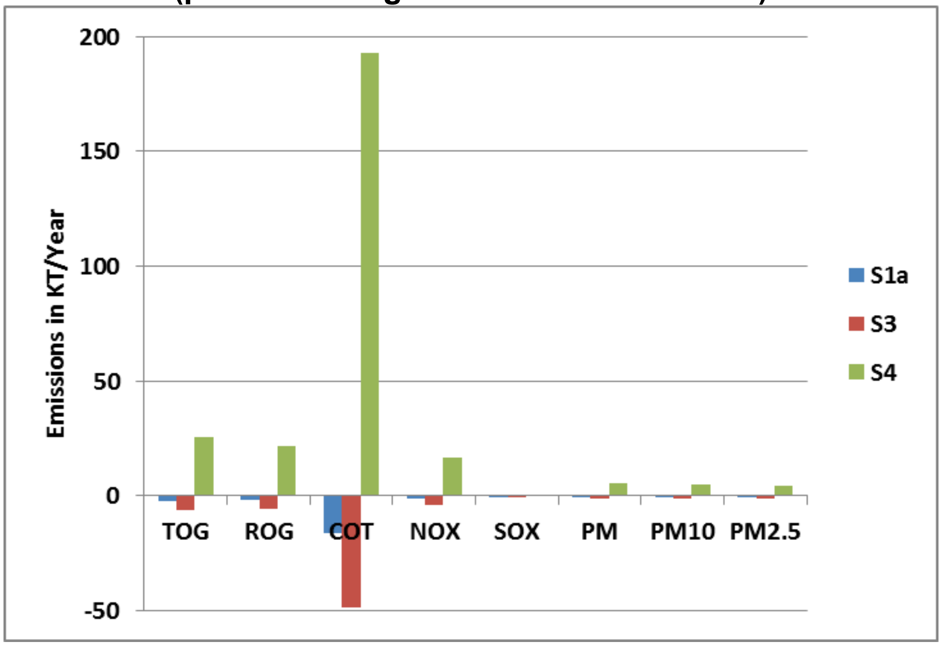
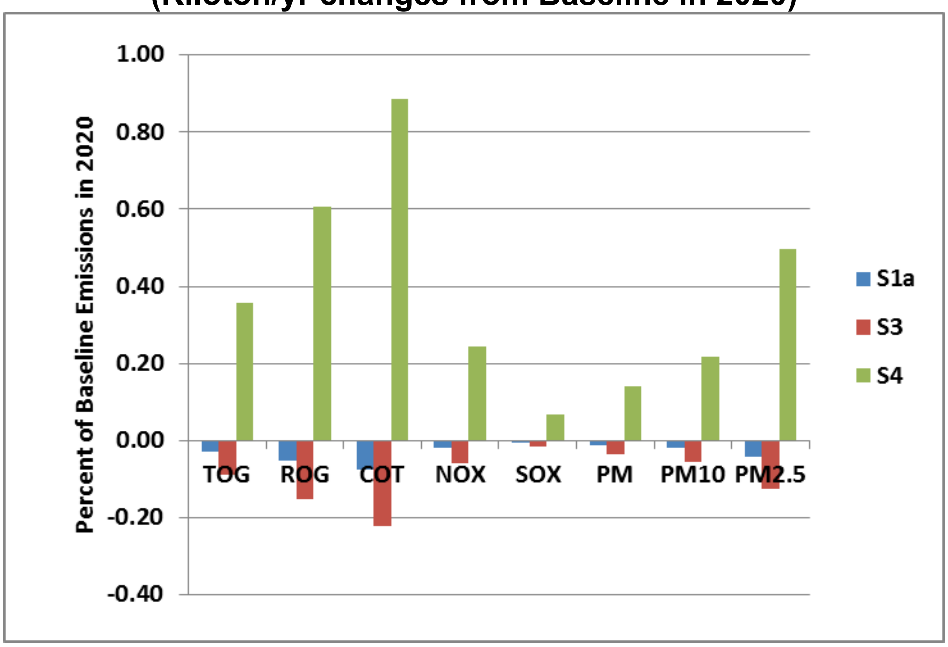


Figure 7: Criteria Pollution Impacts (Kiloton/yr changes from Baseline in 2020)



`

Other Observations

In closing this assessment, it is worth noting that other findings have suggested larger growth costs from climate action policies. The main reason for this, as we interpret our own and alternative analysis, is failure to incorporate the many positive economic stimuli associated with the AB32 policy package. This included significant new demand for construction, technology, natural gas, and other components of a structural transition to greater energy efficiency and green modernization of the state economy.[18]

Emissions adjustments are generally what would be mandated by the component policies themselves, although they can vary in the BEAR model because emission levels are endogenous. This happens for three reasons:

1. Policy interaction – In some cases, policies have interactive direct and indirect effects. The former will be deterministic ex ante, and are simply additive. The latter can be quite complex and require detailed inspection to identify positive and negative synergies.

2. Technical substitution – The current scenarios do not take account of the widely perceived potential for climate policies to induce innovation, but BEAR model does allow for technical substitution. In response to price changes, individual sectors a can be expected to substitute fuels, other inputs, and/or factors of productions to achieve greater cost effectiveness.

3. Indirect price effects – Sometimes referred to as rebound effects, these price responses will create a second round of demand adjustments in sectors with significant price changes. In the case of fuels, for example, falling demand may be somewhat offset by induced price declines. Likewise, rising demand for construction services may be partially attenuated by price increases.

BEAR is currently implemented with fifty production sectors, and even though the current discussion is relatively aggregate there are many interesting

---

[18] Other findings also focus on subjective welfare measures including inconvenience or disutility associated with technical change. We believe these behavioral parameters are open to question and focus our results on the real side of the economy: real output, incomes, and job growth.

`

individual adjustment stories on the industry side. Relevant examples of these include transport-intensive service sectors, like Ground Transport (GndTns) and Wholesale and Retail Trade (WhlTrad). Both sectors experience significant emissions reductions because they are impacted by many components of the AB32 policies, yet rising service sector demand offsets any negative output and employment effects for them. This is a combined result of policy interaction and substitution effects, and is typical of the structural transition benefits captured by BEAR. A partial equilibrium analysis of the individual direct industry policy effects would not identify these offsetting gains, yet though they accrue directly to AB32 targeted sectors and require no redistribution or compensatory measures and yield a net benefit.

The Cement sector is another prime example, where possible adverse consequences of AB32 emissions targeting are more than offset by induced construction demand arising from other AB32 policies. These examples highlight the importance of understanding the AB32 policies as an integrated package of climate action measures, of seeing both supply and demand side effects, linkages between policy components, and induced market effects. During the implementation process, policy dialogue often decomposed among stakeholder interests, and these integrated economic effects can be overlooked. These results demonstrate the essential contributions policies can make to each other, and the importance of a more comprehensive approach to assessment, design, and implementation.

`

3 Conclusions

This report provides an economy-wide assessment of how California's Global Warming Solutions Act will affect patterns of state economic growth, employment, and income. We used the Berkeley Energy and Resources (BEAR) macro-economic model to simulate AB32 Scoping Plan implementation and consider a variety of alternative schemes for auction/allocation of emissions permits and recycling of revenues accruing from these.

