Research Papers on Energy, Resources, and
Economic Sustainability

Energy Efficiency, Innovation, and Job Creation in California

David Roland-Holst

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Research Papers on Energy, Resources, and Economic Sustainability

This report studies the economic impacts of energy policies and climate adaptation generally, and particularly as this relates to employment and innovation. In addition to disseminating original research findings, this study is intended to contribute to policy dialogue and public awareness about environment-economy linkages and sustainable growth. All opinions expressed here are those of the authors and should not be attributed to their affiliated institutions.

For this project on Energy Efficiency, Innovation, and Job Creation in California, we express thanks to Next 10, who recognized the importance of this issue for California's economy and provided essential intellectual impetus and financial support. Thanks are also due for outstanding research assistance by Elliott Deal, Dave Graham-Squire, Maryam Kabiri, Fredrich Kahrl, Mehmet Seflek, and Tom Lueker.

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

Executive Summary

Global climate change poses significant risks to the California economy. Recognizing and responding to these threats, Governor Schwarzenegger signed Executive Order #S-3-05 (Schwarzenegger 2005) which called for a 30 percent reduction below business-as-usual of greenhouse gas emissions by 2020 and 80 percent below 1990 levels by 2050. In September 2006, the California legislature passed and Governor Schwarzenegger signed into law the historic Global Warming Solutions Act (AB 32), which mandates a first-in-the-nation limit on emissions that cause global warming. In June 2006, the California Air Resources Board (CARB) released a "Draft Scoping Plan" – the policy roadmap to meet the emissions reduction target of 169 Million Metric Tons of Carbon (MMTCO2) equivalent by 2020 to stabilize at 427 MMTCO2 overall. The CARB board will take up final adoption of this plan in December 2008.

During the months leading up to this decision, a financial crisis of global proportions is unfolding. The state, nation and world are caught in serial market failures sparked by the collapse of the housing credit market, and there is much speculation about the impact of declining capital gains revenue on the state budget.

Against this backdrop, *Energy Efficiency, Innovation, and Job Creation in California* analyses the economic impact of CARB's past and future policies to reduce fossil fuel generated energy demand. California's achievements in energy efficiency over the last generation are well known, but evidence about their deeper economic implications remains weak. This study examines the economy-wide employment effects of the state's landmark efficiency policies over the last thirty-five years, and forecasts the economic effects of significantly more aggressive policies proposed to reduce emissions to 1990 levels by 2020.

Part I: Economic Impact of California's Existing Energy Efficiency Policies

Over the last thirty-five years, as a result of landmark energy efficiency policies, California has de-coupled from national trends of electricity demand, reducing its per capita requirements to 40 percent below the national average. Using detailed data on the changing economic structure over the period 1972-2006, we examine one of the most potent catalysts of efficiency-based economic growth, household reductions in per capita electricity demand. Because it represents over 70 percent of Gross State Product (GSP), household consumption is the most powerful driver of economic activity in the state, and household expenditure patterns are the leading determinant of state energy use.

Methodology

Producing detailed historical employment impact estimates involved a data intensive process including assembling a series of input-output tables, comprising inter-industry flows, value added, and final demand for about 500 activity and commodity categories over the period 1972-2006. The U.S. Bureau of Economic Analysis (BEA) maintains these accounts and updates them every five years. Each of the seven relevant national tables were obtained from BEA and aggregated up to the 50-sector framework reported in this paper. Also, comparable tables for California, estimated for 2002 and 2006, were aggregated to the same sector standard. In addition to data on economic structure for the last 35 years, detailed employment wage data were obtained by California Regional Economies Employment (CREE) Series. This source provides annual data on enterprises, jobs, and average wages for over 1,200 North American Industry Classification System (NAICS) sector categories across California.

To impute historical employment gains from California's energy efficiency measures, we pose a simple counterfactual question:

Given California's economic structure, how would employment growth have proceeded in the absence of household energy efficiency?

Answering this question requires three kinds of information:

1. Historical national and current California consumption patterns, which were obtained from BEA tables.

2. Historical economic structure for California, which is estimated using seven historical input-output tables for the national economy and one (2002) for California. In particular, we used a combination of national and state tables to approximate California's changing economic structure.

3. Employment by sector, which was provided by the CREE data set.

Part I Core Findings

- Energy efficiency measures have, enabled California households to redirect their expenditures toward other goods and services, creating about 1.5 million FTE jobs with a total payroll of $45 billion, driven by well-documented household energy savings of $56 billion from 1972-2006.

- As a result of energy efficiency, California reduced its energy import dependence and directed a greater percentage of its consumption to in-state, employment-intensive goods and services, whose supply chains also largely reside within the state, creating a "multiplier" effect of job generation.

- The same efficiency measures resulted in slower (but still positive) growth in energy supply chains, including oil, gas, and electric power. For every new job foregone in these sectors, however, more than 50 new jobs have been created across the state's diverse economy.[1]

- Sectoral examination of these results indicate that job creation is in less energy intensive services and other categories, further compounding California's aggregate efficiency improvements and facilitating the economy's transition to a low carbon future.

Part II: Future Economic Impacts of California's Proposed Policies

At this critical moment of economic distress, balanced policy dialogue requires a more complete assessment of both the potential benefits and costs of the options before the state. Because of its pioneering role in climate policy, California faces a significant degree of uncertainty about direct and indirect effects of the many possible approaches to its stated goals for emissions reduction. High standards for economic analysis are needed to anticipate the opportunities and adjustment challenges that lie ahead, and to design the right policies to meet them. Progress in this area can increase the likelihood of two essential results: 1) that California policies work effectively, and 2) that they achieve the right balance between public and private interest.

In this part of the analysis, we conduct a rigorous ex ante economic assessment of draft policies contained in the California Air Resources Board Draft Scoping Plan.

Impact of Technological Change and Innovation

An important limitation of most prior California economic modeling of climate policies is innovation or technological neutrality. This means that factor productivity, energy use intensities, and other innovation characteristics were held constant across policy scenarios. Energy use and pollution levels might change, but the prospect of innovation to reduce energy intensity was not considered.

[1] This comparison is for net combined job creation, meaning we count both cumulative effects of both job creation and job losses.

Inclusion of innovation is important for two main reasons. First, technological change in favor of energy efficiency has been a hallmark of California's economic growth experience over the last four decades. As the earlier estimates show, the resultant energy savings have been an important growth and employment stimulus to the state economy. Second, most observers credit this technological progress to California's energy/climate policy combinations of mandates and incentives. And as discussed in Part I, California has reduced its aggregate energy intensity steadily over this period, attaining levels that today are 40 percent below the national average. Importantly, reductions in energy use were not flat across the last thirty-five years; instead energy efficiency grew at exponential rates.

In the present analysis, we factor in the prospect of innovation to reduce energy intensity by projecting a rate of energy efficiency gains that better reflects historical achievements, as well as the impact of significantly more aggressive policies aimed to reduce energy use. It is reasonable to assume that new climate polices will create new incentives for innovation. This is particularly true for policies like "cap and trade" which is included in the state's Draft Scoping Plan and will put an explicit price on carbon externalities that did not exist before. When firms are faced with new costs from emissions and energy use, they can be expected to make investments in technology that reduces these costs.

To capture this innovation, we assume that, subject to the implementation of the recommended measures, California is able to increase its energy efficiency by one additional percent per year, on an average basis, across the economy. This conservative estimate may be below the state's innovation potential in such circumstances, given that much lower energy prices and less determined policies were in place for the long period of improvement before AB 32.

Recently, the Center for Energy, Resources, and Economic Sustainability (CERES) at the University of California Berkeley conducted scenario analysis for the California Air Resources Board, which is included as a supplement to their economic forecasts conducted using the E-DRAM model. While the policy scenario analyzed here is identical to that modeled for the state, this analysis includes the potential for innovation to reduce energy intensity. The state's official modeling assumes technology characteristics remain static and includes a flat rate of energy efficiency for the time period considered (2008-2020).

Methodology

For the last three years, CERES has been conducting independent research to inform public and private dialogue surrounding California climate policy. Among these efforts has been the development and implementation of a statewide economic model, the Berkeley Energy and Resources (BEAR) model, the most detailed and comprehensive forecasting tool of its kind.

The BEAR model's sectoral detail, model determined emissions, and dynamic innovation and forecasting capabilities enable it to capture a wide range of program characteristics and their role in economic adjustments to climate action. BEAR was designed to model cap and trade systems, and includes all the major design features such as variable auction allocation systems, market determined permit prices, banking options, safety valves, and fee/rebate systems for CO2 and up to thirteen other criteria pollutants. BEAR is a detailed, computable general equilibrium model of California's economy that simulates demand and supply relationships across many sectors of the economy, and tracks the linkages among them. It can thus be used to trace the ripple effects throughout the economy over time of new economic and technology policies.

To assess the future economic impacts of the state's package of proposed policies to reduce greenhouse gas emissions, we used BEAR to model a generic policy scenario, which faithfully represents policies currently in the CARB Draft Scoping Plan.

Part II Core Findings

- By including the potential for innovation, we find that the proposed package of policies in the state's Draft Scoping Plan achieves 100 percent of the greenhouse gas emissions reduction targets as mandated by AB 32, while increasing the Gross State Product (GSP) by about \$76 billion, increasing real household incomes by up to \$48 billion and creating as many as 403,000 new efficiency and climate action driven jobs.

- The economic benefits of energy efficiency innovation have a compounding effect. The first 1.4 percent of annual efficiency gain produced about 181,000 additional jobs, while <u>an additional one percent</u> yielded 222,000 more. It is reasonable to assume that the marginal efficiency gains will be more costly, but they have more intensive economic growth benefits.[2]

[2] Job creation in the second case is larger because we assume energy efficiency applies to electricity use by all sectors, while the 1.4 percent efficiency improvement in the baseline applies only to household electricity demand.

- Existing energy efficiency programs and proposed state climate policies will continue the structural shift in California's economy from carbon intensive industries to more job intensive industries. While job growth continues to be positive in the carbon fuel supply chain, it is less than it would be without implementation of these policies.

Summary

California's legacy of energy policies and resulting economic growth provides evidence that innovation and energy efficiency can make essential contributions to economic growth and stability. Had the state not embarked on its ambitious path to reduce emissions over three decades ago, the California economy would be in a significantly more vulnerable position today. Looking ahead, California's ambitious plan to reduce greenhouse gas emissions as mandated by the California Global Warming Solutions Act (AB 32) puts the state on a more stable economic path by encouraging even greater investment in energy saving innovation. The current financial crisis reminds us of the importance of responsible risk management. The results of this study remind us that, in addition to energy price vulnerability and climate damage, the risks of excessive energy dependence include lower long-term economic growth. A lower carbon future for California is a more prosperous and sustainable future.

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APPENDIX

Energy Efficiency, Innovation, and Job Creation in California

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1. Introduction

As California looks to a future of ambitious climate action, it can reflect with confidence on its own legacy of energy efficiency improvements. Over the last generation, the state has established national and even global precedence with a proactive approach to more efficient energy use, building a solid foundation of experience to sustain progress toward to a lower carbon future. The state's reductions in energy use per capita and per dollar of income are well known, but evidence of the deeper economic implications of efficiency improvement remains weak. As California intensifies its commitments to reduce energy dependence, and as others look to the state for leadership, it is essential that stakeholders have reliable guidance regarding the broader effects of these policies. This report contributes to the policy dialogue by examining economy-wide employment effects of California's historical experience with energy efficiency policies, comparing this with forward looking projections of the economic impacts of new climate policy, as represented by the state's Global Warming Solutions Act (AB 32).

In this report, we conduct original estimates of the employment effects arising from the most potent source of economic stimulus in the state, household consumption. In particular, we find that household energy savings in California over the last thirty years have contributed over one million additional jobs to the state economy. Moreover, these additional jobs have been concentrated in less energy intensive service sectors, further reducing the state's carbon footprint and reinforcing its transition to a post-industrial, greener, and more sustainable future. Looking ahead,

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we estimate the impacts of the package of policies being considered to implement AB 32, and find that the state can reconcile its growth and environmental objectives, although detailed adjustment patterns suggest policies should be carefully designed.

Most prior California economic modeling of climate policies assumes technological neutrality. This means that factor productivity, energy use intensities, and other innovation characteristics were held constant across policy scenarios. Energy use and pollution levels might change, but the prospect of innovation to reduce energy intensity was not considered. Including innovation is important because technological change for energy efficiency has been a hallmark of California's economic growth experience and most observers credit this technological progress to California's energy/climate policy combinations of mandate and incentive. Innovation has been an indispensable part of the history of the state's economic growth and at the same time a consequence of its policies.

This report, for the first time, captures the impacts of innovation in response to state policies. Using the BEAR model, which has been developed with explicit capacity to examine the role of technological change and innovation as it relates to climate policy, we are able to study how incentive and market mechanisms can animate innovation to facilitate the state's adaptation to new climate policy priorities and maintain domestic and global competitiveness.

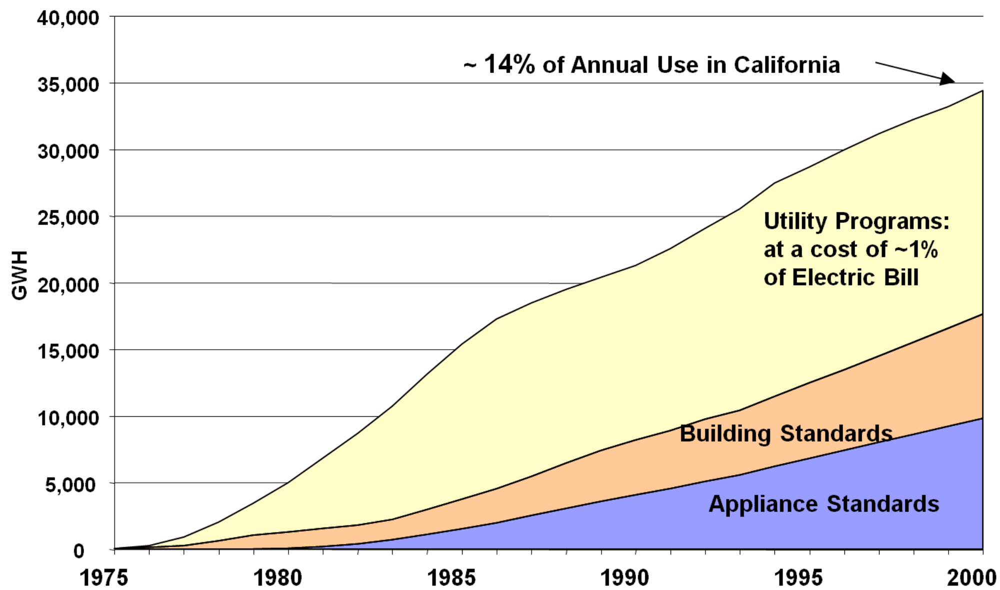
We begin this analysis of the economic impact of past and future energy and climate polices with a review of all of California's major energy efficiency initiatives and existing evidence of their economic impacts. From a very diverse array of research contributions on utilities, building standards, appliances, and transport, similar lessons are drawn. Energy efficiency not only saves money, it promotes demand that is less energy-intensive yet more job-intensive. This evidence contradicts the conventional notion of a trade-off between environmental policy and economic growth. Indeed, the growth-environment trade-off is based on a fallacy - that reduced emissions mean reduced economic activity. In California we can prove this.

2. Overview of Primary Sources of California's Energy Efficiency

Over the course of the last four decades, California and its first-in-the-nation California Public Utilities Commission (CPUC) and California Energy Commission

(CEC) have embarked on an ambitious path to decrease energy demand. Energy efficiency programs in the state focus on two major categories, electricity and fuels for heating and transportation. In the first category, a variety of programs and standards have been applied at various stages of the electricity supply chain, including efficiency standards for utilities (generation and distribution), buildings, and appliances. In the fuel category, utility and building standards are also relevant to natural gas, but another set of policies is targeted as transport fuel usage. In this section, we provide a general overview of these categories with a more detailed discussion of each provided in the Appendix.

Figure 1: Energy Efficiency Gain Impacts from Programs Begun Prior to 2001



Source: Rosenfeld (2008)

As Figure 1 vividly illustrates, California's investment in energy efficiency programs combined with appliance and building standards have played an important role in improving energy efficiency in California. Their combined impact resulted in a constant per capita electricity use in California over the past 30 years while nationwide use has increased by almost 50 percent.[4] The results included saving more than 12,000 MW of peak demand (equivalent to avoiding 24 giant power plants), and about 40,000 GWh each year (equivalent to 15 percent of California's energy consumption)[5].

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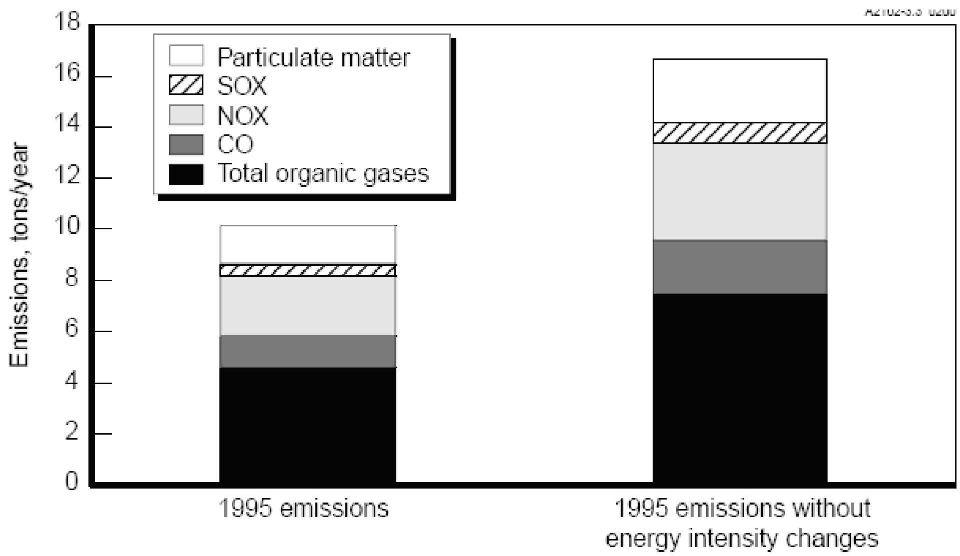
[4] CEC (California Energy Commission), 2005b, Options for energy efficiency in existing buildings. http://www.energy.ca.gov/2005publications/CEC-400-2005-039/CEC-400-2005-039-CMF.PDF

[5] CEC (Californian Energy Commission), 2005c, Pat McAuliffe

Energy consumption in California directly results in greenhouse gas emissions. Figure 2 compares California's actual 1995 emissions with estimated 1995 emissions if California had not improved upon 1977 efficiency levels. (Bernstein: 2001)

Figure 2: Estimated Pollutant Emissions from All Stationary Sources Excluding Waste Disposal



Utility Programs

Beginning in 1970, the CPUC has approved the use of ratepayer funds to promote energy efficiency activities, and authorized the major investor-owned utilities (IOUs) under its jurisdiction to administer a wide variety of energy efficiency programs. CPUC authorized programs to provide information services and financial assistance for consumers. CPUC also deployed a variety of strategies to assess the cost-effectiveness of energy efficiency. In the 1980s and early 1990s, California implemented programs for evaluation and measurement of utility Demand Side Management (DSM) and other publicly funded efficiency programs, which is currently being updated and expanded. The following is a simplified chronology of leading initiatives:

DATE	***CPUC LEADING INITIATIVES***
Late 1970s	The CPUC applied a least-cost planning strategy, whereby demand side reduction in energy usage was compared to supply additions.
Early 1980s	CPUC enacts policy to ensure that utilities' financial health is independent of their retail electricity sales. Sometimes referred to as "decoupling", this policy decision marked a radical shift in industry incentives, and opened the way for major investments in energy efficiency programs.