Seven salient insights emerge from the economic analysis:

1. *Aggregate effects of AB32 on the California economy are very modest; amounting to less than three months deferred growth across a decade.*
2. *Households experience energy efficiency gains that reduce total energy expenses. In other words, the policy as written has a small positive net cost to the overall economy, but a negative net cost in terms of energy expenses to households.*
3. *Scalable permit auctions can facilitate adjustment, without compromising long term climate goals, employment, or equity. In particular:*
   a. *Auctioning permits and distributing the revenue to households (Cap and Dividend) reduces the aggregate cost of climate policies and can increase statewide employment.*
   b. *Returning permit revenues to households with tax reductions is better for growth and total employment than equal per capita lump sum transfers.*
4. *Free allocation of permits might reduce adjustment costs for individual polluting industries, but it increases costs for the population of California.*
5. *Modest autonomous innovation and efficiency responses to AB32 would deliver significant growth dividends across the state.*
6. *The estimated risk of "leakage" posed by AB32, either in terms of job losses or pollution transfers, is negligible.*
7. *AB32 will reduce aggregate criteria pollution, but might change its composition in ways that justify complementary, localized mitigation efforts. In all cases, however, the impacts are very modest.*

California's leadership in climate policy 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 have two important implications for the state's climate policy research agenda. Firstly, even the modest assumptions about innovation show it has significant potential to make climate action a dynamic growth experience for the state economy. Second, the size and distribution of potential growth benefits is large enough to justify significant commitments to deeper empirical research on these questions.

Many studies emphasize the costs of policies that deal with climate change because they look only at the direct effects. This one finds that many policies under active consideration in California actually *save money* and *increase employment* overall because the *indirect and incentive effects* are so important. 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 like that of the BEAR model is needed to balance the individual adjustment and aggregate growth perspectives.

`

4 Background Annexes

Annex 1: 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.** and **Error! Reference source not found.** 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.[19] 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.

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

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

`

model is then used to simulate the economywide (and regional) effects of alternative policies or external events.

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.[20] The result is a single economy model calibrated over the fifteen-year time path from 2005 to 2020.[21] Using the very detailed accounts of the California SAM, we include the following in the present model:

Production

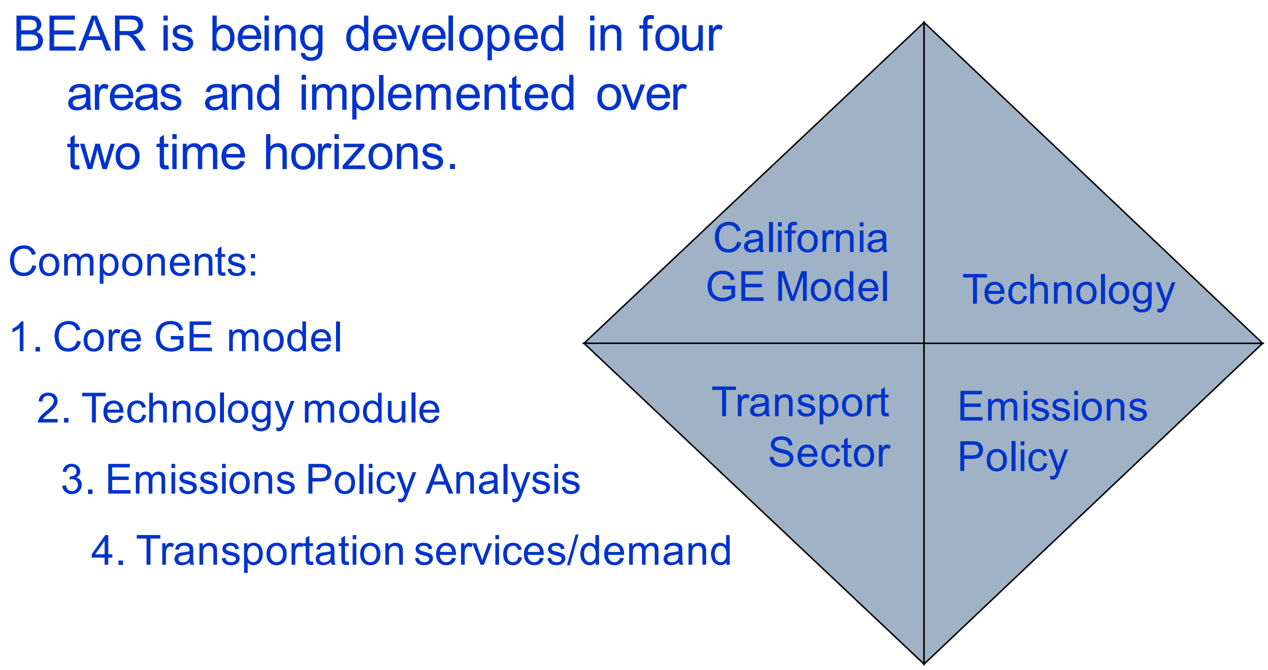
All sectors are assumed to operate under constant returns to scale and cost optimization. Production technology is modeled by a nesting of constant-elasticity-of-substitution (CES) function.

In each period, the supply of primary factors — capital, land, and labor — is usually predetermined.[22] 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

[20] See e.g. Meeraus et al (1992) for GAMS. Berck et al (2004) for discussion of the California SAM.
[21] The present specification is one of the most advanced examples of this empirical method, already applied to over 50 individual countries or combinations thereof.
[22] Capital supply is to some extent influenced by the current period's level of investment.

capital goods across sectors.[23] Once the optimal combination of inputs is determined, sectoral output prices are calculated assuming competitive supply conditions in all markets.

Figure A1.1: Component Structure of the Modeling Facility



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

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

`

that the government deficit/saving is exogenously specified.[24] The indirect tax 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.

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.

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.

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

`

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.

The putty/semi-putty specification

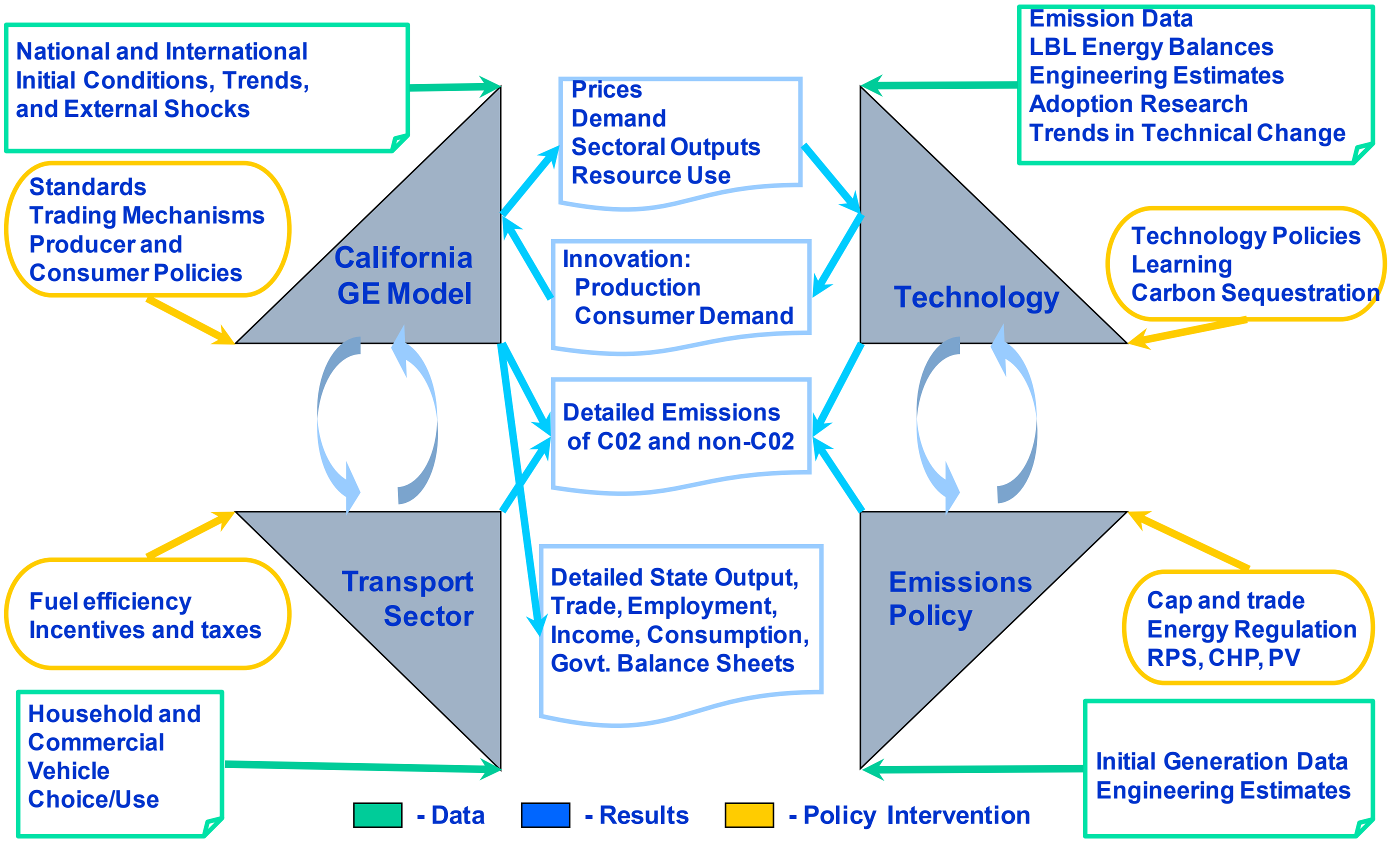
The substitution possibilities among production factors are assumed to be higher with the new than the old capital vintages — technology has a putty/semi-putty specification. Hence, when a shock to relative prices occurs (e.g. the imposition of an emissions fee), the demands for production factors adjust 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.

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).

`

Figure A1.2: Schematic Linkage between Model Components



`

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.[25] 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.

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.[26] 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).

---

[25] 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.

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

`

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

`

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

`

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

`

2. Labor Categories

    1. Skilled

    2. Unskilled

B. Capital
C. Land
D. Natural Resources
E. 8 Household Groups (by income
    1. HOUS0 (<$0k)
    2. HOUS1 ($0-12k)
    3. HOUS2 ($12-28k)
    4. HOUS4 ($28-40k)
    5. HOUS6 ($40-60k)
    6. HOUS8 ($60-80k)
    7. HOUS9 ($80-200k)
    8. HOUSH ($200+k)
F. Enterprises
G. External Trading Partners
    1. ROUS Rest of United States
    2. 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 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 which includes thirteen types of emissions.[27] 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.

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

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

`

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:

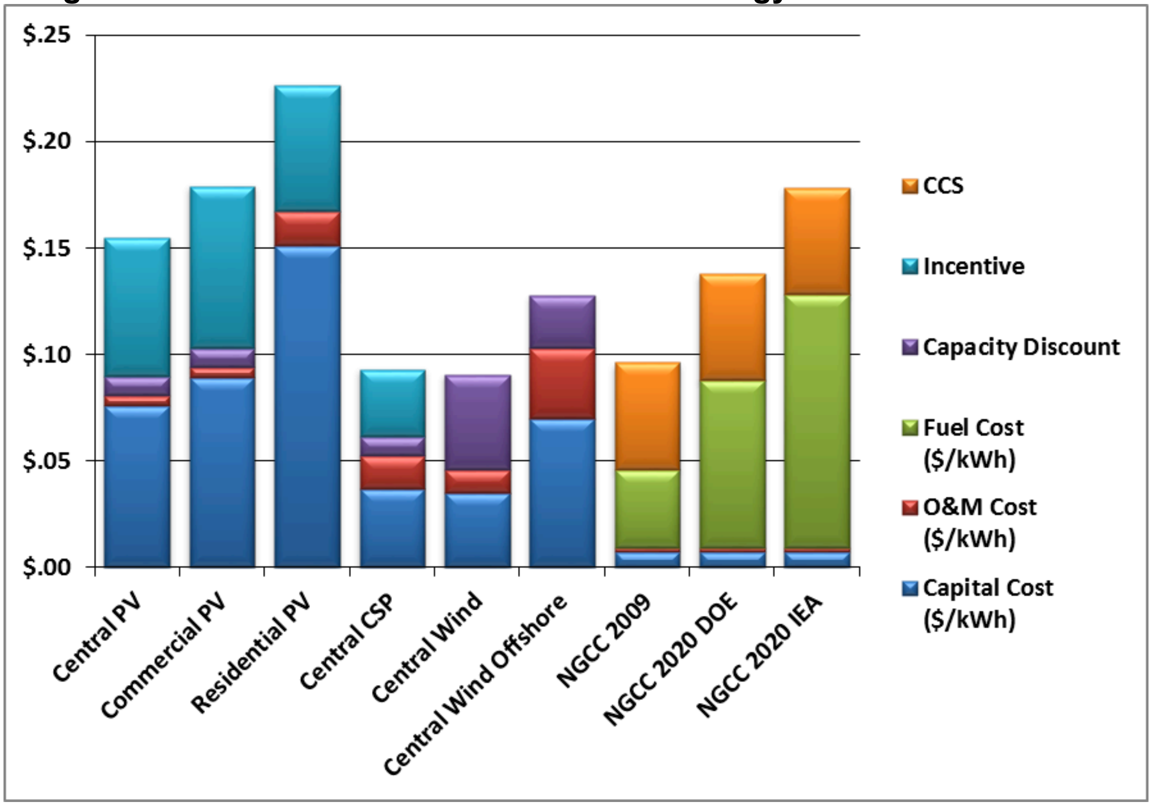
1. Capital costs, which are generally financed
2. Fixed annual costs
3. Operations and maintenance (O&M) costs
4. Fuel costs, if any

`

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.

`

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.

`

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

`

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.