DATE	CPUC LEADING INITIATIVES
1983	The CPUC and CEC established the Standards Practice Manual, which provided several tests for evaluating the cost-effectiveness of publicly funded energy efficiency programs, including the Ratepayer Impact Measure Test, Utility Cost Test, Participant Test, Total Resource Cost Test, and Social Test. Most of the measures improved use monitoring and some included direct incentives for efficiency.
June 1990	The CPUC adopted shareholder incentives in order to increase energy efficiency program funding and established a more rigorous Mechanical & Electrical (M&E) infrastructure.
1995	Energy efficiency spending decreased because of the uncertainty in energy restricting.
1996	The state legislature passed AB 1890 to restructure the electricity industry, which required all publicly-owned utilities to invest in public benefit programs.
1996-1998	Regulators took steps to radically restructure the utility industry, including a temporary regulatory withdrawal of utility capacity to make long-term investment in resources of any kind (energy efficiency or generation).
1998	The CPUC changed the energy efficiency program goal and removed market barriers to energy efficiency so that the private sector would be able to provide energy efficiency services.
May 2001	Regulators set a goal of reaching 100 percent of low-income customers who want to participate in energy efficiency programs. The state's regulated utilities provided energy efficiency services to 845,000 low-income households between 2001 and 2005.[6]
2002	The state legislature restored utilities' resource investment responsibilities, including their mandate to pursue all cost-effective energy efficiency opportunities.
Spring 2003	CPUC, California Consumer Power and Conservation Financing Authority (California Power Authority) and California Energy Resources Conservation and Development Commission (California Energy Commission) adopt their *Energy Action Plan*, which establishes a "loading order" of preferred energy resources, placing energy efficiency as the state's top priority procurement resource, followed by renewable energy generation.[7]
Sept 2004	California regulators set the nation's most aggressive energy savings goals, to more than double the current level of savings over the next decade. Utilities are expected to invest nearly $6 billion over that period to reach the aggressive targets, projected to avoid the need to build ten new power plants (by saving nearly 5,000 MW) and provide approximately $10 billion in net benefits to state consumers over ten years.[8]

[6] Risser, Roland California Utility Low Income Energy Efficiency Program, Presentation given at the Low Income Energy Efficiency Symposium, Low Angeles, June 8 2006.

[7] California Consumer Power and Conservation Financing Authority, California Energy Resources Conservation and Development Commission and CPUC, Energy Action Plan, Adopted May 8, 2003 by CPUC, April 30 2003 by CEC and April 18, 2003 by CPA. Available online at www.energy.ca.gov/energy_action_plan/2003-05-08_ACTION_PLAN.pdf.

[8] CPUC Decision 04-09-060 "Interim Opinion: Energy Savings Goals for Program Year 2006 and Beyond," September 23, 2004.

DATE	CPUC LEADING INITIATIVES
Dec 2004	Governor Schwarzenegger issues a green buildings Executive Order, requiring that all new and renovated state buildings achieve an environmental rating of LEED (Leadership in Energy and Environmental Design) of silver or higher, setting a goal for all state buildings to be 20 percent more efficient by 2015, and encouraging the private sector to do the same. [9]
Jan 2006	California utilities launch the most aggressive energy efficiency program in the nation, providing $2 billion in funding over three years. [10] This investment is projected to provide a return of nearly $3 billion in net benefits to California's economy, avert the need every year to build a new giant power plant and avoid over three million tons of CO2 emissions, equivalent to removing 650,000 cars from the roads.[11]
Sept 2006	Governor Schwarzenegger signed the landmark Global Warmings Solutions Act (AB 32) into law, making California the first state in the nation to cap its statewide greenhouse gas (GHG) emissions.[12] The Governor also signed a law establishing a GHG performance standard for power plants serving the state's customers. All new or renewed long-term financial commitments to baseload power must come from plants that have GHG emissions per megawatt-hour generated no higher than those of a combined-cycle natural gas plant.[13]
2006	AB 2021 is signed into law and requires municipal utilities (which account for approximately 1/4 of statewide electricity sales) to treat investments in energy efficiency as procurement investments and to set annual efficiency targets.
2007	By this time, CPUC has restored shareholder incentives linked to utilities' energy efficiency performance.
2008	Aggregate statewide utility investment in energy efficiency surpasses $1.2 billion annually.

Economic Impact of Utility Efficiency Programs

While there is a fairly extensive body of official data and analysis on California utilities, much of this information remains outside the public domain. In addition, accurately measuring the cost-effectiveness of utility energy efficiency programs is difficult because of their complexity. As a result, to date, the full economic impact of these programs has not been captured. Several studies reviewed below, however, provide evidence of the economic benefits of utility efficiency programs.

The California Climate Action Team (2007) collected data from the investor-owned utilities (IOU) to analyse and estimate the persistence of energy efficiency measures included in IOU energy efficiency portfolios (Table 1 below). They also

[9] Executive Order S-20-04, December 14, 2004

[10] CPUC, Decision 05-09-043, "Interim Opinion: Energy Efficiency Portfolio Plans and Program Funding Levels for 2006-08 – Phase I Issues," September 22, 2005

[11] Calculated from targets in CPUC Decision z04-09-060, September 23, 2004 and CEC, California Energy demand 2000-2016 Staff Energy Demand Forecast Publication #CEC-400-2005-034-SF-ED2, September 2005.

[12] Assembly Bill 32 (Nunez & Pavley, 2006)

[13] Senate Bill 1368 (Perata, 2006)

analysed the avoided costs of energy efficiency measures with respect to natural gas price forecasts (Table 2). The natural gas price forecast is from the CPUC and is known as the Market Price Referent. This forecast predicts that the price of natural gas will decline until 2020. In light of the current state of energy prices and also the large spike in petrol, the estimates of future pricing and avoided costs may prove to be significant underestimates. The CAT estimates, even under such optimistic energy price assumptions, imply that these avoided costs can create energy savings for both business and individuals, and can therefore stimulate the economy through spending on non-energy related goods and services.

Table 1: Estimated Persistence of Energy Efficiency Measures
(Based on Analysis of the IOU Program Portfolios)

Years Following Installation	*Remaining Energy Efficiency Impact*	
	Electric Measures	Gas Measures
1	99.69%	100.00%
2	95.97%	99.46%
3	89.59%	98.51%
4	85.14%	97.84%
5	84.02%	97.11%
6	78.32%	89.75%
7	78.24%	89.75%
8	78.22%	89.75%
9	74.58%	89.70%
10	66.73%	87.45%
11	51.71%	73.71%
12	34.56%	72.45%
13	33.13%	70.45%
14	32.88%	69.27%
15	32.51%	67.90%
16	17.12%	42.47%
17	4.56%	42.47%
18	4.56%	42.47%
19	4.03%	40.40%
20	3.89%	38.64%

Source: California Climate Action Team (2007)

Percentages reflect the portion of the first year energy savings that remains throughout the full 20-year lifetime of the energy efficiency measures. Estimated from the Investor Owned Utilities' energy efficiency portfolio plans for 2006-2008.

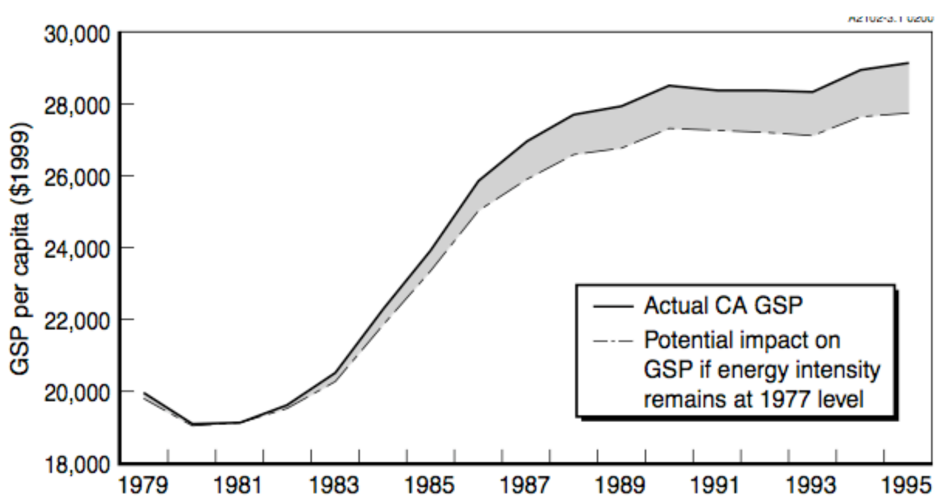
Table 2: Forecast of Annual Standardized Prices of Electricity Avoided Using the 2005 IEPR Natural Gas Price Forecast *(Price of Electricity ($/MWh)*

Year	Applied to Energy Efficiency Savings	Gas Price ($/MMBtu)
2007	$110.88	$8.17
2008	$99.85	$6.55
2009	$98.90	$6.45
2010	$87.14	$5.25
2011	$100.07	$6.56
2012	$95.49	$6.09
2013	$106.10	$7.15
2014	$99.01	$6.42
2015	$106.69	$7.20
2016	$106.12	$7.13
2017	$105.25	$7.03
2018	$108.55	$7.36
2019	$111.85	$7.69
2020	$111.82	$7.69

Source: California Climate Action Team (2007)

A RAND study prepared for the California Energy Commission estimated the historical impacts of energy efficiency investments in California from 1977 to 1995. They estimate that if energy efficiency had stayed constant at 1977 levels, GSP per capita would have been three percent less than its 1995 value (Figure 3). In a contrarian exercise, they find that reductions in energy intensity account for $875 of increased income per capita ($1998), though they do not directly attribute these gains to energy efficiency programs.

Figure 3: GDP Imputed at Higher Energy Dependence



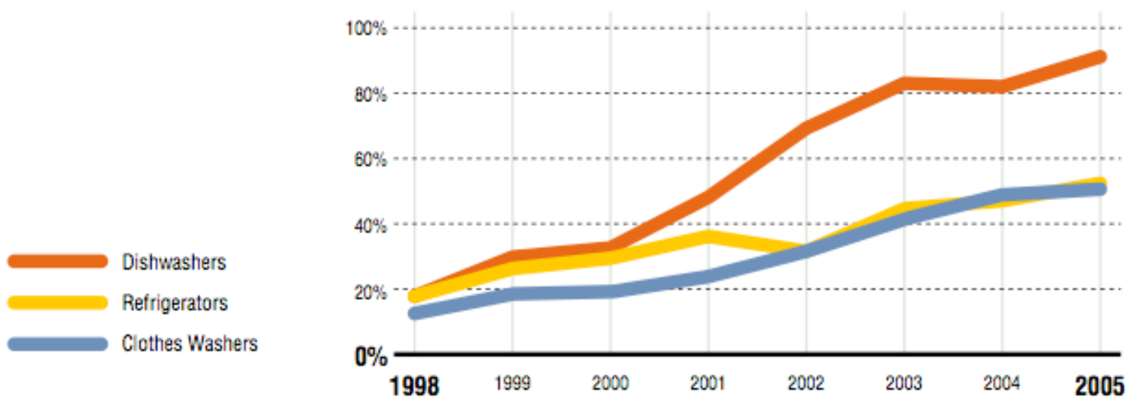
Source: Bernstein (2001)

Appliance and Building Standards

In 1978, California established the first building and appliance standards in the country. Title 24 building standards and Title 20 appliance standards require significant reductions in energy demand, and are revised upward every three years. It was estimated that the 2003 revisions of Title 24 will save 180MW/year[14], and Title 20 will save 100MW/year.[15] Further revisions in 2005 and 2008 are extending these gains and are estimated to produce another $23 billion in savings by 2013. Combing more stringent versions of existing standards with new initiative like outdoor lighting restrictions and reflective roof coatings, these will make important contributions to fulfilling our conjectural one percent annual efficiency gain.

Adoption of energy efficient appliances in California has been both rapid and sustained, as Figure 4 indicates. Nearly 85 percent of all dishwashers in California are Energy Star compliant, and 50 percent of both refrigerators and clothes washers also conform to these standards. What is even more impressive, however, is that this increase in market share occurred over only seven years.

Figure 4: California Market Share of Energy Star Appliances



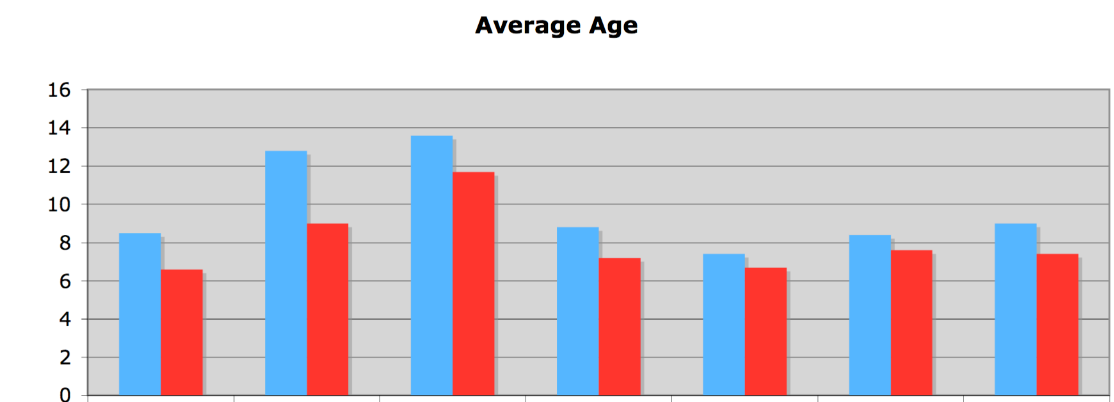
Source: Next 10's California Green Innovation Index

In a survey of 1,250 California households in 2000, and another 1,000 in 2005, Okura et al. (2006) found that appliance standards and energy efficiency programs have helped to decrease the use of older and outdated technologies (Figure 5) and

[14] California Energy Commission, "Energy Commission Approves New Building Standards to Help the State Cut Energy Use," Press Release, November 5, 2003.
[15] California Energy Commission, "Energy Commission Approves New Energy-Saving Rules for Appliances," Press Release, December 15, 2004.

on average lead to the decrease of more than 200 KWhr per year for primary refrigerators (Figure 6).

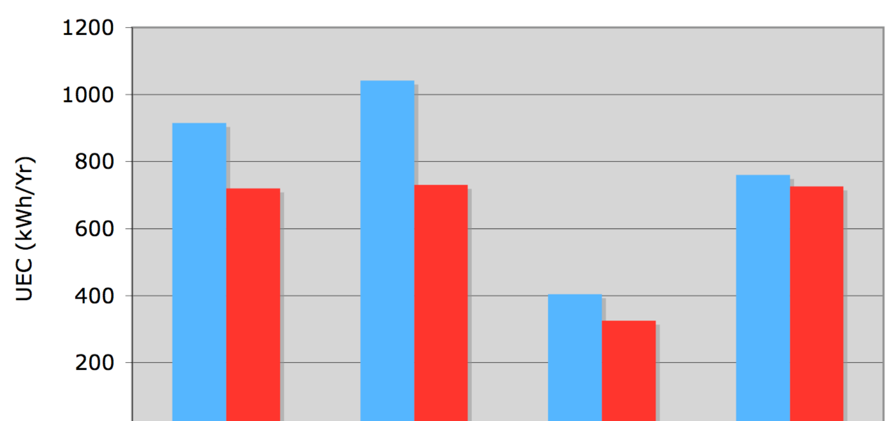
Figure 5: Appliance Renewal Cycles



	Primary Refrigerators	Secondary Refrigerartors	Freezers	Hot Water Heaters	Washers	Dryers	Dishwashers
2000	8.5	12.8	13.6	8.8	7.4	8.4	9
2005	6.6	9	11.7	7.2	6.7	7.6	7.4

Source: Okura et al (2006)

Figure 6: Appliance Average Efficiency

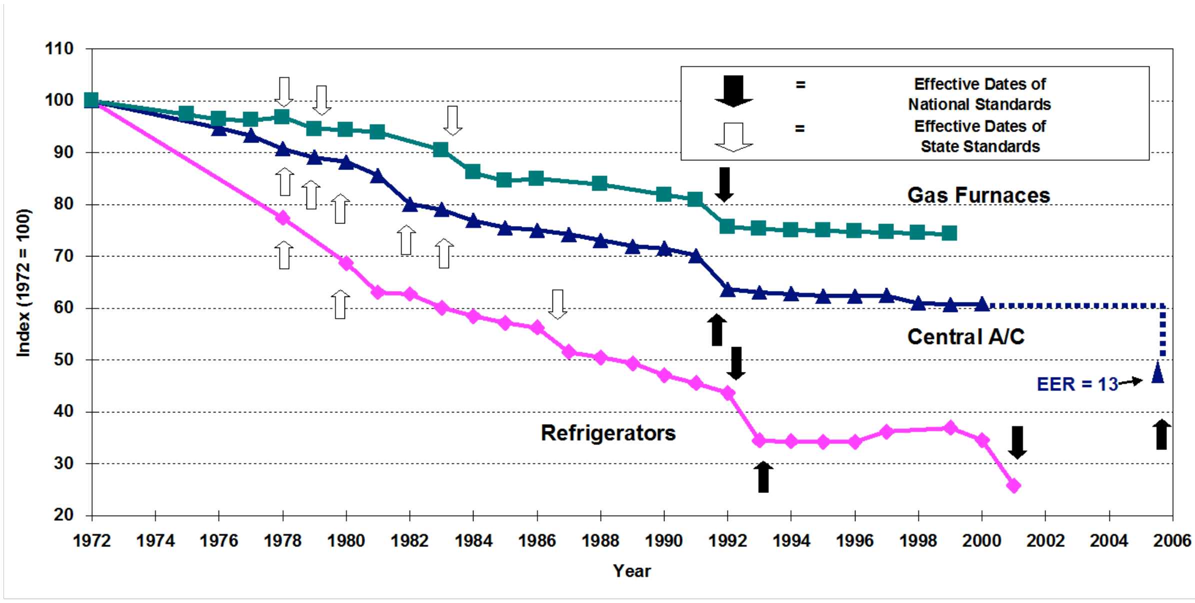


	Primary Refrigerators	Secondary Refrigerartors	Freezers-Chest	Freezers-Upright
2000	914.7	1041.3	403.6	760.4
2005	720.7	730.6	325.3	726.4

Source: Okura et al (2006)

Further, appliance standards targeting central air conditioners and gas furnaces have a notable impact on efficiency. As Figure 7 illustrates, over the past three decades, the implementation of California's Title 24, combined with federal standards, have decreased energy use by furnaces and air conditioners about 25 and 40 percent, respectively, with continued improvements in efficiency expected to continue.