`

Table A2.2: Criteria Pollutants Modeled in BEAR

1. TOG : Total Organic Gases (TOG) means "compounds of carbon, excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate."
    a. TOG includes all organic gas compounds emitted to the atmosphere, including the low reactivity, or "exempt VOC", compounds (e.g., methane, ethane, various chlorinated fluorocarbons, acetone, perchloroethylene, volatile methyl siloxanes, etc.).
    b. TOG also includes low volatility or "low vapor pressure" (LVP) organic compounds (e.g., some petroleum distillate mixtures). TOG includes all organic compounds that can become airborne (through evaporation, sublimation, as aerosols, etc.), excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate.
2. ROG: Total Organic Gas emissions are reported in the ARB's emission inventory and are the basis for deriving Reactive Organic Gas (ROG) emission estimates, which are also reported in the inventory.
    a. ROG means TOG minus ARB's "exempt" compounds (e.g., methane, ethane, CFCs, etc.).
    b. ROG is similar, but not identical, to U.S. EPA's term "VOC", which is based on EPA's exempt list. Also, various regulatory uses of the term "VOC", such as that for consumer products, exclude specific, additional compounds from particular control requirements.
3. CO: The concentration of Carbon Monoxide (CO) in the ambient air depends primarily on local weather conditions and the number of automobiles in the area. High levels of CO can have acute health effects on humans by reducing the supply of oxygen in the bloodstream. Normally, blood cells transport oxygen to, and remove carbon dioxide from, every cell in the body. The blood cells are more attracted to CO than to oxygen. Therefore, exposure to high levels of CO results in oxygen deprivation to various parts of the body. CO exposure can aggravate existing conditions such as heart and lung diseases. At high levels, CO exposure can be fatal. Nationally, a few hundred fatalities a year occur due to high concentrations of CO, usually in poorly ventilated buildings, idling parked cars with faulty exhaust systems and residential fires. The danger from CO is greatest in unborn and newborn infants, the elderly, and those suffering from chronic illnesses.
4. NOX: Nitrous Oxides (NOX) are chemicals formed in high-temperature combustion processes. The substances are themselves toxic and can react to form ozone or PM10 in the form of nitrates. Nitrogen dioxide (NO2) is brownish red gas with a biting odor. It is highly irritating in high concentrations. Nitrogen dioxide is always accompanied by nitric oxide (NO).
5. SOX: Sulfur Oxides are invisible gases with a pungent odor. At low concentrations, these gas can often be tasted before smelled. The major source of sulfur oxides is the combustion of sulfur-containing fuels, primarily coal and fuel oil. Sulfur dioxide is a toxic substance that can impair breathing.
6. PM: Particulate matter (PM), also known as particle pollution, is a complex mixture of dust and soot particles. PM is includes two small diameter categories of special public health interest, PM10 and PM2.5..
7. PM10: PM10 is matter 10 micrometers in diameter or less. That would be about one-seventh the width of a strand of human hair.
8. PM25: PM2.5 is even smaller - measuring 2.5 micrometers or less. These particles are so small that they can become imbedded in human lung tissue, causing or exacerbating respiratory diseases and cardiovascular problems. Other negative effects are reduced visibility and accelerated deterioration of buildings.

PM concentration is reported in micrograms per cubic meter or µg/m3. The particulate is collected on a filter and weighed. This weight is combined with the known amount of air that passed through the filter to determine the concentration in the air.

EPA revised the National Ambient Air Quality Standards(NAAQS) for PM pollution on September 21, 2006. The final standards address two categories of particle pollution: fine particles (PM2.5), which are 2.5 micrometers in diameter and smaller; and inhalable coarse particles (PM10), which are smaller than 10 micrometers. EPA strengthened the 24-hour PM2.5standard from the 1997 level of 65 µg/m3 to 35 µg/m3, and retained the current annual PM2.5 standard at 15 µg/m3. EPA also retained the existing national 24-hour PM10 standard of 150 µg/m3; however, it revoked the annual PM10 standard. These new standards went into effect on December 18, 2006.

VOC: Volatile Organic Compounds (VOC) are any compounds of carbon (other than carbon monoxide, carbon dioxide, carbonic acid, metallic carbonates, metallic carbides and ammonium carbonate) that participate in atmospheric photochemical reactions. A company must report all reactive VOC emissions (including fugitive emissions). VOC emissions which are non-reactive are not reported.

`

5 References

Abderwahab, Walid M. (21 December 1998) Elasticities of Mode Choice Probabilities and Market Elasticities of Demand: Evidence From a Simultaneous Mode Choice/Shipment-Size Freight Transport Model." Transportation Research Part E: Logistics and Transportation Review.

Abraham, S. (2004). "The Bush Administration's Approach to Climate Change." Science 305: 616-617.

Adams, D.M., R.J. Alig, B.A. McCarl, J.M. Callaway, and S.M. Winnett. "Minimum Cost Strategies for Sequestering Carbon in Forests." Land Econ. 75, no. 3(August 1999):360–74.

Adjustment Factor Trends. Integrated Waste Management Board. Retrieved May 2, 2007 from http://www.ciwmb.ca.gov/LGCentral/Rates/Graphs/AFTrend.htm

Air Resources Board: California Environmental Protection Agency (2007). Proposed Early Actions to Mitigate Climate Change in California. April 2007.

Al-Juaied, Mohammed and Adam Whitmore "Realistic Costs of Carbon Capture," Discussion Paper 2009-08, John F, Kennedy School of Public Policy, July 2009.

Ang, B.W. and G. Pandiyan (1997). Decomposition of energy-induced CO2 emissions in manufacturing, Energy Economics, Vol. 19, pp363-374.

Ang-Olson, Jeffery and Will Schroeer. (13 August 2003) Energy Efficiency Strategies for Freight Trucking: Potential Impact on Fuel Use and Greenhouse Gas Emissions.

Armington, Paul (1969), "A Theory of Demand for Products Distinguished by Place of Production," IMF Staff Papers, Vol. 16, pp. 159-178.

Aroonruengsawat, Anin, and Maximillian Auffhammer (2008) "Impacts Of Climate Change on Residential Electricty Consumption: Evidence from Billing Data," Discussion Paper, Department of Agricultural and Resource Economics, UC Berkeley, December.

Babiker, M.H., J.M. Reilly, M. Mayer, R.S. Eckaus, I. Sue Wing, and R.C. Hyman (2001). "The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Revisions, Sensitivities, and Comparisons of Results," MIT Global Change Joint Program, Report No. 1, February.

Ballard, C. L., D. Fullerton, J. B. Shoven, and J. Whalley. A General Equilibrium Model for Tax Policy Evaluation, University of Chicago Press, Chicago, 1985.

`

Barnett, Allen. "Solar-Electric Power: The U.S. Photovoltaic Industry Roadmap." U.S. Photovoltaic Industry Roadmap Steering Committee. http://www.sandia.gov/pv/docs/PDF/PV_Road_Map.pdf

Baumol, W.J., and W.E. Oates. The Theory of Environmental Policy, Cambridge: Cambridge University Press, 1988.

Beghin, J., D. Roland-Holst, and D. van der Mensbrugghe. "Trade and Pollution Linkages: Piecemeal Reform and Optimal Intervention," Canadian Journal of Economics, XXX No. 2, 442-55, 1997.