Figure 7: Impact of Standards on Efficiency of Three Appliances



Source: Rosenfeld (2008)

Like appliance standards, building standards have been an essential source of energy savings for California. By 2003, building standards were saving about 10,000 GWh per year, which is about one-fourth of the over 40,000 GWh saved annually through a combination of utility efficiency programs and building and appliance standards. (See Appendix for additional information on building standards.)

Economic Impacts of Building and Appliance Standards

The California Energy Commission estimates that building and appliance efficiency standards combined have saved a total of more than $56 billion in electricity and natural gas costs, the equivalent to a net savings of more than $1,000 per household, and is money that then goes back into California's economy[16]. By 2013, they are expected to save an additional $23 billion.

[16] Bernstein,M., R. Lempert, D. Lougharn, and D. Oritz. 2000. The public benefit of California's investments in energy efficiency. Prepared for the California in Energy Commission. RAND Monograph Report MR-1212.0-CEC.
http://www.rand.org/pubs/monograph_reports/MR1212.0/index.html

In a retrospective examination of appliances in the year 2000, Gillingham et al (2004) show that appliance standards yield positive net benefits to US consumers on average. The average electricity price in 2000 was $6.3 billion ($2002) per quad of primary energy, while the cost of residential appliance standards was under $3.3 billion per quad. Gillingham notes that even if unaccounted for, costs of appliance standards are so large as to be almost equal to those included in the study, or if actual energy savings were half of what is estimated, the appliance standards studied would still yield positive net benefits on average. He adds that including the positive environmental externalities of reduced electricity consumption would further strengthen the argument that the benefits of appliance standards were worth the cost.

For California and the greater United States, the establishment of appliance efficiency standards has had a positive net employment impact on jobs created directly in the appliance manufacturing industry. A report prepared for the Regional Greenhouse Gas Initiative found efficiency standards among household appliances produced an estimated .8 percent increase in private-sector job growth by 2021 (Prindle: 2006). For manufacturers, appliance efficiency standards spur job creation because producers of standardized technologies must increase employment to meet increased demand for energy efficient technologies. Established standards make the markets for these technologies more secure and reduce uncertainties that often limit voluntary adoption. Furthermore, new efficiency standards increase innovation incentives for producers, reducing marketing risks, creating more jobs and leading to the development of better appliances, some of which are today 75 percent more efficient than their 1970 counterparts. The development of new more efficient appliances also stimulates market demand and producer profits. When these standards are adopted by an interstate agreement the standard becomes more universal, yielding another benefit for manufacturers (Hildt: 2001). As an early adopter, California producers have a better chance of internalizing these innovations and capturing future market advantages.

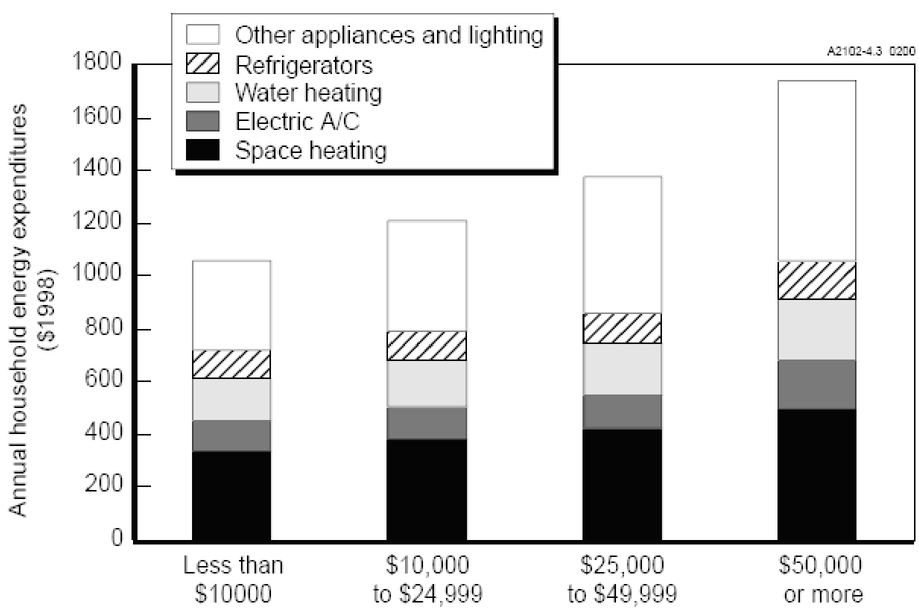
Like appliance standards, building standards have also been an important source of direct employment growth. While standards to promote more energy efficient buildings create new up-front costs and long-term savings, as is usual for California's efficiency policies, the latter far outweigh the former, but even the costs have a silver lining. Most independent studies indicate that the kind of technology adoption needed for building standard conformity is unusually employment intensive, and promotes job creation among relatively high wage, diverse groups of semi-skilled and unskilled workers. For this reason, building standards represent not just economic growth, but more inclusive growth.

Economic Impact on Low Income Families

Though low-income families spend less on energy on average than high-income families, a much larger portion of their lower incomes are spent on energy. The 1997 Residential Energy Consumption Survey (RECS) reported that the average annual energy expenditure for the $5,000-$9,999 income bracket was $985, compared to the average energy expenditure for the $75,000+ income bracket which was $1,835. High-income households spend approximately twice as much on energy as low-income households, but their incomes are over seven-and-a-half times greater. When looked at in terms of end-use, regardless of income, up to two-thirds of household energy use is for space heating, water heating, and refrigeration (Figure 8). These services can be considered essential, for they are shared across all income brackets. In 1997, the average expenditure for these services for households in the $10,000 and below bracket was $714, versus $863 for households between $25,000 and $49,999; only a 20 percent increase though incomes are two to five times greater. Clearly, efficiency increases in essential services provide a substantial benefit for low-income households.

Of course, the state is well aware of these social benefits, and has for decades encouraged utilities to invest in Low Income Energy Efficiency (LIEE) programs. These schemes, including a range of insulation and appliance maintenance services, have been offered by the California Public Utilities Commission and individual utilities for most of the period under discussion (1972-2006).

Figure 8: Annual Energy Expenditures by End Use and Household Income



Source: Bernstein (2001)

Table 3: Annual Household Energy Expenditure by End Use ($1993)

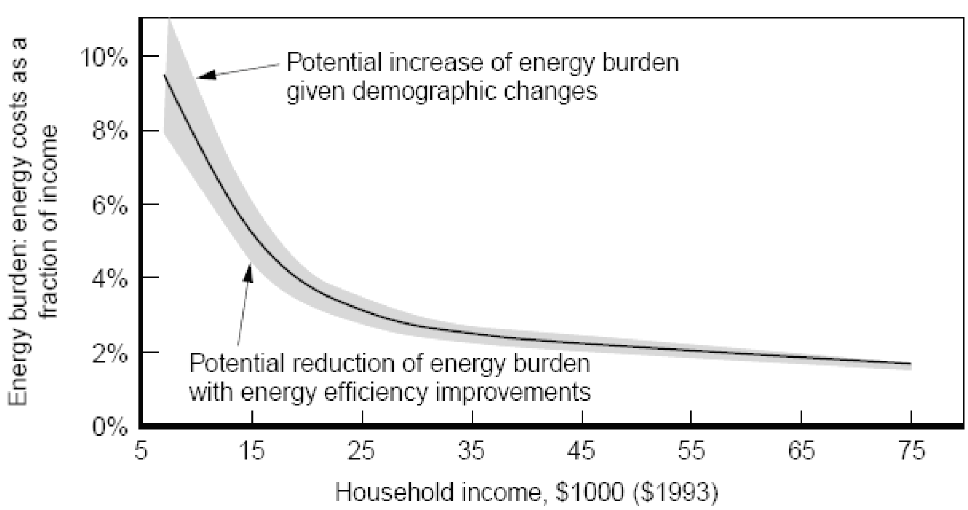
Income Level	Space Heating	Air Conditioning	Water Heating	Refrigeration	Appliances
Low-income	163	88	162	92	351
Median-income	193	137	138	139	519

Source: Bernstein (2001)

Low-income families benefit substantially from appliance efficiency standards not only because of their disproportionate energy expenditures, but also because these families tend to occupy older houses and own older appliances. A study on low-income housing found that only 64 percent of families in the $5,000- annual income bracket have ceiling insulation, versus 91 percent for families in the $50,000+ income bracket. Table 3 illustrates how inefficient housing impacts low-income end use energy consumption. Low-income households spend nearly as much on space heating as median income families, because even though their homes are smaller, the homes are older and less efficient to heat. More startling perhaps is the statistic that low-income households on average spend more than median-income households on water heating, likely due to the prevalence of less efficient electric water heaters and fewer numbers of dishwashers.

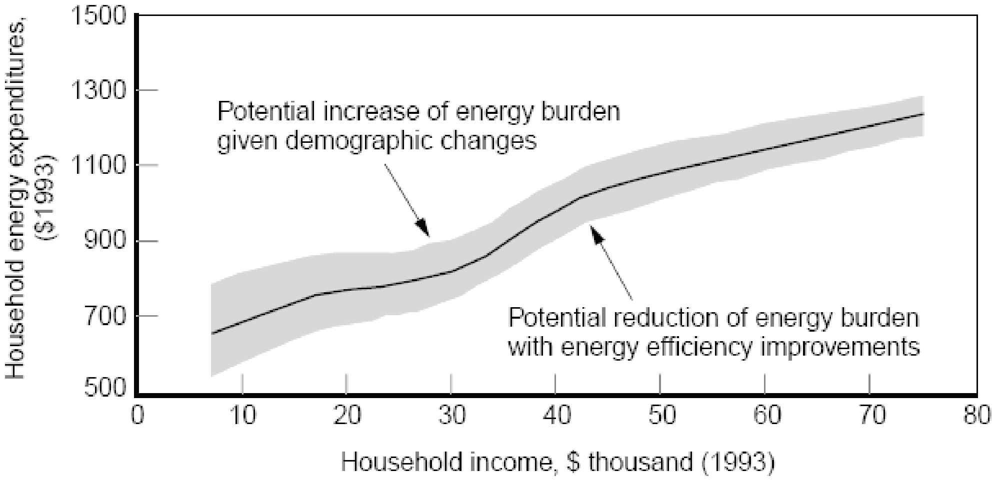
Clearly, low-income families stand to benefit most from the expansion of appliance efficiency standards and the continuing support of LIEE. Figure 9 shows the potential gains from efficiency across income brackets as a fraction of income, and Figure 10 the potential gains in terms of absolute energy expenditure. The broader benefits resultant from efficiency gains include "increased comfort and health, safety, reduced loss of service from termination, and increased housing development and property values." (Bernstein: 2001)

Figure 9: California Household Energy Expenditure as a Percentage of Income



Source: Bernstein (2001)

Figure 10: California Household Energy Expenditure



Source: Bernstein (2001)

Transportation

Fuel economy standards are federally regulated and California does not have the same discretion in transport fuel policy that it has used to establish national leadership with building and appliance efficiency. The state has benefited somewhat from Federal Corporate Average Fuel Economy (CAFE) standards, however, as they have increased on-road fuel economy of cars and light-duty trucks from 12.6 miles per gallon (mpg) in 1970 to 20.7 in 1985 in California. Although these standards have not changed substantially in the last 22 years, in 2004 alone the state's combined fleet's fuel economy increased by about two mpg. This improvement was due to a decrease in light truck sales, especially sports utility vehicles (SUVs), which conform to a lower mile-per-gallon fuel economy standard. In 2005, Governor Schwarzenegger appealed to the United States House of Representatives to establish new fuel economy standards that doubled the fuel efficiency of new cars, light trucks, and SUVs.

In January 2008, the United States Congress passed the Energy Independence and Security Act (EISA), which increased the national fleet wide fuel economy standards for cars and trucks to 35 mpg by 2020. A study by the Union of Concerned Scientists (UCS) estimated that a fleet wide average of 35 mpg by 2018 would increase employment by 241,000 across country by 2020 – including 23,900 job opportunities in automotive sector – and consumers would save $61 billion dollars in gasoline in the year 2020. In California, UCS estimated the program would save $8,407 million and create several thousand new jobs by 2020.

In 2008, a provision in a 2003 California law required that all replacement automobile tires sold in California are, on average, as fuel efficient as the original tires of new vehicles sold in the state.[17] The law is expected to increase the statewide fuel economy of cars and trucks by three percent, save over 545 million gallons of gasoline, over $1 billion in fuel costs and 4.8 million metric tons of CO_2.[18]

Conclusion

California's leadership in energy efficiency, from utility programs to standards, has put the state on an energy consumption path that has diverged greatly from the nation's path. While the dramatic reductions in energy consumption are well documented, the economic impacts are less well known. We have reviewed existing studies extensively (here and in the Appendix), which provide evidence of positive net economic benefits and job creation directly in the appliance and building sectors.

While multiple studies have recognized the positive economic benefits of energy efficiency programs, none have analyzed the economy-wide impacts of innovation associated with the consumer savings resulting from these efficiency improvements.

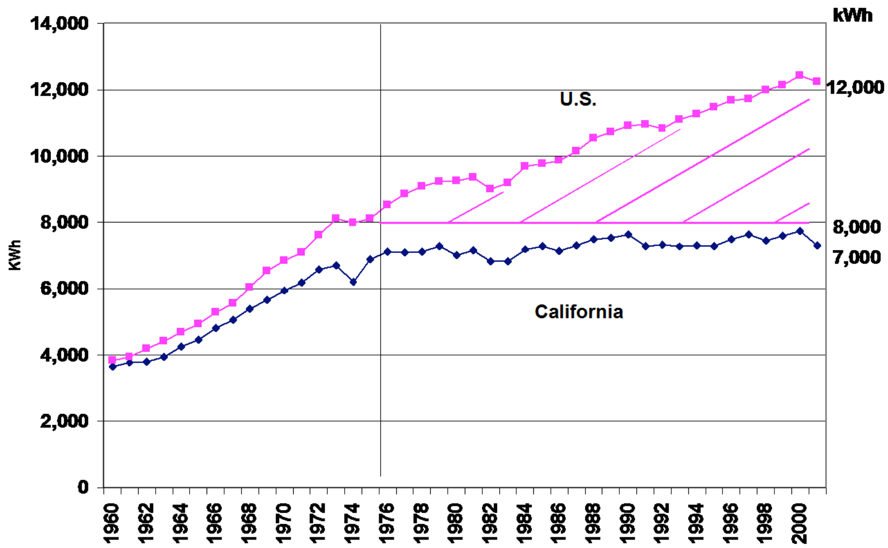
In the next section, we will present the first comprehensive economy-wide analysis of the impacts of California's history of energy efficiency and innovation.

3. Economic Impact of California's Legacy of Energy Efficiency

Because it represents over 70 percent of GSP, household consumption is the most important driver of economic activity in the state. For the same reason, household expenditure patterns are the leading determinant of state energy use. This includes direct energy use, for residential electricity and transport fuels, as well as an extensive web of indirect energy demand, embodied in all the other goods and services consumers purchase. Because of its significance, household energy demand was selected for detailed analysis in the employment context. In this work, we focus on electricity demand because California has a much longer history of promoting efficiency in this area.

[17] AB 844 (Nation: 2003)
[18] California State Fuel-Efficient Tire Report: Volume II, Consultant Report 600-03-001CR Vol. II, January 2003

Figure 11: Total Electricity Use, per capita, 1960-2001



Source: Rosenfeld (2008)

Deeper insight into the economy-wide effects of energy efficiency can be gained by detailed demand analysis. This approach is described in technical detail the Appendix, but for the present we describe it heuristically. As Figure 11 illustrates, over the last generation, California has de-coupled from national trends of electricity demand, reducing its per capita requirements to 40 percent below the national average. If this trend had not been established, the state would have been obliged to build over 24 additional power plants and statewide emissions would have increased accordingly. This is only the direct effect of averted energy use, however, and captures just a fraction of the economic impact of efficiency measures. Consumers were able to reduce energy spending vis-à-vis a no-efficiency baseline, and these savings were diverted to other demand. The stimulus thus provided by energy savings increased employment across a broad spectrum of consumer goods, services, and the activities in all their supply chains.