Beghin, J., S. Dessus, D. Roland-Holst and D. van der Mensbrugghe (1996). General Equilibrium Modelling of Trade and the Environment, Technical paper, No. 116, OECD.

Bemis, Gerry and Jennifer Allen. (2005) "Inventory of California Greenhouse Gas Emissions and Sinks

Bennathan, Esra, Julie Fraser and Louis S Thompson. (October 1992) What Determines Demand for Freight Transport? Policy Research Working Papers: Infrastructure and Urban Development Department, World Bank.

Berkwick, Mark and Frank Dooley. (October 1997) Truck Costs for Owner/Operators.

Berman, E., & Bui, L. T. M. (2001). Environmental regulation and labor demand: Evidence from the south coast air basin. Journal of Public Economics, 79(2), 265-295.

Bernstein, M. (2000). The public benefits of California's investments in energy efficiency. prepared for the California Energy Commission, RAND corporation.

Beyond 2000: The Continuing Need for Landfills (1996). Retrieved May 2, 2007 from http://www.ciwmb.ca.gov/Landfills/NeedFor/

Board, C. A. R. (2004). California environmental protection agency. Staff Proposal regarding the Maximum Feasible and Cost-Effective Reduction of Greenhouse Gas Emissions from Motor Vehicles," Sacramento: CARB/CEPA, June, 14

Bovenberg, A. Lans, and Lawrence H. Goulder, 2001. "Neutralizing the Adverse Industry Impacts of O2 Abatement Policies: What Does It Cost?," in Behavioral and Distributional Effects of Environmental Policy. C. Carraro and G. Metcalf ed. Chicago: University of Chicago Press, pp. 45-85.

Brown, M.A., Levine, M.D., Romm, J.P., Rosenfeld, A.H., and Koomey, J.G. (1998). Engineering- Economic Studies of Energy Technologies to Reduce Greenhouse

`

Gas Emissions: Opportunities and Challenges. Annual Review of Energy and Environment, 23, 287- 385.

Burtraw, D. and K. Palmer (2004). The SO2 Cap-and-Trade Program in the United States: A "Living Legend" of Market Effectiveness. Choosing Environmental Policy. W. Harrington, R. D. Morgenstern and T. Sterner. Washington, DC, RFF Press.

Burtraw, D., Alexander E. Farrell, Lawrence H. Goulder, and Carla Peterman (2006). "Lessons for a Cap and Trade Program," in Hanemann and Farrell (eds.) Managing Greenhouse Gas Emissions in California, op. cit.

Burtraw, Dallas and Karen Palmer, 2008. "Compensation Rules for Climate Policy in the Electricity Sector." Discussion Paper 07-41. Washington, D.C.: Resources for the Future.

Burtraw, Dallas, Karen Palmer, Ranjit Bharvirkar, and Anthony Paul, 2002. "The Effect on Asset Values of the Allocation of Carbon Dioxide Emission Allowances." Discussion Paper 02-15. Washington, D.C.: Resources for the Future.

California Air Resources Board (2009), "Example Base Allowance Budgets for the California Cap-and-Trade Program," November, http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm, accessed June 14, 2010.

California Air Resources Board. 2005. "Update to the Board on Biodiesel." June 2005. California EPA. 14 May 2007 <http://www.arb.ca.gov/fuels/diesel/altdiesel/062405boardhrng.pdf>.

California Climate Action Team: California Environmental Protection Agency A (2006). Climate Action Team Report to Governor Schwarzenegger and the Legislature. March 2006.

California Climate Action Team: California Environmental Protection Agency B (2007). Proposed Early Actions to Mitigate Climate Change in California. April 2007.

California Economic Census (2002). Administrative and Support and Waste Management and Remediation Services. U.S. Census Bureau

California Energy Commission (2003). Proposed Energy Savings Goals for Energy Efficiency Programs In California. Staff report prepared in support of the 2003 Integrated Energy Policy Report Proceeding (02-IEP-01). California Energy Commission #100-03-021, October 27.

California Energy Commission (2005). Commission Report: Options for Energy Efficiency in Existing Buildings.

`

California Energy Commission (2005a). California Energy Demand 2006-2016 – Staff Energy Demand Forecast, Revised September 2005. Staff final report, California Energy Commission-400-2005-034-SF-ED2, September.

California Energy Commission (2005b). Energy Demand Forecast Methods Report: Companion Report to the California Energy Demand 2006-2016 Staff Energy Demand Forecast Report. Staff report, California Energy Commission-400-2005-036, June.

California Energy Commission (2005c) Implementing California's Loading Order for Electricity Resources. Staff report California Energy Commission-400-2005-043, July.

California Energy Commission (2005d). Statewide - Projected Funding and Energy Savings by Utility and Sector (2006-2008). Demand Analysis Office, private communication, November.

California Energy Commission 2007-9 2007-9 Integrated Energy Policy Report, California Energy Commission-100-2007-008-CMF.

California Energy Commission, California Energy Commission, California Transportation Energy Demand Forecast Methodology: 2007 Integrated Energy Policy Report, 2007, accessed August 10th 2008, http://www.energy.ca.gov/2007_energypolicy/documents/2007-05-08_workshop/presentations/Petroleum%20Demand%20Forecast%20Methodology%20Final.pdf

California Energy Commission, Mike Messenger, Principal Author. 2003. Proposed Energy Savings Goals for Energy Efficiency Programs In California. Staff report prepared in support of the 2003 Integrated Energy Policy Report Proceeding (02-IEP-01). California Energy Commission #100-03-021, October 27.

California Energy Commission, Tom Gorin and Lynn Marshall, Principal Authors. 2005. California Energy Demand 2006-2016 – Staff Energy Demand Forecast, Revised September 2005. Staff final report, California Energy Commission-400-2005-034-SF-ED2, September.

California Energy Commission. "Public Interest Energy Research Program: Final Project Report." Intermittency Analysis Project. URL: http://www.energy.ca.gov/pier/project_reports/California Energy Commission-500-2007-081.html

California Energy Commission. "Wind Energy in California – Overview." URL: http://www.energy.ca.gov/wind/overview.html

`

California Energy Commission. (2005). Staff Report: 2004 Annual Review of the PIER Program Volume 2- Residential and Commercial Buildings End-Use Efficiency Projects Summaries: California Energy Commission- 500- 2005- 055- V2.

California Energy Commission. 2007. 2007 Appliance Efficiency Regulations.

California Energy Commission. California Electrical Energy Generation, 1996 to 2006 by Resource type. http://www.energyalmanac.ca.gov/electricity/electricity_generation.html.

California Energy Commission. California's Renewable Energy Programs. 2008. http://www.energy.ca.gov/renewables/index.html.

California Energy Commission. Solar Electricity Generation in California. 2008. http://energyalmanac.ca.gov/electricity/solar_generation.html.

California Energy Commission-ARB (2003). Reducing California's Petroleum Dependence. Joint Agency Report P600-03-005F.

California Environmental Protection Agency (2006). "Climate Action Team Report to Governor Schwarzenegger and the Legislature," March, http://www.climatechange.ca.gov/climate_action_team/reports/2006-04-03_FINAL_CAT_REPORT.PDF

California Environmental Protection Agency. (March 2006) Climate Action Team Report to Governor Schwarzenegger and the Legislature.