The estimates presented here take fuller account of these extensive indirect growth linkages (what economists call multiplier) effects. As many authors have already observed, energy supply chains are not job intensive, and for California they mainly include capital intensive refining, conveyance, and electric power generation. Other consumer spending is concentrated mainly on job intensive services, retail consumer goods, and foodstuffs. Thus expenditure diversion from energy to other consumption results in net job creation. The extent of this depends on specific characteristics of consumption patterns and linkages to upstream supply chains. These are captured in detailed industry accounts of the Bureau of Economic

Analysis, including 500 sector input-output tables estimated every five years from 1972 to the present. For the current estimates, we exhaustively researched these tables, aggregating them to fifty sectors and calculating multipliers for each of seven semi-decadal accounting systems (described in more detail in the Appendix). Using this information and detailed historical demand patterns for both California and the United States as a whole, we then calculated the contribution to total state employment resulting from reducing household energy expenditure over the 35 year period 1972-2006. The results, in terms of net job creation, are presented in Table 4 (sectors are defined in the Appendix). These estimates strongly support the argument that energy efficiency stimulates net job creation. Although energy sector industries may be adversely affected, efficiency saves households money. The resulting expenditure shifting leads to demand driven job growth that far exceeds the losses to the carbon fuel supply chain, and 1,463,611 net new jobs created over the period considered. Moreover, sectoral examination of these results indicate that job creation is in less energy intensive services and other categories, further compounding California's aggregate efficiency improvements and facilitating the economy's transition to a low carbon future.

More specifically, the results in Table 4 can be interpreted as estimates of the cumulative employment effects that have resulted because California households broke away from national trends in electricity consumption. These are calculated at each five-year milestone in the table, with the fairly conservative assumption that the attendant multiplier effects would take five years to run their course. In fact, the savings from additional efficiency are realized every year over the period considered, so our estimates may be significantly below the actual values. Having said this, it should be noted that we do not incorporate adoption costs, which beyond renewal and replacement might reduce net savings somewhat. Taking account of this and the degree to which five-year calculations underestimate the savings, we believe the results are robust indicators of net job creation from electricity efficiency. Table 5 translates efficiency-induced job growth into incomes. These estimates are based the detailed historical average wage data from the California Regional Economies Employment dataset (CREE, see the Appendix), and indicate that induced job growth has contributed approximately $45 billion to the California economy since 1972.

Table 4: Job Creation from Household Energy Efficiency

	1972	1977	1982	1987	1992	1997	2002	2007	Total
Agriculture	-	36	112	204	266	631	849	869	2,967
EnergyRes	-	(0)	(1)	(1)	(0)	(1)	(1)	(1)	(5)
ElectPwr	-	(266)	(1,140)	(2,236)	(3,405)	(4,720)	(5,809)	(5,944)	(23,520)
OthUtl	-	(12)	(78)	(2)	13	71	77	79	149
Construction	-	-	-	-	-	-	-	-	-
Light Industr	-	821	2,688	4,593	6,095	8,392	9,247	9,463	41,300
OilRef	-	(14)	(6)	(9)	(10)	(14)	(24)	(25)	(102)
Chemica	-	48	190	448	764	555	2,234	2,287	6,526
Cement	-	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Metals	-	2	1	4	(5)	(16)	(16)	(16)	(46)
Machinery	-	14	26	54	44	(38)	(51)	(52)	(2)
Semicon	-	0	0	3	8	176	318	325	830
Vehicles	-	20	38	133	133	240	427	437	1,428
OthInd	-	37	125	265	397	1,136	1,770	1,811	5,541
WhlRetTr	-	4,740	15,254	32,236	46,139	83,118	136,402	139,587	457,475
VehSales	-	-	-	-	-	215	0	0	215
Transport	-	9	31	(211)	76	202	305	312	724
FinInsREst	-	1,191	5,340	15,075	30,808	21,500	34,201	35,000	143,114
OthPrServ	-	3,063	11,456	25,848	45,596	64,397	96,352	98,602	345,313
PubServ	-	74	3,360	22,488	56,060	98,866	148,691	152,163	481,703
	-	9,763	37,396	98,892	182,977	274,710	424,974	434,898	1,463,611

Table 5: Employee Compensation Gains from Household Energy Efficiency
(millions of 2000 US dollars)

	1972	1977	1982	1987	1992	1997	2002	2007	Total
Agriculture	-	0	2	3	4	9	16	17	52
EnergyRes	-	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
ElectPwr	-	(10)	(50)	(111)	(190)	(303)	(441)	(546)	(1,652)
OthUtl	-	(1)	(4)	(0)	0	4	5	6	10
Construction	-	-	-	-	-	-	-	-	-
LightIndustr	-	20	70	117	162	214	284	323	1,190
OilRef	-	(1)	(0)	(0)	(1)	(1)	(2)	(3)	(8)
Chemica	-	2	7	16	27	23	87	97	258
Cement	-	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)
Metals	-	0	0	0	(0)	(1)	(1)	(1)	(2)
Machinery	-	0	1	2	2	(1)	(2)	(2)	(2)
Semicon	-	0	0	0	0	11	25	32	69
Vehicles	-	1	2	7	7	11	22	22	72
OthInd	-	1	3	7	12	36	67	82	208
WhlRetTr	-	105	336	707	1,026	1,859	3,530	3,647	11,211
VehSales	-	-	-	-	-	7	0	0	7
Transport	-	0	1	(8)	3	8	14	13	32
FinInsREst	-	31	158	512	1,207	971	2,036	2,415	7,329
OthPrServ	-	76	209	438	824	1,356	2,440	2,679	8,022
PubServ	-	2	107	730	1,866	3,160	5,526	6,422	17,814
	-	227	840	2,420	4,950	7,363	13,605	15,205	44,611

Source: Author's estimates

Unlike previous studies that estimate direct job creation as a result of energy efficiency programs and standards, our data-intensive multiplier analysis takes fuller account of the indirect effects of expenditure shifting. When consumers shift one dollar of demand from electricity to groceries, for example, one dollar is removed from a relatively simple, capital intensive supply chain dominated by electric power generation and carbon fuel delivery. When the dollar goes to groceries, it animates much more job intensive expenditure chains including retailers, wholesalers, food processors, transport, and farming. Moreover, a larger proportion of these supply chains (and particularly services that are the dominant part of expenditure) resides within the state, capturing more job creation from Californians for California. Moreover, the state reduced its energy import dependence, while directing a greater percent of its consumption to in-state economic activities.[19]

It should be noted that construction employment effects are omitted from this analysis because this is not classified as household (but investment) demand. Independent evidence (See Appendix) indicates, however, that construction has benefited significantly from building standards and expenditure diversion to housing and real estate. Other forces are at work over this period that can move our results in both directions. Significantly, aggregate energy demand in California has continued to rise, meaning some of the job losses estimated for energy sectors have probably been mitigated.

4. Future Economic Impacts of California Energy Efficiency and Climate Policies

After reviewing the economic impact of California's past achievements in energy efficiency, we turn to the future to evaluate the economic costs and benefits of the state's energy efficiency and climate polices. Because the state has recently redoubled its commitment to climate action, reducing energy dependence and global warming pollution (GWP) emissions, it is reasonable to expect increased structural change and job growth of the kind observed since the 1970s. For the last two years, we have been conducting independent research to inform public and private dialogue surrounding California climate policy. Among these efforts has been the development and implementation of a statewide economic model, the Berkeley Energy and Resources (BEAR) model, the most detailed and comprehensive forecasting tool of its kind. (See Appendix for technical

[19] There is a technical argument that reducing imported energy dependence might reduce California's export opportunities, but California exports are also less job-intensive than in-state goods and services. Thus the net employment gains remain positive.

discussion of BEAR model.) The BEAR model has been used in numerous instances to promote public awareness and improve visibility for policy makers and private stakeholders.[20] In the legislative process leading to the California Global Warming Solutions Act (AB 32), BEAR results figured prominently in public discussion and were quoted in the Governor's Executive Order establishing the 2020 and 2050 emissions reductions.

While researchers who developed and implement the BEAR model do not advocate particular climate policies, their primary objective is to promote evidence-based dialogue that can make public policies more effective and transparent. California's bold initiative in this area makes it an essential testing ground and precedent for climate policy in other states, nationally, and internationally. Because no other state has done this before, the state faces a significant degree of uncertainty about direct and indirect effects of the many possible approaches to its stated goals for emissions reduction. High standards for economic analysis are needed to anticipate the opportunities and adjustment challenges that lie ahead and to design the right policies to meet them. Progress in this area can increase the likelihood of two essential results: 1) that California policies work effectively, and 2) that they achieve the right balance between public and private interest.

The last round of BEAR analysis was broadly in accord with the state's findings and buttressed the public interest in legislative discussion of AB 32. In the next phase of climate action dialogue, more specific policies will be subjected to intensive public and private scrutiny. At this critical moment of policy debate, balanced policy dialogue requires a more complete assessment of both the potential benefits and costs of the options before the state. Here we continue to extend the scope and depth of these findings.

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 determined by the model itself or specified in advance, and in either case the level of emissions from the sector in question is model determined 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. The BEAR model's sectoral detail, model determined emissions, and dynamic innovation and forecasting characteristics enable it to capture a wide range of program characteristics and their role in economic adjustments to climate action. BEAR was designed to model cap and trade systems, and includes all the major design

[20] See e.g. Roland-Holst (2006ab, 2007a)

features such as variable auction allocation systems, market determined permit prices, banking options, safety valves, and fee/rebate systems for CO2 and up to thirteen other criteria pollutants.

In this section, we use BEAR to provide independent economic assessment of California energy efficiency and climate action policies recommended for the implementation of AB 32 by CARB in its Draft Scoping Plan.

Scenario Discussion

To elucidate the economic effects of different combinations of mitigation strategies, we now examine California's climate action policies in more detail. In particular, we evaluate a policy scenario, which faithfully represent policies currently being evaluated for their potential to meet the state's 2020 target of 427 MMTCO2 equivalent overall emissions of greenhouse gases. In our scenario analysis, "RCT" refers to the entire set of Recommended Greenhouse Gas Reduction Measures (Table 6) with the cap and trade mechanism modeled without offsets (i.e. recognition of emission reduction outside the sectors covered by the mechanism) as delineated in the Draft Scoping Plan.

In the "cap and trade" (C&T) scenario modeled here, we assume that 100 percent of pollution permits are allocated by an efficient auction mechanism. This means the state realizes all the value of the permits in the first instance, and we assume this is rebated to taxpayers in a lump sum fashion. Permits are then re-allocated with a market mechanism between sectors, assuming all sectors are covered by the scheme and there are no offsets. This is similar to the California Air Resources Board's E-DRAM[21] model approach, which covers all carbon fuels and does not consider offsets, but BEAR explicitly models the sectoral adjustments and market costs of permits, as described earlier.[22]

[21] E-DRAM is the official macroeconomic assessment model used by the California Air Resources Board. It shares the same official baseline data with the BEAR model including, for example, an assumed gasoline price of $3.67/gallon.

[22] There have been several discussions of offset schemes for the 28 percent of estimated emissions mitigation committed to cap and trade (C&T) for the RCT policies, but none represent official policy. The WCI calls for 10 percent of total mitigation to be offset, but this is a different percent of targeted mitigation for the region and is not directly comparable.

Table 6: Recommended GWP Reduction Measures

Measure Description	Reduction (Mmtco$_2$e In 2020)	Cost $Million	Savings $Million
Transportation			
Pavley I Light-Duty Vehicle GHG Standards	31.7	1,372	11,142
Pavley II - Light-Duty Vehicle GHG Standards		594	1,609
Low Carbon Fuel Standard	16.5	(11,000)	(11,000)
Low Friction Oil	4.8	520	954
Tire Pressure Program		49	69
Tire Tread Program (Low resistance)		0.6	119.7
Other Efficiency (Cool Paints)		360	370
Ship Electrification at Ports	0.2	0	0
Goods Movement Efficiency Measures	3.5		
Vessel Speed Reduction		0	86
Other Efficiency Measures		0	0
Heavy-Duty Vehicle GHG Emission Reduction (Aerodynamic Efficiency)	1.4	1,136	973
Medium and Heavy-duty Vehicle Hybridization	0.5	93	163
Heavy-Duty Engine Efficiency	0.6	26	133
Local Government Actions and Targets	2.0	200	858
High Speed Rail	1.0	0	0
Building and Appliance Energy Efficiency and Conservation			
Electricity Reduction Program 32,000 GWH reduced	15.2	1,809	4,925
Utility Energy Efficiency Programs			
Building and Appliance Standards			
Additional Efficiency and Conservation			
Increase Combined Heat and Power Use by 30,000 GWh	6.9	362	1,673
Natural Gas Reduction Programs (800 Million Therms saved)	4.2	420	640
Utility Energy Efficiency Programs			
Building and Appliance Standards			
Additional Efficiency and Conservation			
Renewable Energy			
RPS (33%)	21.7	3,206	1,650
California Solar Programs (3000 MW Installation)	2.1	0	0
Solar Water Heaters (AB 1470 goal)	0.1	0	0
High GWP Measures			
MVACS: Reduction of Refrigerant from DIY Servicing	0.5	60.00	0.00
SF6 Limits in Non-Utility and Non-Semiconductor Applications	0.3	0.14	0.00
High GWP Reduction in Semiconductor Manufacturing	0.15	2.60	0.00

Measure Description	Reduction ($Mmtco_2e$ In 2020)	Cost $Million	Savings $Million
Limit High GWP Use in Consumer Products	0.25	0.06	0.23
Low GWP Refrigerants for New Motor Vehicles AC Systems	3.3	15.80	0.00
AC Refrigerant Leak Test During SMOG Check		220.80	0.00
Refrigerant Recovery from Decommissioned Refrigerated Shipping Containers			
Enforcement of Federal Ban on Refrigerant Release During Service or Dismantling of MVACS			
High GWP Recycling and Deposit Program Specifications for Commercial and Industrial Refrigeration	11.6	1.24	0.66
Foam Recovery and Destruction Program		94.83	0.00
SF6 Leak Reduction and Recycling in Electrical Applications			
Alternative Suppressants in Fire Protection Systems		1.96	0.20
Gas Management for Stationary Sources--Tracking/Recovery/Deposit Programs		1.02	3.60
Residential Refrigeration Early Retirement Program		18.90	24.79
Others			
Landfill Methane Capture	1.0	0.5	0
Methane Capture at Large Dairies	1.0	156	0
Sustainable Forest Target	5.0	50	0
Water Use Efficiency	1.4	-	-
Water Recycling	0.3	-	-
Pumping and Treatment Efficiency	2.0	-	-
Reuse Urban Runoff	0.2	-	-
Increase Renewable Energy Production	0.9	-	-
Total Recommended Measures	*135.5*	*10,771*	*25,394*

Source: CARB Scoping Plan, Supplement

Taking Account of Innovation and Technological Change

Because innovation has been an indispensable part of the history of the state's economic growth and at the same time a consequence of its policies, the BEAR model has been developed with explicit capacity to examine the role of technological change and innovation as it relates to climate policy. The model includes features that allow for technological change with respect to every product/sector, factor of production, and pollutant category. Moreover, these detailed efficiency rates can be specified *a priori* or modeled, arising from other innovation processes such as induced R&D, technology transfer, and learning by doing. With these characteristics, BEAR is the most advanced decision tool of its kind for studying how incentive and market mechanisms can animate innovation to facilitate the state's adaptation to new climate policy priorities and maintain domestic and global competitiveness.

Since there is no agreement in economic theory or empirical work about how to model innovation processes, we can still elucidate this question, however, by posing a hypothetical scenario that provides a metric for the costs and benefits with enhanced efficiency. In the present analysis, we factor in the prospect of innovation to reduce energy intensity by projecting a rate of energy efficiency gains that better reflect historical achievements, as well as the impact of significantly more aggressive policies aimed to reduce energy use. It is reasonable to assume that new climate polices will create new incentives for innovation. This is particularly true for policies like "cap and trade" that put an explicit price on carbon externalities that did not exist before. When firms are faced with new costs from emissions and energy use, they can be expected to make investments in technology that reduces these costs. To capture this innovation, we assume that, subject to the implementation of the recommended measures, California is able to increase its energy efficiency by one additional percent per year, on an average basis, across the economy. This conservative estimate may be below the state's innovation potential in such circumstances, given that much lower energy prices and less determined policies were in place for the long period of improvement before AB 32.

Relationship to State Economic Analysis

Recently, we conducted scenario analysis for the California Air Resources Board, which is included as supplement to their economic forecasts conducted using the E-DRAM model (See Appendix). While the policy scenario analyzed here is identical to those modeled for the state, this analysis includes the potential for innovation to reduce energy intensity. The state's official modeling assumes technology characteristics remain static and includes a flat rate of energy efficiency for the time period considered (2008-2020).

Economic Impacts

Generally speaking, our results support the view that the state can reconcile its goals for economic growth and more sustainable climate policy. The policy choices informed by the scoping process will be more effective, however, if they are supported by rigorous *ex ante* assessment like that reported here. More evidence-based work of this kind will broaden the basis of stakeholder interest in the state's climate initiative and facilitate constructive policy dialogue.

When innovation is taken into account[23], our results show that the Draft Scoping Plan is a dynamic economic growth policy, significantly increasing aggregate mitigation, lowering adjustment cost, and contributing to dramatic job growth.

Assuming climate action measures intensify California's upward efficiency trend by one percentage point above the historic rate, we find:

- Existing efficiency programs combined with the proposed package of policies in the state's Draft Scoping Plan achieves 100 percent of the greenhouse gas emissions reduction targets as mandated by AB 32 while increasing the Gross State Product (GSP) by about $76 billion, increasing real household incomes by up to $48 billion and creating as many as 403,000 new efficiency driven jobs.

- The economic benefits of energy efficiency innovation have a compounding effect. The first 1.4 percent of annual efficiency gain produced about 181,000 additional jobs, while an additional one percent yielded 222,000 more. It is reasonable to assume that the marginal efficiency gains will be more costly, but they have more intensive economic growth benefits.