California Environmental Protection Agency. 2004, "Staff Proposal Regarding The Maximum Feasible And Cost-Effective Reduction Of Greenhouse Gas Emissions From Motor Vehicles," Draft Report, Sacramento, June.

California Public Utilities Commission Staff Progress Report. California Solar Initiative, California Public Utilities Commission. 2008. July 2008. http://www.energy.ca.gov/2008publications/California Public Utilities Commission-1000-2008-020/California Public Utilities Commission-1000-2008-020.pdf.

CALIFORNIA PUBLIC UTILITIES COMMISSION (2004a). Interim Opinion: Energy Savings Goals for Program Year 2006 and Beyond. Decision 04-09-060, September 23.

CALIFORNIA PUBLIC UTILITIES COMMISSION (2004b), Proposed Savings Goals for Energy Efficiency Programs in California, Publication 100-03-021F.

California Public Utilities Commission (2009) "33% Renewables Portfolio Standard Implementation Analysis Preliminary Results," June.

`

California Trucking Association. (10 July 2006) Average Cost/Retail Diesel Prices: Selected U.S. Cities.

California Trucking Association. (7 April 2006) Emission Reduction Strategies.

Callan, S.J., & Thomas, J.M. (2001). Economies of Scale and Scope: A Cost Analysis of Municipal Solid Waste Services. Land Economics, 77(4), p. 548- 560.

CCAP (2005a). Reducing CO2 Emissions from California's Cement Sector, Center for Clean Air Policy report to the California Energy Commission, October.

CCAP (2005b). Spreadsheets providing additional data in support of the cement sector study (CCAP 2005a), via personal communication.

CCAP (2005c). Analysis of Measures for Reducing Transportation Emissions in California. Report to the California Energy Commission, October.

CDOF (2005). "Gross State Product, California." Spreadsheet from California Department of Finance. http://www.dof.ca.gov/html/fs_data/LatestEcon Data /documents/bbgsp.xls

Center for Clean Air Policy (2005) Reducing CO2 Emissions from California's Cement Sector, October.

Center for Clean Air Policy (2005). Design of a Cap on Emissions from California Power Demand. Washington, DC: 27.

Center For Land Use Interpretation. Retrieved Nov Dec 2 from http://ludb.clui.org/tag/Mining/

Charles River Associates (2010). "Analysis of the California ARB's Scoping Plan and Related Policy Insights," Working Paper, March.

Copeland, B.R. "International Trade and the Environment: Policy Reform in a Polluted Small Open Economy," Journal of Environmental Economics and Management 26 (1994): 44-65.

Cropper, M.L., and W.E. Oates. "Environmental Economics: A Survey," Journal of Economic Literature 30 (1992): 675-740.

Daniel M. Kammen, Kamal Kapadia, and Matthias Fripp (2004) Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate? RAEL Report, University of California, Berkeley.

`

Department of Energy, Annual Energy Outlook 2009. With Projections to 2030, DOE/EIA-0383(2009). March 2009.

Duych, Ron et al., California Transportation Profile, United States Department of Transportation, 2002, accessed August 10th 2008, http://www.bts.gov/publications/state_transportation_statistics/california/pdf/entire.pdf

Dvorak, Michael J., Jacobson, Mark Z., and Archer, Cristina L. "California Offshore Wind Energy Potential." Department of Civil and Environmental Engineering, Stanford University. AWEA, 2007. URL: http://www.stanford.edu/~dvorak/papers/offshore-wind-ca-analysis-awea-2007.pdf

Economic and Technology Advancement Advisory Committee (EAAC). 2010. Allocating Emissions Allowances Under a California Cap-and-Trade Program Recommendations to the California Air Resources Board and California Environmental Protection Agency from the Economic and Allocation Advisory Committee," Report to the California Air Resources Board, March, 2010.

Economic and Technology Advancement Advisory Committee (EAAC). 2008. "Recommendations of the Economic and Technology Advancement Advisory Committee (EAAC), Final Report: Technologies and Policies to Consider for Reducing Greenhouse Gas Emissions in California." Report to the California Air Resources Board, February 11, 2008.

Economic Outlook: Governors Budget 2007-2008. Retrieved on April 28, 2007 from http://www.ebudget.ca.gov/BudgetSummary/ECO/1249562.html

Ehrhardt-Martinez, Karen and John A. "Skip" Laitner. 2008 "The Size of the U.S. Energy Efficiency Market: Generating a More Complete Picture." ACEEE Report E083. Washington, DC: American Council for an Energy-Efficient Economy.

Eldridge, Maggie, R. Neal Elliott, and William Prindle et al. 2008b. "Energy Efficiency: The First Fuel for a Clean Energy Future – Resources for Meeting Maryland's Electricity Needs," ACEEE Report E082. Washington, DC: American Council for an Energy-Efficient Economy.

Ellerman, A. D., P. L. Joskow, et al. (2000). Markets for Clean Air: the U.S. Acid Rain Program. Cambridge, UK, Cambridge University Press.

Ellerman, A. Denny and Paul L. Joskow, 2008. "The European Union's Emissions Trading System in Perspective." Report Prepared for the Pew Center on Global Climate Change. Washington, D.C., May.

Elliott, R.N., A.M. Shipley, E. Brown, R. Cleetus and S. Bernow. 2003. State-level Analysis of Industrial Energy Use. Proc. 2003 ACEEE Summer Study on Energy Efficiency in Industry, pp.6- 76-85, Washington, DC: ACEEE.

Energy Efficiency Task Force. (2005). The Potential for More Efficient Electricity Use in the Western United States: Energy Efficiency Task Force Report to the Clean and Diversified Energy Advisory Committee of the Western Governors' Association: Final Report.

Energy Information Administration (2008), "State Energy Profile – California." Retrieved August 4th 2008 from http://tonto.eia.doe.gov/state/state_energy_profiles.cfm?sid=CA#Con

Energy Information Administration. 2007. "Gasoline and Diesel Fuel Update." 07 May 2007. <http://tonto.eia.doe.gov/oog/info/gdu/gasdiesel.asp>.

Energy Information Administration: Office of Coal, Nuclear, Electric and Alternate Fuels. (April, 1997). Renewable Energy Annual.

Executive Orders-20-04 by the Governor of the State of California. (2004). Executive Department State of California. Retrieved on May 06, 2007 from http://www.energy.ca.gov/greenbuilding/documents/executive_order_s-20-04.html.

Expert Group on Energy Efficiency. 2007. "Realizing the Potential of Energy Efficiency: Targets, Policies, and Measures for G8 Countries." Washington, DC: United Nations Foundation.

Farrell, A. E. and L. B. Lave (2004). "Emission Trading and Human Health." Annual Review of Public Health 25: 119-138.

Fischer, C. and A. Fox (2004). Output-Based Allocations of Emissions Permits: Efficiency and Distributional Effects in a General Equilibrium Setting with Taxes and Trade. Washington, DC, Resources For the Future.