Table 7: Aggregate Results, Innovation Scenarios

	1	2	3
	Baseline	**Change Due to Existing Efficiency**	**Change due to RCT**
Real Output (2008$Billions)	**3,606**	**22**	**63**
Gross State Product	**2,598**	**37**	**39**
Personal Income	**2,096**	**31**	**17**
Employment (Thousands)	**18,410**	**181**	**222**
Emissions Total (MMTCO2e)	**596**	**N.A.[24]**	**-169**
Carbon Price (Dollars)	**0**	**0**	**12**

[23] We are not *estimating* the state's rate of energy efficiency improvement, but we are making reasonable assumptions in order to evaluate a calibrated scenario where the state improves energy efficiency by a single additional percentage point per year. This yields an elasticity type reference point for evaluating ex post efficiency contributions. If they achieve only 0.5% more efficiency, about half the estimated benefits can be expected to accrue to the state.

[24] Existing or assumed baseline efficiency measures (1.4%/yr) will reduce emissions 11.4% below what they would have been without any improvements. These reductions are included in the Baseline.

Percentage Changes

	1	2	3
	Baseline	Existing Efficiency	RCT
Real Output (2008$Billions)	3,606	.6	1.7
Gross State Product	2,598	1.4	1.5
Personal Income	2,096	1.5	.8
Employment	18,410	1.0	1.2
Emissions	596	N.A.	-28.3
Percent of Targeted Reduction		N.A.	100

The first column of Table 7 gives baseline or business-as-usual (BAU) values for macro variables in a scenario without AB 32 implementation. The second column, labeled Efficiency, measures changes in the same variables (in 2020), for the future impacts of existing energy efficiency programs[25], without AB 32 implementation. When actual abatement policies are implemented, adaptation costs will be set against these benefits, while other benefits will also come into play. RCT measures changes in the same variables (2020) with implementation of all policies contained in the Draft Scoping Plan including a "cap and trade" mechanism. While BAU contains the changes decomposed in the Efficiency column, RCT does not.

Job creation is robust in both existing efficiency and RCT scenarios because technological change permits the economy to reduce energy dependence more cost effectively. This compounds the benefits of the climate policies by either increasing the energy savings per dollar of adaptation cost or, for the same energy saving investment, freeing money for other demand. Both forces are at work, and over 400 thousand new jobs could be created in California by 2020, while the state attains its climate action objectives.

Employment Effects by Sector

We have seen that climate action can create jobs, and robustly so when the economy's innovation capacity is animated to improve efficiency in a context of rising energy costs. As is often the case with economic adjustment, however, small changes in aggregate variables can mask more dramatic structural change. In the following tables, we disaggregate the employment effects of existing efficiency measures, and the climate action policy scenario.

[25] The model assumes the state will continue its historical trend of 1.4% per capita energy efficiency gains without costs above normal renewal and replacement.

Existing efficiency programs and standards creates employment growth in every sector outside the carbon fuel supply chain, and significantly so, promising nearly 200,000 new jobs by 2020. While RCT affects jobs inside and outside the carbon fuel supply chain, RCT creates even greater employment, promising nearly 222,000 new jobs by 2020. The carbon fuel supply chain continues to experience positive job growth, albeit at a lower rate than the baseline.

Table 8: Sector Employment Effects, Innovation *(Thousands of FTE Jobs)*

	Sector	Baseline	Existing Efficiency	RCT
1	Agriculture	509	7	0
2	EnergyRes	29	0	-3
3	ElectPwr	27	-8	1
4	OthUtl	42	-8	6
5	Construction	1,351	6	37
6	Light Industr	501	6	-7
7	OilRef	20	0	-4
8	Chemica	187	3	-5
9	Cement	33	0	1
10	Metals	265	5	1
11	Machinery	127	0	-1
12	Semicon	471	7	7
13	Vehicles	170	1	2
14	OthInd	237	3	1
15	WhlRetTr	2,786	42	22
16	VehSales	287	5	7
17	Transport	413	2	12
18	FinInsREst	1,167	14	4
19	OthPrServ	6,998	84	123
20	PubServ	2,790	11	16
	Total	18,410	181	222

In response to the RCT measures, sectors with high levels of energy sector dependence experience modest job losses. Most of these are in the range of a few percentage points, and the state's aggregate job gains significantly outweigh these as households shift their expenditure away from the carbon fuel supply chain. Like the historical analysis that preceded this section, these prospective estimates reveal how energy efficiency liberates economic resources for job creation. By saving firms and households money, more expenditure can be channeled away from fuel imports and fuel services toward employment intensive, in-state goods and services. Overall, existing and recommended efficiency and climate action policies could generate over 400,000 new jobs by 2020, assuming the state only increases average efficiency by one percent annually.

Although these results are best interpreted as indicative, rather than precise forecasts, they have three 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, accelerating California's energy innovation may seem ambitious, but the added premium of steeply rising energy prices and the prospect of a price for carbon emissions should provide strong impetus for this. Third, the size and distribution of potential growth benefits is large enough to justify significant commitments to deeper empirical research on these questions.

If the state is to maintain its leadership as a dynamic and innovation oriented economy, it may be essential for climate policy to include explicit incentives for competitive innovation, investing in discovery and adoption of new technologies that offer win-win solutions to the challenge posed by climate change for the state's industries and for consumers. In this way, California can sustain its enormous economic potential and establish global leadership in the world's most promising new technology sector, energy efficiency, as it has done so successfully in ICT and biotechnology.

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. For these reasons, it is important to consider the potential contribution of continued innovation to the economic effects of California climate policy. Modeling innovation processes, their spillovers and linkages, and their ultimate economic impacts is a very complex process.

Additional Observations

Aggregate Real Effects are Modest but Positive

Despite the political and environmental importance of the state's climate policy initiatives, the aggregate economic impact of the proposed policies is modest relative to the overall California economy. Although detailed sector adjustments may be more dramatic, the state largely remains on its long-term growth trajectory. To the extent that the sectoral adjustment costs are passed on, they would not significantly reduce aggregate state income and consumption. In particular, they are much smaller than most climate damage estimates (see e.g. Stern).

Individual Sector Demand, Output, and Employment can Change Significantly (Economic Structure Changes)

Energy fuel and carbon capped sectors can experience important adjustments, but these are offset by expansion elsewhere, including services, construction, and consumer goods. The California economy is seen undergoing an important structural adjustment, reducing aggregate energy intensity and increasing the labor-intensity of state demand and output. These shifts, masked at the aggregate level, may present opportunities for policymakers to mitigate adjustment costs.

In other words, the aggregate results indicate that the policies considered will pose no significant net cost to the California economy. They might raise costs for some firms and individuals, but as a whole the California economy will probably experience higher growth and create more jobs than it would have without this action (even before considering climate damage aversion). The task for California policymakers in the near term will be to design policies that fairly and efficiently distribute the costs of reducing Global Warming Pollution.

Employment Effects are Positive

The reason for this result, as in past BEAR estimates, is that energy efficiency saves money (relative to the baseline), and the resulting re-direction of consumer expenditure results in net job creation for the state. This is one of the most important economic effects of climate action policy, reducing import dependence on capital-intensive fuels and increasing spending on in-state goods and services. In the last round of estimates, the E-DRAM model revealed the same benefits, amplified by migration into California. The current BEAR scenarios do not allow for migration, but are otherwise qualitatively similar.

No Significant Leakage is Observed in the BEAR Scenarios

Import and export adjustments are significant in some sectors, but with no discernable interaction with the carbon constraint in the capped sectors. Imports of fuels fall sharply as the policies dictate, but there is negligible evidence of pollution outsourcing in targeted or energy dependent sectors.

No Forgone Damages, Including Local Pollution or Public Health Costs, are Taken into Account in these Results

Over a thirteen year time horizon, and considering the amount of pollution reduction, damages in the business-as-usual baseline could be significant. At present, no climate policy simulation models include such damages in the baseline. When interpreting the present results and comparing them to others, this fact must be considered. A number of studies have produced positive climate policy cost estimates without acknowledging that the cost of doing nothing might well exceed these.[26]

5. Conclusions and Extensions

This study presents original estimates and reviews other research on the employment effects of California's legacy of energy efficiency policies. Using detailed data on changing economic structure over the last four decades, we show that energy efficiency programs, by saving households money, have created more than one million new jobs since 1972. While employment in the carbon fuel supply chain has grown more slowly than it would without California's efficiency improvements, this is far outweighed by induced job creation across a broad spectrum of in-state goods and services activities. Over the intervening 35 years, households have saved more than $56 billion on energy by comparison to their national counterparts. These energy savings rendered unnecessary the capacity of 24 traditional coal fired power plants, and instead they were diverted to other expenditure, creating about 1.5 million new jobs with over $45 billion in payroll.

We then reverse perspective and assess the benefits of energy efficiency going forward, including proposed policies to implement California's AB 32 climate action initiative. Using a dynamic forecasting model and scenario for policies recommended in the state's Draft Scoping Plan, we find that existing energy efficiency programs and standards will contribute an additional 181,000 jobs from now until 2020, and the policies themselves could add 222,000 more when innovation is taken into account.

Evidence from a variety of officially sponsored and independent research supports these results, indicating that every significant efficiency measure has created more jobs than it might have displaced. Many estimates of net job creation are more moderate than ours because they measure only direct employment impacts on specific sectors while ours analyses impacts economy-wide, but all support the same fundamental message. Energy efficiency saves money, promotes more employment intensive demand and growth, and reinforces lower carbon growth patterns across the economy.

In other words, individual efficiency begets aggregate efficiency, and aggregate efficiency begets growth and sustainability. Adam Smith understood this fact two

[26] See e.g. CRA (2007), EPRI (2007) for Florida and California. The public health impacts of climate change are being activity studied in another component of this project, with findings to be disseminated by the end of the year.

hundred years ago, and today we are reminded of the fact that efficiency is a social good that, though long expenditure chains, compounds its benefits across the economy or over time. This is true whether regardless of whether efficiency is facilitated by private market forces or by public standards.

It should be recalled that aggregate benefits can often mask adjustment challenges. Given the magnitude of most of the benefits estimated here, however, there appears to be ample scope for supporting policies that target adjustment needs, particularly for job categories whose skills need reorientation to adapt to an innovating economy. The primary drivers of California's superior growth experience over the last generation were education and technology. This legacy can be extended with education and training programs targeted at climate adaptation.

An important next step for this work is deeper analysis of the qualitative characteristics of employment created by energy efficiency. Employment in the carbon fuel supply chain is relatively high wage, with average or above average education levels and relatively long job tenure. Even though job creation from energy efficiency far outweighs losses in these sectors, it is important that we better understand the same qualitative characteristics of these new opportunities.

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Appendix

1. Technical Overview of the BEAR Model

The Berkeley Energy and Resources (BEAR) model is a constellation of research tools designed to elucidate economy-environment linkages in California. The schematics in Figures A1 and A2 (below) 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.[27] 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.

Technically, a Computable General Equilibrium (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 economy-wide resource allocation, production, and income determination.

The role of markets is to mediate exchange, usually with a flexible system of prices, the most important 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 variables in the system. In CGE models, an equation system is solved for prices that correspond to equilibrium in markets and satisfy the accounting identities governing economic behavior. If such a system is precisely specified, equilibrium always exists and such a consistent model can be calibrated to a base period data set. The resulting calibrated general equilibrium model is then used to simulate the economy-wide (and regional) effects of alternative policies or external events.

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

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 economy-wide 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.[28] The result is a single economy model calibrated over the fifteen-year time path from 2005 to 2020.[29] 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) functions, which are standard in the economic literature.

In each period, the supply of primary factors — capital, land, and labor — is usually predetermined.[30] The model includes adjustment rigidities. An important feature is the distinction between old and new capital goods. In addition, capital is assumed to be partially mobile, reflecting differences in the marketability of capital goods across sectors.[31]

Once the optimal combination of inputs is determined, sectoral output prices are calculated assuming competitive supply conditions in all markets.

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28 See e.g. Meeraus et al (1992) for GAMS. Berck et al (2004) for discussion of the California SAM.

29 The present specification is one of the most advanced examples of this empirical method, already applied to over 50 individual countries or combinations thereof.

30 Capital supply is to some extent influenced by the current period's level of investment.

31 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.

Consumption and Closure Rule

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

The government collects income taxes, indirect taxes on intermediate inputs, outputs and consumer expenditures. The default closure of the model assumes that the government deficit/saving is specified externally.[32] 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, with investment allocation going to capital according to the capital accumulation rules discussed below.

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 of 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.

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

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: 1) accumulation of productive capital and labor growth, 2) shifts in production technology, and 3) the putty/semi-putty specification of technology discussed below.

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.

Dynamic Calibration

The model is calibrated to external data on 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.[33] When alternative scenarios around the baseline are

[33]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.

simulated, the technical efficiency parameter is held constant, and the growth of capital is determined by the saving/investment relation.

Modeling Emissions

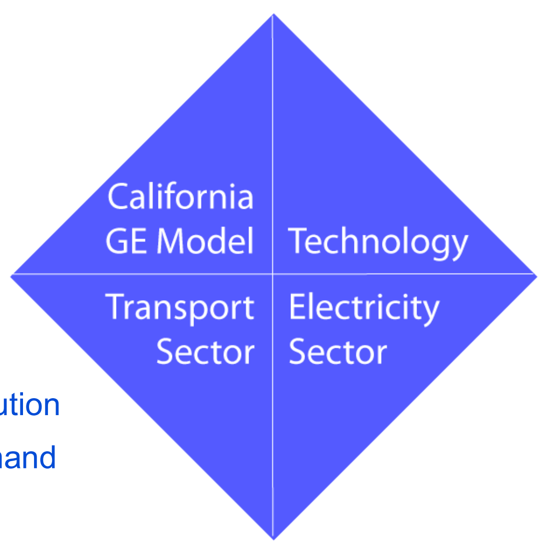
The BEAR model captures emissions from production activities in agriculture, industry, and services, as well as in final demand and use of final goods (e.g. appliances and autos). This is done by calibrating emission functions to each of these activities that vary depending upon the emission intensity 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.[34] In this framework, emission 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.

Figure A1: Component Structure of the Modeling Facility

BEAR is being developed in four areas and implemented over two time horizons.

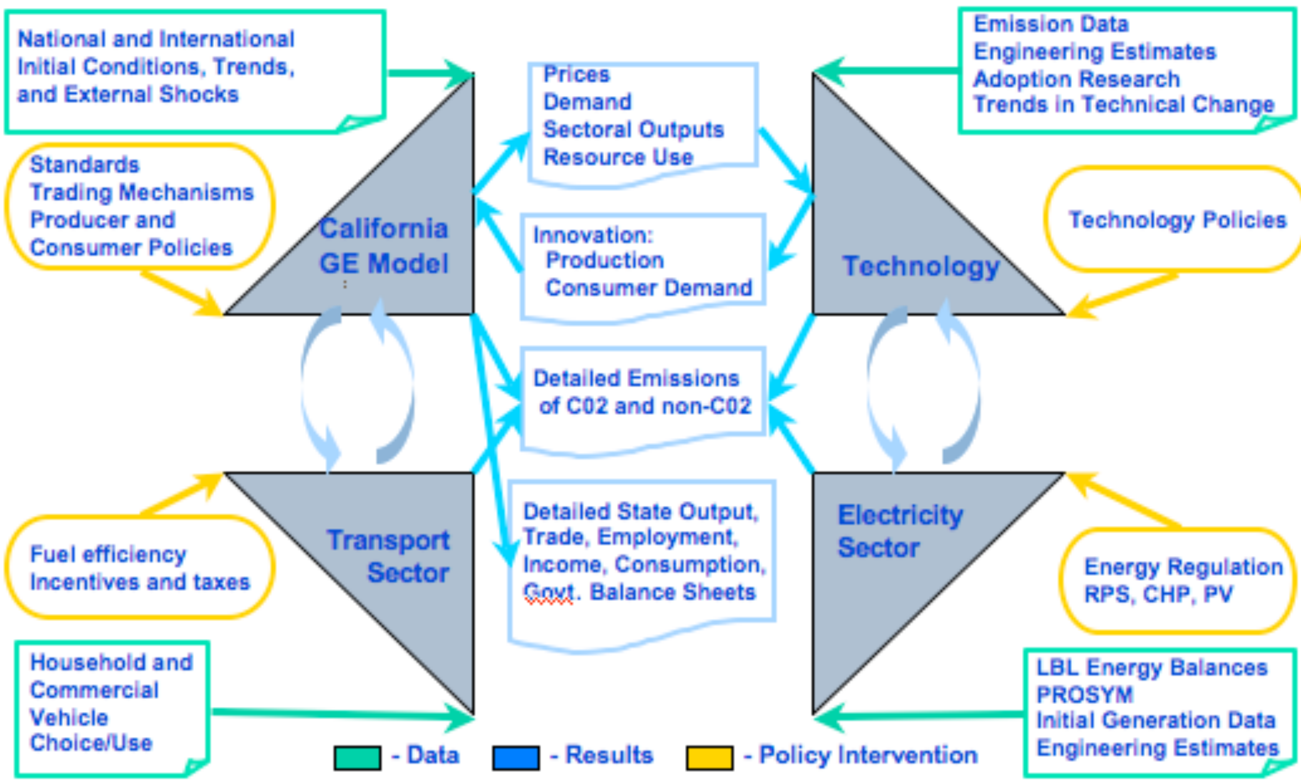
Components:

1. Core GE model
2. Technology module
3. Electricity generation/distribution
4. Transportation services/demand



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

Figure A2: Schematic Linkage between Model Components



The model has the capacity to track 13 categories of individual pollutants and consolidated emission indexes, each of which is listed in Table A1. 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.

Table A1: 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

2. Appliance Standards

Appliance Efficiency Standards are among the few government regulations that have net-negative costs for both consumers and businesses. By mandating levels of efficiency for various appliances, California has directly created jobs in manufacturing sectors related to appliances across the state. These policies have also indirectly created jobs by saving California residences and businesses hundreds of millions on their utility bills (see the results of Section 2 above). These impacts have been especially important for California's low-income populations, because they both spend a larger share of their income on energy, and benefit more (in terms of health and comfort) from improvements in appliance efficiency. These appliance efficiency standards have also helped California reduce emissions growth, put downward pressure on the cost of energy, and lessened peak electricity demand. Increasing the appliance efficiency will continue to be a cost effective way for California to simultaneously encourage economic growth and protect the environment.