Fischer, C., I. W. H. Parry, et al. (2003). "Instrument choice for environmental protection when technological innovation is endogenous." Journal of Environmental Economics and Management 45(3): 523-545.

Fourer, Gary. "Residential Electric Power Security Project." California Energy Commission. September 2001.

Garner, Thesia, and and David Betson (2010). "Setting and Updating Modern Poverty Thresholds," Working Paper, United States Bureau of the Census,

`

http://www.census.gov/hhes/www/povmeas/papers/Garner%20and%20Betson%20ASSA%202010%203-3-10.pdf , accessed June 20, 2010.

Geller, Howard, Philip Harrington, Arthur H. Rosenfeld, Satoshi Tanishima, and Fridtjof Unander. 2006. "Polices for increasing energy efficiency: Thirty years of experience in OECD countries," Energy Policy, 34 (2006) 556–573.

Goulder, Lawrence H., Hafstead, Marc A. C. and Dworsky, Michael, Impacts of Alternative Emissions Allowance Allocation Methods Under a Federal Cap-and-Trade Program (August 18, 2009). Available at SSRN: http://ssrn.com/abstract=1457155

Hanemann, W. Michael, and A.E. Farrell (eds.) (2006) "Managing Greenhouse Gas Emissions in California," California Climate Change Center, University of California, Berkeley, January, http://calclimate.berkeley.edu/managing_GHGs_in_CA.html

Harrison, K. and W. Antweiler (2003). "Incentives for pollution abatement: Regulation, regulatory threats, and non-governmental pressures." Journal of Policy Analysis and Management 22(3): 361-382.

Heavner, B., & Del Chiaro, B. (2003). Renewable energy and jobs: Employment impacts of developing markets for renewables in california. Environment California Research and Policy Center, Sacramento, California,

Helme, Ned, Tom Peterson, and Eric Williams (2004). "Allowance Allocation: Who wins and loses under a carbon dioxide control program?" Center for Clean Air Policy, http://www.ccap.org/pdf/CRA_Background_Paper.pdf

Howat, J., & Oppenheim, J. (1999). Analysis of low-income benefits in determining cost-effectiveness of energy efficiency programs. Washington, DC National Consumer Law Center,

ICF (2005a). Emission Reduction Opportunities for Non-CO2 Greenhouse Gases in California, report to the California Energy Commission, PIER Energy-Related Environmental Research. California Energy Commission-500-2005-121

ICF (2005b). Spreadsheets providing additional data in support of ICF(2005a), op.cit., personal communication from A. Choate.

ICF Consulting, "EMISSION REDUCTION OPPORTUNITIES FOR NON-CO2

J.A. Laitner (2006). "An Annotated Review of 30 Studies Describing the Macroeconomic Impacts of State--Level Scenarios Which Promote Energy Efficiency and

Renewable Energy Technology Investments." American Council for an Energy Efficiency Economy: Comment Draft (July).

Jochem, E., & Madlener, R. (2002). The forgotten benefits of climate change mitigation: Innovation, technological leapfrogging, employment and sustainable development. OECD Workshop on the Benefits of Climate Policy: Improving Information for Policy Makers, 12-13.

Kahrl, Fredrich, and David Roland-Holst (2008), "California Climate Risk and Response," Research Paper, Department of Agricultural and Resource Economics, UC Berkeley, November, www.next10.org.

Kartha, S., M. Lazarus, et al. (2004). "Baseline recommendations for greenhouse gas mitigation projects in the electric power sector." Energy Policy 32(4): 545-566.

Kerr, S. and R. G. Newell (2003). "Policy-induced technology adoption: Evidence from the US lead phase down." Journal of Industrial Economics 51(3): 317-343.

Kling, Catherine and Jonathan Rubin, 1997. "Bankable Permits for the Control of Environmental Pollution." Journal of Public Economics 64:101-15.

Laitner, John A. "Skip" and Vanessa McKinney. 2008. "Positive Returns: State Energy Efficiency Analyses Can Inform U.S. Energy Policy Assessments." ACEEE Report E084. Washington, D.C.: American Council for an Energy-Efficient Economy.

Lawrance, Emily, 1991. "Poverty and the Rate of Time Preference: Evidence from Panel Data." Journal of Political Economy 99(1):54-77.

Lee, H. and D. Roland-Holst (1997). The Environment and Welfare Implications of Trade and Tax Policy, Journal of Development Economics, Vol. 52, pp.65-82.

Leiby, Paul and Jonathan Rubin, 2000. "Intertemporal Permit Trading for the Control of Greenhouse Gas Emissions." Environmental and Resource Economics 2000.

Lemoine, Derek M., Daniel M. Kammen, and Alexander E. Farrell. 2008. "An innovation and policy agenda for commercially competitive plug-in hybrid electric vehicles." Environmental Research Letters 014003.

McKitrick, Ross (1999). Derivation of the Marginal Abatement Cost Curve, Working Paper, Department of Economics, University of Guelph, January.

McManus, W. (2006). Can proactive fuel economy strategies help automakers mitigate fuel-price risks? University of Michigan, Ann Arbor, Transportation Research Institute

Messenger, Mike (2003) “Discussion of Proposed Energy Savings Goals for Energy Efficiency Programs In California,” Staff Paper, California Energy Commission, Sacramento, September.

Milliman, S. R. and R. Prince (1989). "Firm Incentives to Promote Technological-Change in Pollution-Control." Journal of Environmental Economics and Management 17(3): 247-265.

Montero, J. P. (1999). "Voluntary compliance with market-based environmental policy: Evidence from the US Acid Rain Program." Journal of Political Economy 107(5): 998-1033.

Murtishaw, Scott, and David Roland-Holst (2005), “Data Sources for Climate Change Research with BEAR: A Dynamic General Equilibrium Model of the California Economy,” Discussion Paper, Department of Agricultural and Resource Economics, University of California, Berkeley, November.

Ono, T. (2002). "The effects of emission permits on growth and the environment." Environmental & Resource Economics 21(1): 75-87.

Palmer, K., D. Burtraw, et al. (2005). In Search of Simple Rules for Using CO2 Allowances to Compensate Firms. Washington, DC, Resources For the Future.

Paltsev, S., J.M. Reilly, H.D. Jacoby, R.S. Eckhaus, J. McFarland, M. Sarofim, M. Asadoorian, and M. Babiker, 2005. "The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4." Report 125, MIT Joint Program on the Science and Policy of Global Change, Cambridge, Mass.

Parry, Ian W. H., 2003. "Fiscal Interactions and the Case for Carbon Taxes over Grandfathered Carbon Permits." Oxford Review of Economic Policy 19:385-99.

Pew Center on Global Climate Change(2006). “Designing a Mandatory Greenhouse Gas Reduction Program for the U.S.” http://www.pewclimate.org/global-warming-in-depth/all_reports/mandatory_ghg_reduction_prgm/usgas_conc.cfm

Poterba, James M. and Lawrence H. Summers, 1985. "The Economic Effects of Dividend Taxation," in Recent Advances in Corporate Finance. E. Altman and M. Subramanyam eds. Homewood, Ill: Irwin.

Ramseur, Jonathan L., 2008. "Emission Allowance Allocation in a Cap-and-Trade Program: Options and Considerations." CRS Report for Congress. Washington, D.C.: U.S. Congressional Budget Office.