With new household technology adoption has come substantial energy savings. Meier notes that there is uncertainty about energy consumption labels on appliances, as they can either underestimate, overestimate, or come close to actual energy consumption. Given that there is this uncertainty in labelling, it may create doubt as to whether it will be worth the upfront costs to upgrade appliances. Meier (1997) counters this argument by surveying a multitude of studies and national appliance standard experiences and concludes that the most convincing demonstrations of savings result from appliance standards occur in homes where an old model is replaced by a new model meeting the standards. Thus, there is a link between new standards and energy efficiency, and that these standards can create significant energy savings.

In his estimates the US energy savings and cost-to-benefits ratio of various new national appliance standards, Kuno (2002) finds that through 2020, the average benefit/cost ratio of the new national appliance standards is five, and the average national energy savings through 2020 is 1,800 trillion Btu. Nadel (2002) also analyzes the national historical experience with appliance standards and appliance efficiency. He finds that there have been significant energy efficiency improvements and that standards have driven efficiency.

National and state standards are already in place for most household appliances (air conditioners, refrigerators, shower heads, and space heaters just to name a few). Existing appliance standards in California are will save the average household $1,750 by 2020. Standards on the National level are expected to reduce national energy consumption by 341 billion kilowatt hours/year by 2020, over 7.5 percent of projected United States energy use. At that point, these standards will have already saved the equivalent annual energy use of about 23 million American households (Hildt: 2001), but these estimates only take account of current standards to predict future benefits. If California sustains its leadership in efficiency regulation, these savings will increase in proportion to the amount of energy they conserve. Table A2 illustrates the various savings projections from specific national appliance regulations, the most gains arising from showerhead standards.

Table A2: Summary of National Effects of Residential Efficiency standards in 2010

End-use	Fuel	Annual (in 2010)					Cumulative (1990–2010)				
		Primary energy savings (petajoules)	Carbon savings (MT-C)	Bill savings (M1995$/ year)	Incremental costs (M1995$/ year)	Net benefit (M1995$/ year)	Primary energy savings (petajoules)	Carbon savings (MT-C)	Bill savings (M1995$/ year)	Incremental costs (M1995$/ year)	Net PV benefit (M1995$/ year)
CAC	Electricity	0	0.00	0	0	0	112	1.70	536	379	157
Clothes washer	Electricity	52	0.75	390	5	385	721	10.37	3239	40	3198
Clothes dryer	Electricity	51	0.74	397	235	163	500	7.19	2148	1291	857
Dishwasher	Electricity	25	0.35	186	55	131	283	4.00	1238	360	878
Dishwasher motors	Electricity	20	0.28	150	62	88	228	3.22	998	407	592
Freezer 1990	Electricity	1	0.02	9	2	7	39	0.58	213	55	158
Freezer 1993	Electricity	6	0.08	42	26	16	106	1.57	541	338	203
Faucets	Electricity	19	0.27	153	25	128	207	2.85	894	152	743
HP	Electricity	0	0.00	1	0	0	46	0.67	262	129	133
Refrigerator 1990	Electricity	5	0.07	39	15	24	220	3.01	1228	507	720
Refrigerator 1993	Electricity	69	0.94	542	247	295	1348	18.57	6780	3229	3551
RAC	Electricity	1	0.02	12	1	10	214	3.12	1147	123	1024
Showers	Electricity	120	1.65	943	99	843	1278	17.62	5529	606	4922
Water heater	Electricity	6	0.08	43	8	36	724	10.32	4186	704	3446
Central heat	Natural gas	5	0.07	28	8	19	132	1.81	532	158	374
Clothes washer	Natural gas	31	0.42	181	7	174	427	5.85	1459	59	1400
Clothes dryer	Natural gas	10	0.14	59	60	− 1	100	1.38	330	340	− 10
Dishwasher	Natural gas	15	0.20	86	79	7	169	2.32	564	524	40
Faucets	Natural gas	12	0.16	73	38	35	128	1.76	415	227	188
Oven	Natural gas	18	0.25	111	57	54	237	3.25	840	454	386
Room heat	Natural gas	0	0.00	0	0	0	19	0.25	92	1	91
Range	Natural gas	27	0.37	163	65	98	350	4.80	1243	523	720
Showers	Natural gas	74	1.02	451	151	299	792	10.86	2566	908	1658
Water heater	Natural gas	42	0.58	250	45	205	2014	27.62	8268	1512	6756
Central heat	Distillate oil	0	0.00	0	0	0	0	0.00	0	0	0
Clothes washer	Distillate oil	2	0.04	15	0	15	31	0.59	123	4	118
Dishwasher	Distillate oil	1	0.02	7	6	2	12	0.23	47	38	9
Faucets	Distillate oil	1	0.02	7	4	4	12	0.23	45	21	23
Showers	Distillate oil	7	0.13	45	14	31	75	1.42	276	85	191
Water heater	Distillate oil	1	0.01	4	1	3	25	0.47	117	19	99
Total	Electricity	374	5.24	2906	780	2125	6026	84.8	28,938	8355	20,583
Total	Natural gas	234	3.21	1402	511	891	4368	59.9	16,309	4705	11,603
Total	Distillate oil	12	0.23	79	25	54	156	3.0	609	168	441
Total	All	620	8.68	4387	1316	3071	10,550	147.7	45,856	13,229	32,627

Electricity converted to primary energy at 11.4 MJ/kWh. Cumulative costs and benefits present-valued to 1995 at a 7% real discount rate.

Source: Koomey: 1997

Employment Impacts

While the job creation estimates of Section 2 are presented generally, the components of indirect consumption impacts play out among individual industries across the state and beyond. The United States Department of Energy predicts that new national standards for lamp ballasts, water heaters and clothes washers *alone* would create over 100,000 jobs by 2020 (Hildt: 2001). This economic stimulus is further amplified by multiplier effects like those discussed in Section 2.

Table A3: Job Impacts by State

	State	Net Job Gain 2010	Net Job Gain 2020
1	Alabama	13,100	22,600
2	Alaska	2,800	5,000
4	Arizona	11,200	19,900
5	Arkansas	7,500	13,200
6	California	77,400	141,400
8	Colorado	10,000	17,700
9	Connecticut	7,800	14,100
10	Delaware	2,200	3,800
11	District of Columbia	1,600	3,500
12	Florida	37,000	66,800
13	Georgia	21,300	38,300
15	Hawaii	2,700	5,000
16	Idaho	3,500	6,200
17	Illinois	31,900	56,400
18	Indiana	20,900	36,000
19	Iowa	8,300	14,700
20	Kansas	7,100	12,500
21	Kentucky	11,500	19,300
22	Louisiana	19,200	32,900
23	Maine	3,700	6,600
24	Maryland	12,500	22,000
25	Massachusetts	14,500	26,700
26	Michigan	29,800	51,000
27	Minnesota	13,400	24,000
28	Mississippi	7,200	12,600
29	Missouri	15,100	26,600
30	Montana	2,300	4,000
31	Nebraska	4,700	8,500
32	Nevada	5,300	9,100
33	New Hampshire	2,800	5,000
34	New Jersey	20,200	26,200
35	New Mexico	4,200	7,100
36	New York	38,000	68,200
37	North Carolina	22,400	38,900
38	North Dakota	1,900	3,300
39	Ohio	34,600	59,900
40	Oklahoma	8,200	13,700
41	Oregon	8,600	15,600
42	Pennsylvania	31,600	55,500
44	Rhode Island	2,100	3,900
45	South Carolina	11,500	20,000
46	South Dakota	2,000	3,500
47	Tennessee	17,100	29,800
48	Texas	71,500	123,400
49	Utah	5,700	10,300
50	Vermont	1,600	2,800
51	Virginia	18,500	32,100
53	Washington	16,600	29,700
54	West Virginia	3,800	6,000
55	Wisconsin	14,900	26,300
56	Wyoming	1,700	2,600
	TOTAL	**744,900**	**1,314,300**

Source: Hildt: 2001

Job creation would not be universal however, for an increase in energy efficiency would potentially lessen the demand for energy and reduce jobs in energy sectors. Those not benefited by the new standards may need adjustment assistance to ensure minimal frictional unemployment during the transition. However, this support could easily come from the gains in efficiency experienced in the larger economy, and could even come from the energy companies themselves should they choose to invest more heavily in energy efficient technologies. A proposal for a national Climate Protection Scenario, which includes new appliance efficiency standards along with building and transportation regulations, estimates that even with this initial friction, net job growth would be universal for the United States. Even more conservative estimates suggest that efficiency increases employment and income, but also has the potential to support for policies that recognise adjustment needs. The overall gains estimated in Section 2 could easily justify measures to facilitate transition toward greater statewide energy efficiency.

Other Advantages of Appliance Efficiency Standards

Cost Effectiveness

From a state perspective, Appliance Efficiency Standards are an incredibly low cost and efficient way to save energy, reduce emissions, and spur economic growth. [Hildt] They are relatively inexpensive to create and enforce because individuals and businesses have an incentive to comply to improve their own energy efficiency.

Peak Demand Reduction

Because California's energy is linked with Nevada, Arizona, and other members of the Western Systems Coordinating Council (WSCC) future heat waves are expected to demand more energy than the region can provide. Energy efficient appliances will directly reduce California's demand for energy during these times of peak demand. This will reduce the risk of power shortages during extreme weather across all states of the WSCC. (Bernstein: 2001)

Energy Security

National energy security is well served by increases in appliance efficiency, which reduce energy consumption and increase American energy independence. [Hildt]

Conclusion

The creation of appliance efficiency standards has been a highly successful program in California, both as a way to simultaneous promote economic growth and simultaneously promote environmental protection. New appliance efficiency standards will continue to create jobs in California and the greater United States, both for appliance manufactures and other economic sectors. These efficiency standards also present a direct way to provide assistance for low-income families. If expanded diligently, appliance efficiency standards will continue to reduce the cost of energy, producing a number of substantial benefits for California businesses and residences.

Utility Efficiency

Bernstein also approximates the demand-side management expenditures of utilities to be $4 billion ($1998), or $125 per capita. Although this may seem like a small amount compared the benefits, they also note that:

> "[T]here also exist indications that some of the drivers of lower energy intensity may reverse. It is widely believed that electricity industry restructuring will lead to lower energy prices: there may no longer be an economic motivation to encourage improvements in energy efficiency."

Thus Bernstein argued that government incentives to invest further in energy efficiency may be necessary as input prices decline. However, given the rising prices of energy globally, the market incentives may be reason enough to pursue energy efficiency. This does not mean, however, that government, especially California, does not have a role to play in these new investments in efficiency.

Bernstein also went further and estimated the future impact of improvements in energy efficiency in California. They estimated to 2010, and derived the following results:

Table A4: Estimates of future economic benefits of reductions in energy intensity to California in terms of per capita GSP ($1998)

Estimate of the effect of energy intensity on the CA economy	1995 Benefits	*2010 Changes in GSP per capita from 1995*		
		1986-1995 trend Increase in energy intensity	1977-1995 trend Moderate decrease in energy intensity	1977-1985 trend Large decrease in energy intensity
Higher Impact	$1,331	-$534	$1,112	$3,101
National Average	$876	-$302	$597	$1,622
Lower Impact	$470	-$68	$98	$226

Source: Bernstein: 2001

3. Building Standards

HVAC/Improved Efficiency in Heating and Cooling Buildings

There is a clear precedent for improvements in energy efficiency in buildings, particularly in their heating and cooling. A report given by the Commissioner of the California Energy Commission, Art Rosenfeld, proposes that due to efficiency improvements over the last 34 years, California saves $70 billion annually just from space heating and air conditioning. (Rosenfeld, 2008, pg. 5)

The Impact of 2004 Office of Energy Efficiency and Renewable Energy Buildings-Related Projects on United States Employment and Earned Income is an important report assessing the potential effects on employment and income due to projects. This report was generated by the Pacific Northwest National Laboratory for the US Department of Energy (DOE). The Office of Energy Efficiency and Renewable Energy (EERE), a division of the DOE, commissioned this study to examine 37 projects proposed or in progress. In the report, EERE projects are grouped into two categories, the Weatherization and Intergovernmental Program, and Building Technologies.

Two basic economic components characterize EERE projects, large investments and reduced expenditures on energy. There are three channels through which EERE projects can affect the economy. First, if any difference in the incremental cost exists between the new and old technologies, the manufacturing, distribution, and installation industries involved will be affected in terms of altered purchasing levels, as well as any firms linked to these original firms. Second, the investment in efficiency through the EERE projects can lead to a crowding out of domestic saving, investments, and consumer spending, decreasing some of the net positive impact due to energy savings. Third, expenditures on energy and other goods will be reduced because of the increase in efficiency. This decrease in expenditures will result in a smaller volume of sales for utility companies, as well as related manufacturing, distribution, and service sectors providing parts or labor for maintenance, operation, and general upkeep. However, this savings will also have the effect of increasing disposable income for households and businesses (including utilities, manufacturing, distribution, and service sectors), inspiring an increase in spending across all sectors.

Additionally, the report examines two scenarios. The energy savings stemming from EERE projects account for a large part of the effects on employment and income, but this neglects the effects caused by the large and continuous investment in new building practices and energy technology required by the projects. The Full Investment Scenario accounts for these investments. It is important to note that because some of the investment in the Weatherization and Intergovernmental Program falls within capitally-intense, high-wage industries, the full investment scenario predicts a slightly negative net change in employment and positive change in earnings.

The Weatherization and Intergovernmental division consists of three programs. The first is the Weatherization Assistance Program, dedicated to reduce energy losses through upgrades to building components such as insulation, air sealing, and windows. The other two components are the State Energy Program, which provides funds to states to improve the condition of buildings, and Gateway Development, which is an umbrella for programs such as Rebuild America, Information Outreach, and Energy Star, all of which focus on increases in energy efficiency. When the study was completed in 2003, the energy savings alone from the Weatherization and Intergovernmental Program was estimated to potentially create almost 133,000 jobs and about $1.61 billion earned income by the year 2030.

The second set of EERE programs are placed under the Building Technologies division. This includes Residential and Commercial Buildings Integration, Emerging Technologies, and Equipment Standards and Analysis. Not all of the divisions within the last two categories are directly applicable to buildings, as some appliances, such as refrigerators and lighting systems, are included. By 2030, the energy savings from this division was estimated to create almost 172,000 jobs and $2.18 billion in earned income.

The investment in energy technology would be in industries that are more capitally intense than the average investment. This is because most of the investment would be in the manufacturing industry, which is more capital-intense than the average industry. Assuming that the investment in the EERE programs is redirected evenly from other potential investments (which include labor-intense service industries), these investments will displace employment in the short run. Because the required investments, which initially increase, are diverting money away from other less capital-intense potential investments, the early net effect of investment in EERE projects will be lower rate of employment growth than under normal circumstances. It is not until the cumulative energy-saving effects become large enough to eclipse the massive investment, will the net effects on employment and income be clear.

It is important to note that the model used for this analysis operated under the assumption that these investments were on too small of a scale to impact prices in the energy market or production markets, or wages in the labor market. Similarly, changes in employment can be more realistically viewed as changes in demand, and changes in wages or labor supply could affect actual employment conditions.

Investment can be roughly divided into its effects on procurement, installation, and the investment that is saved. These effects cause increased growth of jobs and income in some industries, but divert investment from other industries. At the same time, increases in energy efficiency might negate the need for other construction or service provision (such as power plants), altering growth in those industries. Increases in energy efficiency will also require individual consumers or business to purchase less energy, and services related to energy consumption. As mentioned earlier, this will decrease sales of these to sectors, but provide businesses and consumers with increased disposable income to cycle through the economy.

California is at the forefront of energy efficiency and although it is difficult to determine what percent of the *Impact of 2004…* report applies directly to California, the "Building America" program might give some indication. Build America is a part of the Building Technologies segment of EERE, mainly concerned with creating public and private partnerships to implement new, efficient building innovations. To date, 40,748 houses have been built nationwide as a part of Build America. Nearly 30 percent, 12,169, of these houses have been built in California. Although this program is only a small fraction of the whole, if the other EERE projects are implemented in California on a similar scale, the impact on employment and income would be quite large.

Lastly, there are of course other effects that are not attributed monetary value in this examination, but are nonetheless valuable: Improved energy security, operational savings resulting from more efficient and durable equipment, improved quality of life stemming from decreased environmental degradation and increased liveability, and increases in property value are all examples.

One example of economic benefits from energy efficient building materials is illustrated in Figure 7 above, a chart from a report compiled by CEC Commissioner Art Rosenfeld, examining rewards derivable from new technologies. These results clearly reveal the potential savings for new technologies. Also, it is important to note that the energy efficiency improvements listed for the Low-E windows are only calculating an improvement from double-glazed windows. If single-pane windows are converted to Low-E windows or a more modern, more efficient type of window, an even greater amount of energy can be saved. Although some increase in employment would be generated in the retrofit of new windows, increased disposable income resulting from energy savings would indirectly increase employment more widely through increased consumption.

Similar solutions are available for other aspects of the house. The Heat Islands Research Project at Lawrence Berkeley National Laboratory found a massive potential for energy savings in the city of Los Angeles when they modeled a scenario implementing passive energy saving measures. In the scenario, houses in Los Angeles replaced traditional dark roofs with white roofs and planted trees alongside the houses. Direct air-conditioner savings to the buildings with lighter roofs and trees totaled $100 million. Indirect savings to the entire city resulting from a decrease in temperature of by about six degrees Fahrenheit came out to $70 million. Also, a decrease in health care costs and sick days because of reduced smog amounted to a savings of $360 million. Although this program might not yield as great a benefit in parts of Northern California, areas such as San Diego and the Central Valley could reap proportionate savings benefits.

4. Vehicle and Transportation Standards

Mobile emissions represent over 40 percent of California's greenhouse gas emissions, and fuel costs are an important and rapidly escalating share of household income. Like electricity, transport fuels thus offer an attractive opportunity for combining climate initiative with expenditure oriented economic stimulus. Although electricity efficiency has a much longer policy history in California, the state is moving quickly take advantage of these opportunities. In this section we review the leading policies and an emerging literature estimating its benefits. Although most of the potential remains to be realized, there is already evidence that transport standards save money and stimulate net employment growth.

In September 2004, the CARB staff released the results of an evaluation of vehicular GHG emissions and the technologies available to reduce them. Their primary focus was on technologies that were currently in use in some vehicle models or had been shown by auto companies and/or vehicle component supplies in at least prototype form. Auto manufactures were also allowed to use their own R&D to determine the most effective technology for their fleet, and were permitted the use of alternative methods of compliance such as reducing GHG emissions from their manufacturing facilities or by purchasing emissions-reducing credits from other sources. They did not consider hybrid gas-electric vehicles. The were two emissions standards for different classes of cars (one for cars and small trucks/SUVs, and the other for large trucks/SUVs) and they took the form of fleet average emissions per vehicle in grams of CO2 equivalent per mile driven, with a declining annual schedule for each model year between 2009 and 2016. The standards called for a reduction of GHG emissions by 22 percent compared to the 2002 fleet and by 30 percent by 2016.

The staff estimated that the 2016 standards would result in an average cost increase of $1064 for passenger cars and small trucks/SUVs, and $1029 for large trucks/SUVs. These costs were estimated to be paid back to the consumer through operating costs within five years, assuming a gasoline price of $1.74/gallon. They concluded that the net savings to vehicle operators would provide an overall benefit to the California economy in terms of GSP and statewide employment

The auto industry argued against the staff's predictions and noted that the upfront costs to consumers would be greater than the operating cost savings. They also argued that the total Vehicle Miles Traveled (VMT) would increase due to the impact of lower fuel costs per mile. Small and Van Dender (2005) analyzed this claim and found that California, due to its high average income and its culture of conservation, has one of the smallest elasticities of VMT with respect to fuel cost per mile (short-run -0.022 and long-run -0.113). Thus, if the operating costs were to decrease by 25 percent in 2009, the number of miles traveled would increase by about 0.6 percent in 2009 and 2.8 percent in 2020 (Hanemann, 2008).

The CARB staff's analysis of the costs savings attributed to decreased operating costs can today be considered quite conservative as gasoline prices were reported to be $4.01 in California for May, 2008 by the US Department of Energy. Thus, consumers would have recovered the up-front increased cost of the vehicle within less than three years (Hanemann, 2008).

Sperling et al. (2004) note that overall, vehicle prices in real dollars have increased significantly over the years due to both technology and quality changes in the vehicles, but consumers have continued to purchase the vehicles even at the higher prices. Thus consumers have been willing to pay more for cars for changes in technology and quality. Sperling continues by saying that about $1000 of today's retail vehicle price is incurred to meet emission standards. This is roughly the same cost that was incurred in the early 1980, when emission standards were far less stringent (Sperling et al. 2004). Sterling also notes that government regulations have accounted for about 1/3rd of overall vehicle price increases and that cost increases associated with regulations have been swamped by year-to-year variability in vehicle prices. The increase in the sticker price of a vehicle due to regulations should not decrease the quantity of cars demanded significantly for the reasons stated above (Sperling et al. 2004).

It is also argued by the motor vehicle industry within California that regulations such as AB 1493 and AB 32 impose significant competitive disadvantages to automobile manufacturers within the state. However, it is of value to note that Automobile manufacturing in California represents a small fraction of the state's economy, about 0.27 percent (CalEPA 2004). The California businesses impacted by regulations tend to be the affiliated businesses such as gasoline service stations, automobile dealers, and automobile repair shops. Affiliated businesses are mostly local businesses and compete within the state and generally are not subject to competition from out-of-state businesses. Therefore, the proposed regulations are not expected to impose significant competitive disadvantages on affiliated businesses (CalEPA 2004). Thus it is unlikely that large employment losses will occur either in California's Automobile sector or affiliated businesses due to inter-state competition.

CalEPA also addresses the job losses attributed to regulation by noting that according to their research (following tables) consumers would now spend more on the purchase of motor vehicles, thus having less money to spend on the purchase of other goods and services. Since most automobile manufacturing occurs outside of the state, the increased consumer expenditures on motor vehicles would be a drain on the California economy. The reduction in operating costs that results from improved vehicle technology would, however, reduce consumer expenditures and would therefore leave California consumers with more disposable income to spend on other goods and services. Businesses that serve local markets are most likely to benefit from the increase in consumer expenditures. Therefore, the California economy has to potential to grow from the increase in consumer expenditures and thereby cause the creation of additional jobs.

Table A5: California projected income and employment 2010 – 2030

Economic Impacts of the Proposed Climate Change Regulations on the California Economy in Fiscal Year 2010 (2003$)

California Economy	W/O Climate Change Regulations	With Climate Change Regulations	Difference	% of Total
Output (Billions)	$2,228.06	$2,227.97	- $0.09	- 0.004
Personal Income (Billions)	$1,451.01	$1,451.49	+ $0.48	+ 0.03
Employment (thousands)	16,354	16,362	+ $8	+ 0.05

Economic Impacts of the Proposed Climate Change Regulations on the California Economy in Fiscal Year 2020 (2003$)

California Economy	W/O Climate Change Regulations	With Climate Change Regulations	Difference	% of Total
Output (Billions)	$3,078.02	$3,075.44	- $2.58	- 0.08
Personal Income (Billions)	$2,003.54	$2,014.92	+ $5.38	+ 0.30
Employment (thousands)	18,661	18,718	+ 57	+ 0.30

Economic Impacts of the Proposed Climate Change Regulations on the California Economy in Fiscal Year 2030 (2003$)

California Economy	W/O Climate Change Regulations	With Climate Change Regulations	Difference	% of Total
Output (Billions)	$4,41.54	$4,236.83	- $4.71	- 0.1
Personal Income (Billions)	$2,781.44	$2,789.14	+ $7.71	+ 0.3
Employment (thousands)	21,763	21,839	+ 76	+ 0.4

Source: CalEPA (2005)

5. POLICIES UNDER EVALUATION

Feebates

Feebates is an incentive-based program for people to purchase more fuel efficient automobiles. It is self-funded and involves fees on vehicles above a size, weight, or fuel economy threshold, and a rebate for vehicles under that threshold. Feebates are designed such that consumers select smaller or more fuel efficient vehicles, and conversely, manufacturers produce the vehicles that provide them with the most profit, which, in this case, would be the more fuel efficient vehicles.

Although AB 1493 restricts the use of fees and thereby feebates, it is still an interesting policy tool to consider in order to better understand how much GHG can be reduced and at what cost/benefit. McManus (2006) analyzed the potential benefits of a feebates program using fuel prices of $1.74 per gallon, and a five percent discount rate to estimate the present value of future savings to consumers due to the technology investments by automobile manufacturers. Looking at the table below, we see in each scenario, there is a net increase in personal income for California residents. Also, retailers will also gain as their sales increase by up to six percent according to McManus. Thus, the increased personal income by consumers can greatly stimulate the California economy as they spend on other goods and services.

Table A6: Vehicle Lifetime Savings to Consumers

Scenario		Car	Van	Pickup	SUV	Market
Pavley Alone	Lifetime Fuel Cost	($2,432)	($3,090)	($3,712)	($3,786)	($2,928)
	Retail Price	$1,253	$989	$1,367	$1,242	$1,275
	Total Change	($1,178)	($2,100)	($2,344)	($2,544)	($1,652)
Feebates Alone ($18g per g/mi)	Lifetime Fuel Cost	($1,428)	($2,117)	($2,456)	($2,429)	($1,892)
	Retail Price	$536	$743	$959	$920	$658
	Net Feebates	($652)	$172	$1,187	$928	$0
	Total Change	($1,544)	($1,203)	($311)	($581)	($1,234)
Feebates Alone ($36g per g/mi)	Lifetime Fuel Cost	($2,281)	($3,254)	($3,812)	($3,817)	($2,957)
	Retail Price	$979	$1,270	$1,633	$1,516	$1,164
	Net Feebates	($877)	$235	$1,444	$1,353	$0
	Total Change	($2,179)	($1,748)	($735)	($948)	($1,793)
Pavley plus Feebates ($18g per g/mi)	Lifetime Fuel Cost	($2,904)	($3,949)	($4,817)	($4,770)	($3,670)
	Retail Price	$2,618	$2,726	$3,514	$3,227	$2,866
	Net Feebates	($541)	$280	$966	$673	$0
	Total Change	($287)	($1,222)	($1,303)	($1,543)	($804)

Source: McManus (2006)

CARB has previously (under AB 2076) investigated vehicle feebates as an option for reducing California's petroleum dependence, but AB 1493's prohibition on fees precludes the use of such feebates for greenhouse gas emissions control. If feebates are applied to a class of commodities that are relatively similar and interchangeable then they can be very effective in inducing a consumption shift toward low-emission technologies without forcing consumption restriction. (A good example of a successful feebate-type policy outside the automotive industry is the Swedish Nitrogen Oxide program, which induced power plants to reduce specific emissions of NOX by 60 percent between 1990 and 1995) However, vehicle feebates of the type investigated by CARB would not have this effect because fees would be levied primarily on heavy vehicles while rebates would accrue primarily to lightweight vehicles. The feebate would induce a weight-stratified cost and profitability imbalance whose primary effect would be to induce downweighting, which is a relatively inefficient way of inducing emissions reduction because heavy and lightweight vehicles are not functionally interchangeable. (Johnson, 2005)

Partial-Zero Emission Vehicles (PZEVs)

A RAND report by Dixon (2005) argues that automobile manufacturers will be producing large numbers of partial-zero emission vehicles (PZEVs) to satisfy part of California's Zero Emission Vehicle Program, which went into effect with model-year

2005 vehicles. The California Air Resources board requires that PZEVs must have a 15 year/150,000 mile extended exhaust system warranty in order to keep emissions low as the vehicle ages. These warranties will only be valid at dealer repair stations, and thus may adversely affect revenues of independent repair shops. Zero Emission Vehicles (ZEVs) are very expensive to produce, and thus automobile manufacturers are expected by RAND to fulfill as much of the California Zero Emission Vehicle program as possible with Partial Zero Emission Vehicles (so-called the "Maximum PZEV scenario"). They note that independent repair shop revenue will grow, but slower than if the warranty on PZEVs was not restricted to dealer repair shops (see the following tables and figures). RAND also predicts that there should be no need to lay off current workers at independent repair shops as a whole, because revenues at independent repair shops are projected to grow even with extended warranties. However, Dixon predicts that some independent repair shops may be more affected by extended emission warranties than others. Thus, they predict there may be some losses, but the impact of extended warranties are felt only gradually over time, and workforce reductions could be handled through normal attrition. Secondly, workers may be able to find employment at other independent repair shops, or at dealer repair shops.

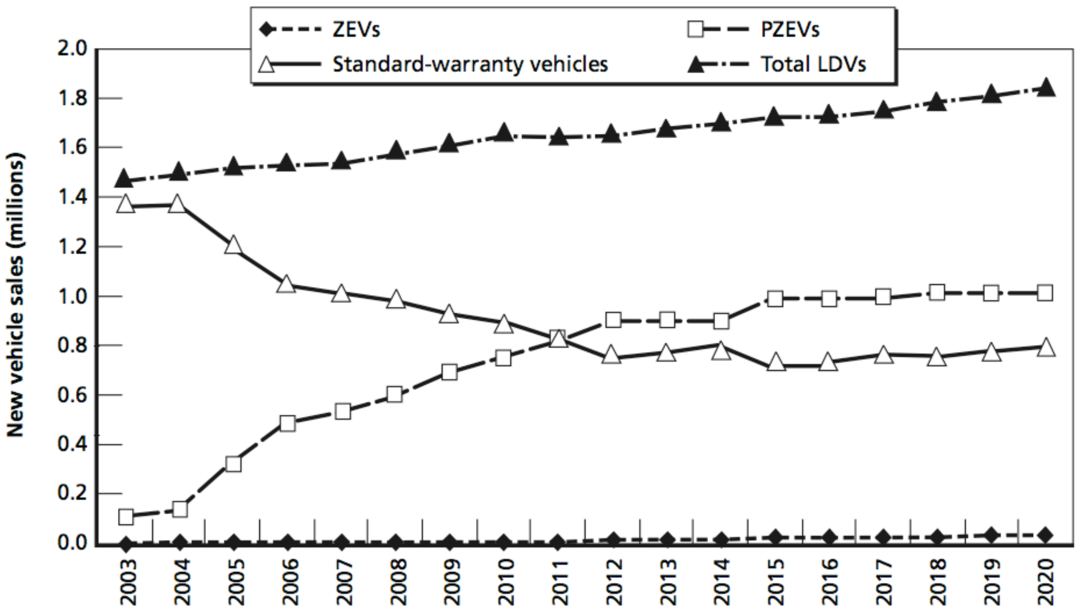
Dixon further notes that extended emission warranties will mean fewer opportunities for future workers in the independent-repair industry, but that these fewer opportunities may be offset by positions at dealer repair shops.

Table A7: Changes in Economic Welfare
(Percent Change Compared to Business-as-Usual)

Example	Sector	2012	2017	2022	2030	2050
Example 1: Ethanol and Hydrogen	State Output	0.06%	0.03%	0.08%	0.02%	0.14%
	Personal Income	0.01%	0.05%	0.13%	0.16%	0.05%
	Employment	0.06%	0.08%	0.14%	0.16%	0.14%
Example 2: Advanced Biofuel and PHEV	State Output	0.06%	0.11%	-0.11%	-0.04%	-0.24%
	Personal Income	0.02%	0.09%	0.01%	0.12%	-0.09%
	Employment	0.05%	0.09%	0.15%	15.00%	0.00%
Example 3: Advanced Biofuel and Hydrogen	State Output	0.08%	0.11%	-0.11%	-0.04%	0.21%
	Personal Income	0.01%	0.09%	0.01%	0.14%	0.08%
	Employment	0.06%	0.09%	0.15%	0.16%	0.15%

Source: Dixon (2005)

Figure A3: Sales of New Light-Duty Vehicles in California in the Maximum-PZEV Scenario



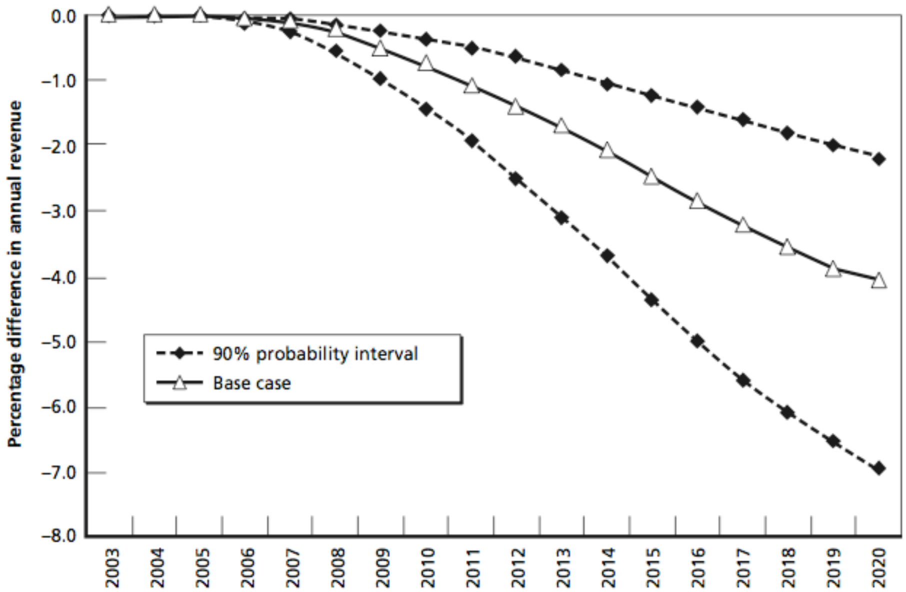
Source: Dixon (2005)

Table A8: Sales of New Light-Duty Vehicles Used in the Five PZEV Scenarios *(millions of vehicles)*

Scenario	PZEVs	Standard-Warranty Vehicles	Total LDVs
1. Maximum number of PZEVs that can be used to satisfy ZEV program requirements			
2003-2010	3.6	8.74	12.34
2011-2020	9.46	7.74	17.21
2. 75 percent of maximum number of PZEVs			
2003-2010	2.76	9.58	12.34
2011-2020	7.10	10.11	17.21
3. 50 percent of maximum number of PZEVs			
2003-2010	1.92	10.42	12.34
2011-2020	4.73	12.47	17.21
4. 25 percent of maximum number of PZEVs			
2003-2010	1.08	11.26	12.34
2011-2020	2.37	14.84	17.21
5. All new vehicles sold after 2008 are PZEVs			
2003-2010	6.58	5.76	12.34
2011-2020	17.21	0	17.21

Source: Dixon (2005)

Figure A4: Percentage Difference in Annual Revenue at Independent Repair Shops Due to Extended Warranties, 2003-2020, Maximum-PZEV Scenario



Source: Dixon (2005)

Alternative fuel strategies for California

The CEC (2007) in a report about alternative fuel strategies for California, make employment and growth predictions for California's economy (Table A7 above). They assume three different examples of fuel strategies:

> Example 1: Ethanol continues to be used as a gasoline blendstock. Lightduty fuel cell vehicles dominate the alternative vehicle market. Also includes natural gas, propane, and renewable diesel fuels, as well as plug-in hybrid electric vehicles.
>
> Example 2: Similar to example 1, except that hydrogen fuel cell vehicles do not achieve market success, and plug-in hybrid vehicles dominate the light-duty alternative vehicle market. Also, an advanced biofuel is developed and replaces ethanol as a gasoline blendstock.
>
> Example 3: Hybrid of examples 1 and 2. Assumes that both hydrogen vehicles and the advanced biofuel achieve market success.

Almost all examples until 2050 show significant employment increases. However, the various scenarios included in the examples are not completely available currently and are based on future availability of these technologies (eg. “an advanced biofuel”).

6. Energy Efficiency in the broader US context

A World Wildlife Fund (Bailie et al.) study in 2001 modelled the “Climate Protection Scenario”, a comprehensive environmental policy package, which included:

Buildings and Industry Sector

- Building Codes
- Appliance and Equipment Standards
- Tax Credits
- Public Benefits Fund
- Research and Development
- Voluntary Measures
- Cogeneration for Industrial and District Energy

Electric Sector

- Renewable Portfolio Standard
- NOx/SO2 cap and trade
- Carbon cap and trade

Transport Sector

- Automobile Efficiency Standard Improvements
- Promotion of Efficiency Improvements in Freight Trucks
- Aircraft Efficiency Improvements
- Greenhouse Gas Standards for Motor Fuels
- Travel Demand Reductions and High Speed Rail

The resulting estimated job creation would be quite substantial. As summarized in the following table, these estimates are qualitatively similar to our own estimates for California’s electricity measures, but to not take full account of stimulus from expenditure linkages.