Roland-Holst, David (2007). “Economic Analysis of California Climate Policy Initiatives using the Berkeley Energy and Resources (BEAR) Model,” Economics Subgroup,

`

Climate Action Team, “Updated Macroeconomic Analysis Of Climate Strategies Presented In The March 2006 Climate Action Team Report, Public Review Draft,” Economics Subgroup, Climate Action Team, CalEPA, Sacramento, September.

Roland-Holst, David (2008a), “Efficiency, Innovation, and Job Creation in California,” Research Paper, Department of Agricultural and Resource Economics, UC Berkeley, November, www.next10.org.

Roland-Holst, David (2008b), “Berkeley Energy and Resources (BEAR) Model: Documentation for a Dynamic California CGE Model for Energy and Environmental Policy Analysis,” Department of Agricultural and Resource Economics, University of California, Berkeley, Processed.

Roland-Holst, David (2009), “Energy Pathways for the California Economy,” Research Paper, Department of Agricultural and Resource Economics, UC Berkeley, November, www.next10.org.

Roland-Holst, David and Fredrich Kahrl. 2007. “Net Positive: California and the Cost of Curbing Carbon,” Research Paper 0708241, Center for Energy, Resources, and Economic Sustainability, University of California, Berkeley, August

Roland-Holst, David. 2006a. “Economic Assessment of Some California Greenhouse Gas Control Policies: Applications of the BEAR Model.” In Managing Greenhouse Gas Emissions in California, ed. Michael Hanemann and Alexander Farrell, Chapter 2. University of California at Berkeley: The California Climate Change Center. January.

Roland-Holst, David. 2006b. “Economic Growth and Greenhouse Gas Mitigation in California.” University of California at Berkeley: The California Climate Change Center. August.

Rosenfeld, A. (2008). Energy Efficiency: The first and most profitable way to delay climate change. EPA Region IX, California Energy Commission.

Rubin, J. D. (1996). "A model of intertemporal emission trading, banking, and borrowing." Journal of Environmental Economics and Management 31(3): 269-286.

Rufo, Michael, and Fred Coito. 2002. California’s Secret Energy Surplus: The Potential for Energy Efficiency. Report prepared by Xenergy, Inc., for the Hewlett Foundation and the Energy Foundation, September 23.

Russek, Frank S., 1996. "Labor Supply and Taxes." Working paper, Macroeconomics Division, Congressional Budget Office, Washington, D.C.

`

Sanstad, A., Hanemann, W. M., & Auffhammer, M. (2006). End-use energy efficiency in a postcarbon California economy: Policy issues and research frontiers. In W. M. Hanemann & A. E. Farrel (Eds.), Managing greenhouse gas emissions in California. Berkeley: University of California. Retrieved on April 21 from http://calclimate.berkeley.edu/managing_GHGs_in_CA.html

Sathaye, Jayant, and Scott Murtishaw. (2004). Market Failures, Consumer Preferences, and Transaction Costs in Energy Efficiency Purchase Decisions. Lawrence Berkeley National Laboratory for the California Energy Commission, PIER Energy-Related Environmental Research. California Energy Commission-500-2005-020.

Schennach, S. M. (2000). "The economics of pollution permit banking in the context of Title IV of the 1990 Clean Air Act Amendments." Journal of Environmental Economics and Management 40(3): 189-210.

Schennach, S. M. (2000). "The economics of pollution permit banking in the context of Title IV of the 1990 Clean Air Act Amendments." Journal of Environmental Economics and Management 40(3): 189-210.

Smith, Anne E. and Martin T. Ross, 2002. "Allowance Allocation: Who Wins and Loses under a Carbon Dioxide Control Program?" Discussion Paper, Charles River Associates, Washington, D.C.

Smith, Anne E., Martin E. Ross, and W. David Montgomery, 2002. "Implications of Trading Implementation Design for Equity-Efficiency Tradeoffs in Carbon Permit Allocations." Working paper. Washington, D.C.: Charles River Associates.

State of California: Green Building Action Plan: Work In Progress. Retrieved on May 06, 2007 from http://www.energy.ca.gov/greenbuilding/documents/background/02_GREEN_BUILDING_ACTION_PLAN.PDF.

Stavins, R. (2003). Experience with Market-Based Environmental Policy Instruments. The Handbook of Environmental Economics. K. Goren-Maler and J. Vincent. Amsterdam, North-Holland/Elsevier Science. 1.

Stavins, R.N. (2009) “The Costs of Carbon Sequestration: A Revealed-Preference Approach.” Amer. Econ. Rev.

Stavins, Robert N., 2007. "A US Cap-and-Trade System to Address Global Climate Change." Discussion paper 2007-13, The Hamilton Project. Washington, DC: The Brookings Institution.

Stavins, Robert N., Judson Jaffe, and Todd Schatski. 2007. “Too Good to be True? An Examination of Three Economic Assessments of California Climate Change

`

Policy," Working Paper, AEI-Brookings Joint Center for Regulatory Studies, January.

Stern, Nicholas (2006). "Stern Review executive summary". New Economics Foundation, London.

Summers, Lawrence H., 1981. "Taxation and Corporate Investment: A q-theory Approach." Brookings Papers on Economic Activity 1:67-127.

Swartz, Paul, and Peter Tillman, 2010., "Foreign Ownership of U.S. Assets," Quarterly Update, Council on Foreign Relations, October 8, 2010.

Taylor, M. R., E. S. Rubin, et al. (2003). "Effect of Government Actions on Technological Innovation for SO2 Control." Environmental Science & Technology 37(20): 4527-4534.

Tietenberg, T. (2003). "The tradable-permits approach to protecting the commons: Lessons for climate change." Oxford Review of Economic Policy 19(3): 400-419.

Train, K. (1985) Discount rates in consumers' energy-related decisions: a review of the literature. Energy, 10, 12, 1243–1253.

Tribble, Sarah Jane. "Gains Powered by Clean Energy." Kight-Ridder Tribune Business News: NA, April 16, 2007.

US Department of Energy. 2008a. California State Energy Profile—Energy Information Administration, Department of Energy.

US DOE-OIT, 2002b. Industrial Combustion Technology Roadmap, A Technology Roadmap by and for the Industrial Combustion Community. Office of Industrial Technologies, US Department of Energy, Washington, DC.

Worrell, E. and Galitsky, C. (2004). Energy Efficiency Improvement Opportunities for Cement Making: An ENERGY STAR Guide for Energy and Plant Managers.

Worrell, E., D. Phylipsen, D. Einstain and N. Martin. 2000. Energy Use and Energy Intensity of the U.S. Chemical Industry. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-44314).

Worrell, E., J-W.Bode, and J. de Beer. 1997. Energy Efficient Technologies in Industry (ATLAS project for the European Commission). Utrecht University, Utrecht, The Netherlands.

`

Yang, J. and S. Benkovic (2002). The Feasibility of Using Cap and Trade to Achieve Sulfur Dioxide Reductions in China, The Sinosphere Journal, Vol. 4, Issue 1, July, 2002, pp10-14.