Table A9: Net Changes in Jobs and GDP by Sector

	Net Change in Jobs	Net Change in Compensation *(Million 1998$)*	Net Change in GDP *(Million 1998$)*
Agriculture	63,100	$620	$2,120
Other Mining	11,200	$870	$1,830
Coal Mining	(23,900)	($2,340)	($4,940)
Oil/Gas Mining	(61,400)	($5,210)	($20,600)
Construction	340,300	$10,460	$15,030
Food Processing	16,100	$750	$1,380
Other Manufacturing	77,900	$9,360	$14,160
Pulp and Paper Mills	5,000	$570	$950
Oil Refining	(6,300)	($650)	($1,910)
Stone, Glass, and Clay	24,800	$1,630	$2,750
Primary Metals	18,600	$2,190	$3,180
Metal Durables	42,000	$4,670	$7,670
Motor Vehicles	54,300	$5,090	$8,350
Transportation, Communication, Utilities	50,500	$3,320	$6,750
Electric Utilities	(35,100)	($5,180)	($27,540)
Natural Gas Utilities	(26,200)	($3,080)	($11,180)
Wholesale Trade	12,400	$1,030	$1,890
Retail Trade	190,300	$4,410	$7,680
Finance	42,100	$4,570	$9,410
Insurance/Real Estate	11,900	$350	$2,420
Services	394,600	$13,080	$18,460
Education	33,200	$1,330	$1,340
Government	78,900	$3,550	$4,660
TOTAL	**1,314,300**	**$51,390**	**$43,860**

Source: Bailie et al (2001)

7. Energy Efficiency in the International Context

Although California is currently a pioneer in GHG reduction policy and technology, there have been other policies internationally that have led to changes in employment due to energy efficiency investments. Jochem/Hohmeyer (1992), for example, reported that the 4.1 exajoules per year of energy savings achieved in Western Germany between 1973 and 1990 alone created approximately 400,000 new jobs. Today, the net employment effect due to increased labour productivity since the 1980s and reduced energy prices between 1986 and 1999 found in

European and North American studies in the late 1990s is in the order of 40 to 60 new jobs per petajoule of primary energy saved (Laitner: 1998).

8. Technical Details

Data Resources

Producing the detailed employment impact estimates of Section 2 was a very data-intensive exercise. This process began with assembly of a series of input-output tables, comprising inter-industry flows, value added, and final demand for about 500 activity and commodity categories over the period 1972-2006. The U.S. Bureau of Economic Analysis maintains these accounts and updates them every five years. Each of the seven relevant national tables were obtained from BEA and aggregated up to the 50 sector framework reported in this paper. Also, comparable tables for California, estimated for 2002 and 2006, were aggregated to the same sector standard.

In addition to data on economic structure for the last 35 years, detailed employment wage data were obtained by California Regional Economies Employment (CREE) Series. This source provides annual data on enterprises, jobs, and average wages for over 1200 NAICS sector categories across California.

Estimation Technique

To impute historical employment gains from California's energy efficiency measures, we pose a simply counterfactual question: Given California's economic structure, how would employment growth have proceeded in the absence of household energy efficiency? Answering this question requires three kinds of information:

1. Historic National and current California consumption patterns
2. Historic economic structure for California
3. Employment by sector

The first item was obtained from the BEA tables, and third is provided by the CREE data set. To estimate California's historic economic structure, we use seven historic input-output tables for the national economy and one (2002) for California. In particular, we used a combination of national and state tables to approximate California's changing economic structure. Consider a series of tables representing intermediate expenditure shares $A_t = \hat{y}^{-1}T_t$, where y is a vector of total outputs (a caret denotes the corresponding diagonal matrix), and T_t is the input-output table for period t. These represent intermediate usage of goods and services, linking production activities across the economy through expenditure chains.

Now consider national expenditure share matrices A_t^N for period t=1972, 1977, 1982, 1987, 1992, 1997, 2002. The California counterpart data are A_t^C for t=2002. From this data, we construct a series of approximate California expenditure shares with an averaging procedure as follows:

$$E_t = A_t^N (2002 - t)/30 + A_{2002}^C (t - 1972)/30$$

Thus the estimated consumption shares represent national patterns in the initial year and converge to California consumption patterns by 2002. These matrices are then converted to multiplier matrices with the routine calculation $M_t = (I - E_t)^{-1}$. Multipliers in this matrix show how much an additional unit of demand for one good creates economy-wide demand for all other goods and services. Following the long expenditure chains of the A matrices, multipliers take account of all resource requirements and other induced demand. Next, we define the counterfactural consumption shares d_t defined as follows:

$$d_t(electricity) = (1 - .4(t - 1972)/30)c_t^N(electricity)$$

and

$$d_t(other) = d_t(other)/(1 - (c_t(electricity) - d_t(electricity))$$

Intuitively, the vector d_t represents the difference in California household consumption patterns due to a transition from 1972 national norms to California's current consumption shares, including a 40 percent reduction in electricity consumption per capita.

The final estimation stage entails computing the economy-wide effects of expenditure shifting with the multiplier calculation, then rescaling for California consumption by commodity (C_t) and sectoral labor output ratios (J_t). This final expression (i.e. the estimated columns in Table 4) takes the form:

$$M_t d_t \widehat{C}_t \widehat{J}_t$$

This rather dense expression takes account of four factors. First is the structural multiplier matrix, which indicates how demand changes in one sector impact all others. Second is the d_t vector of estimated consumption changes, assuming California did and did not achieve its historic reductions in per capita electricity consumption. The C vector converts from US to California magnitudes, the last factor translates output into employment.

It should be noted that using national IO tables in our sample introduces some bias in the estimates for early years. Because state economies are generally more trade dependent than the nation as a whole, average intermediate consumption shares and in-state multipliers may be smaller. It should be noted, however, that most of the job creation for California arises in sectors providing non-tradable services, while estimated job losses are in energy and manufactures with significant trade shares. For these reasons, net state employment gains from energy efficiency are probably estimated with reasonable accuracy.

Table A10: Sector Definitions for the Current BEAR Aggregation

	Label	Description
1	A01Agric	Agriculture
2	A02Cattle	Cattle Production
3	A03Dairy	Dairy Production
4	A04Forest	Forestry, Fishery, Mining, Quarrying
5	A05OilGas	Oil and Gas Extraction
6	A06OthPrim	Other Primary Activities
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 of Transport Infrastructure
13	A13FoodPrc	Food Processing
14	A14TxtAprl	Textiles and Apparel
15	A15WoodPlp	Wood, Pulp, and Paper
16	A16PapPrnt	Printing and Publishing
17	A17OilRef	Oil and Gas Refineries
18	A18Chemicl	Chemicals
19	A19Pharma	Pharmaceuticals
20	A20Cement	Cement
21	A21Metal	Metal Manufacture and Fabrication
22	A22Aluminm	Aluminium Production
23	A23Machnry	General Machinery
24	A24AirCon	Air Conditioner, Refridgerator, Manfacturing
25	A25SemiCon	Semiconductors
26	A26ElecApp	Electrical Appliances
27	A27Autos	Automobiles and Light Trucks
28	A28OthVeh	Other 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
35	A35WatTrns	Water Transport
36	A36TrkTrns	Truck Transport
37	A37PubTrns	Public Transport
38	A38RetAppl	Retail Appliances
39	A39RetGen	General Retail Services
40	A40InfCom	Information and Communication Services
41	A41FinServ	InfTel
42	A42OthProf	Other Professional Services
43	A43BusServ	Business Services
44	A44WstServ	Waste Services
45	A45LandFill	Landfill
46	A46Educatn	Educational Services
47	A47Medicin	Medical Services
48	A48Recratn	Recreation and Cultural Activity
49	A49HotRest	Hotel and Restaurant Services
50	A50OthPrSv	Other Private Services

9. BEAR Assessment of the Scoping Plan Scenarios

In this section, we provide a brief summary of the BEAR assessment for ARB climate action scenarios. For the purposes of this attachment, these results are preliminary and represent independent assessment. Analytical approaches, methodological assumptions, data, and evaluation discusses in this attachment represent the opinions of the author and should not be ascribed to the California Air Resources Board or any of their staff.[35]

Scenarios

For the purposes of policy comparison, BEAR was used to evaluate two representative scenarios that take account of Scoping Plan policy recommendations. These scenarios represent the primary policies currently being evaluated for their potential to meet the state's 2020 target of 427 MMTCO2 equivalent overall emissions of greenhouse gases, and are discussed in detail in the main body of the Plan.

The Preliminary Recommendation scenario, in Table III.2, represents the Preliminary Recommendation approach described in the Draft Scoping Plan. This scenario includes the recommended measures that provide the reductions of 169 MMTCO2e in emissions needed to meet the 2020 target.[36] These measure include both a broad-based cap and trade program and sector specific measures. In the same table, Sector Specific Measures scenario refers to a scenario that includes the measures other than the cap and trade program from the Preliminary Recommendation together with the measures listed as "other measures under evaluation" in the Draft Scoping Plan. Together, these are envisioned to achieve an estimated 169 MMTCO2e aggregate emission reduction all through developing measures other than the cap and trade program that apply to specific economic sectors.

Table A11: General Scenarios

Number	Label	Description
1	Preliminary Recommendation	Regulations and Standards Recommended in the Scoping Plan, plus cap and trade to Attain AB 32 Emission Goals for 2020
2	Sector Specific Measures	Sector-specific measures other than the cap and trade program included in the Preliminary Recommendation and 'Other Measures Under Evaluation' in the Draft Scoping Plan

[35] This Annex reproduces exactly the text of the Scoping Plan Supplement, written by the author.
[36] For full discussion of the Preliminary Recommendation, see 6/26/08 release of the Draft Scoping Plan.

Preliminary Recommendation Scenario

E-DRAM results have been discussed in the main body of this document as well as a separate appendix. In this section, we present independent results with general interpretation, offered from the perspective of current and previous research with the BEAR model. In particular, the following tables present aggregate results for the Preliminary Recommendation, including a Baseline or business-as-usual (BAU) that assumes historical trends of energy efficiency. We see here that macroeconomic impacts are relatively (percentage results in Table A12) limited.

Table A12: Aggregate Results for Preliminary Recommendation Scenario

Impact Indicator	BAU	Recommended
Real Output ($billion)	3,606	3,640
Gross State Product ($billion)	2,598	2,602
Personal Income ($billion)	2,096	2,092
Per Capita Income (1000s)	48.000	47.479
Employment (Millions)	18.410	18.431
Emissions (MMTCO2e)	596	427
Carbon Price (Dollars)	0	12
Job Growth (thousands)	0	21
Emissions Change (percent)	0	-28
Targeted Reduction (percent)	0	100

This policy package combines significant emissions reduction with in-state economic growth, as measured by real GSP and employment. This result has been a robust characteristic of BEAR and E-DRAM scenarios since the original assessments in support of AB 32 and it is driven by the pro-growth characteristics of energy efficiency and expenditure shifting.[37] Aggregate personal income for the BEAR estimates declines very slightly (less than 2/10 of one percent) in 2020, yet more than 186,000 new jobs are created as the state shifts to more service-intensive economy. The primary reason real GSP differs from real Personal Income is price effects. Real incomes are affected because the policies considered increase the cost of living for most households, but by only a few tenths of one percent, about one tenth of California's average inflation rate over the last two decade. In light of the scope of GHG mitigation achieved,

[37] For a more detailed recent assessment of this issue, see Roland-Holst: 2008

this price effect should be seen as extremely modest. Moreover, this result is consistent with earlier BEAR and E-DRAM work.

Table A13: Aggregate Variation for Preliminary Recommendation Scenario
(all figures in percent change from the BAU unless otherwise noted)

	Recommended
Real GSP	0.2
Personal Income	-0.2
Employment (Millions)	0.1
Jobs	21
Emissions Change (percent)	-28
Targeted Reduction (percent)	100
Permit Price (Dollars)	12

It is noteworthy that the permit cost for cap and trade component, or model-determined carbon fee arising from the trading system, is relatively low. Permit price estimates are important to the policy debate, since they represent a proxy for adjustment costs. This price is relatively low because, after the Recommended policies, emissions need to be lowered by only an additional (35 out of remaining 462) 7.6 percent to reach the state's 2020 goal. These results suggest that the private sector can complete the residual mitigation to meet the 2020 goals at relatively modest cost if market mechanisms distribute the adjustment burden across the state's diverse economy.

Sector-Specific Measures Scenario

Table A14 shows the results for the Sector-Specific Measures Scenario. The results of this scenario also show positive impacts on the California economy. Real output and GSP, both increase. Personal income decreases slightly but employment increases as jobs are shifted to service industry and more labor-intensive sectors.

Table A14: Aggregate Results for All Regulations Scenario

Impact Indicator	BAU	All Regs
Real Output	3,606	3,656
Gross State Product	2,598	2,608
Personal Income	2,096	2,093
Per Capita Income (1000s)	48.000	47.503
Employment (Millions)	18.410	18.476
Emissions (MMTCO2e)	596	427
Carbon Price (Dollars)	0	0
Job Growth (thousands)	0	66
Emissions Change (percent)	0	-26
Targeted Reduction (percent)	0	100

Table A15 shows the percent change from the business-as-usual case. The impacts can be characterized as generally positive. California economy is enormous and the proposed regulations, from an economics point of view, are not only doable, but add stimulus and maintain a sound economy. The BEAR analysis shows that the state can attain its climate action objectives without sacrificing aggregate economic growth.

Table A15: Aggregate Variation for Sector-Specific Measures Scenario
(all figures in percent change from BAU unless otherwise noted)

	All Regs
Real GSP	0.4
Personal Income	-0.1
Employment (Millions)	0.4
Jobs	66
Emissions Change (percent)	-26
Targeted Reduction (percent)	93
Permit Price (Dollars)	0

Model Limitations

While researchers who developed and implement the BEAR model do not advocate particular climate policies, their primary objective is to promote evidenced-based dialogue that can make public policies more effective and transparent. California's bold initiative in this area makes it an essential testing ground and precedent for climate policy in other states, nationally, and internationally. As part of its leadership on climate change the state must assess the direct and indirect economic effects of the many possible approaches to its stated goals for emissions reduction. High standards for economic analysis are needed to anticipate the opportunities and adjustment challenges that lie ahead and to design the right policies to meet them. Progress in this area can increase the likelihood of two essential results: that the California mechanism works effectively and that it achieves the right balance between public and private interest.

The BEAR model's sectoral detail, model-determined emissions, and dynamic innovation and forecasting characteristics enable it to capture a wide range of program characteristics and their role in economic adjustments to climate action. BEAR was designed to model cap and trade systems, and includes all the major design features such as variable auction allocation systems, model-determined permit prices, banking options, safety valves, and fee/rebate systems for CO2 and up to thirteen other criteria pollutants.

All models are necessarily simplifications of reality. While many details of California's economy are omitted from the BEAR assessment framework, however, it does provide reliable guidance regarding the economic impacts that would ensue from climate action measures of the kind considered in the Scoping Plan. The BEAR model has been peer reviewed and represents the most advanced research technologies for economic policy simulation. Still, it is important to understand the uncertainties and limitations that forecasting entails, particularly for complex and unprecedented policy initiatives like the ones considered here. There are three general contexts where the model's results should be interpreted with care.

External shocks: Although it is the world's eighth largest economy, California is and will remain subject to external events beyond its own control. Seismic activity, extreme weather events, and even global energy prices are largely exogenous to the state, yet these will all affect our future. In most cases, however, it can be argued that BEAR results comparing baseline and policy impact will remain applicable. If energy prices were to rise substantially, however, the current estimates of economic benefits from climate action would be lower than actual benefits (compared to the baseline).

Heterogeneity: The main way in which models like BEAR simplify economic reality is by aggregation, examining the behavior of whole sectors of the state economy rather than individual enterprises. Thus a single bank might fail, but the banking sector looks fine on average. Likewise, heterogeneity of technology, decision making, and other firm and plant level characteristics will make climate adaptation a complex and variegated process. BEAR does not predict these individual adjustments, and will thus not capture many adverse and beneficial experiences that make up the aggregate outcomes estimated here. Because this type of heterogeneity is at the core of the potential for market mechanisms, such as a cap and trade program, to reduce the costs of implementing regulations, BEAR can be expected to underestimate the benefits from market-based compliance mechanisms in implementing AB 32. Investing in this kind of detailed insight is more resource intensive, might be desirable for private actors in the economy, but it is not necessarily an efficient use of public resources.

Innovation: The overall process of technological change is notoriously difficult to forecast, and individual innovation events virtually impossible. Although we know innovation will be important to California's progress toward a lower carbon future, BEAR does not attempt to predict this component of adjustment determined withing the model. Having said this, more innovation research would certainly improve guidance for policy makers who want to structure appropriate incentives for technological progress.

The more modest goal of the modeling was to elucidate economic effects of Preliminary Recommendation scenario. In this context, further progress in the policy dialogue will require greater sophistication in both the positive research and its appraisal. In the former category, three areas of improvement should be high priorities for climate change economic modeling:

1. Raw engineering data. There is a tremendous need for increased coverage and greater precision in data on costs, technology profiles, point source emissions across detailed US industrial classifications. It would also be desirable to have more data of this kind in raw form, as opposed to secondary aggregates which may include discount rates and other adjustment factors.
2. More intensive sensitivity analysis and counterfactual experiments. All modeling work in this area needs to evolve from "just-in-time" individual policy analysis to more detached appraisal of structural characteristics. This takes time, but will provide essential insight about future research

priorities and policy robustness. This research can help adjudicate disputes about behavioral questions, while also improving the structural features of policy models.

3. Wider policy and research dialogue. Policy making and research processes in the US should continue to widen and improve their internal dialogues, including drawing on insights from European experience and developing country issues, and encouraging greater interaction between the science/technology and economic communities.