Energy Prices & California's Economic Security

Prepared by: David Roland-Holst, UC Berkeley

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EXECUTIVE SUMMARY

Introduction

California's response to rising greenhouse gas (GHG) emissions has drawn one of the world's largest economies into an unprecedented policy dialogue that will influence energy and environmental decisions around the world. At the end of 2008, the California Air Resources Board (CARB) approved one of the world's most ambitious GHG reduction plans, consisting of a comprehensive set of standards and incentives to promote energy efficiency and renewable energy and decrease the use of fossil fuels. Aligned with that plan, the state legislature recently passed the nation's boldest commitment to renewable energy development, mandating a 33 percent Renewable Portfolio Standard (RPS) for its electric power utilities.

Globally, the financial crisis has left millions unemployed, drained personal savings and gutted national and subnational public sector budgets. In California, the impacts have been severe. The state now has the fourth-highest unemployment rate at 12.2 percent, the third-highest rate of mortgage foreclosures, and for two years has had the highest state budget deficit in the history of the country. Considerable pressure is mounting to delay or derail California's GHG policies already implemented and under consideration.

As the state commits to ever more determined efforts to promote energy efficiency and renewables, a thorough assessment of the economic impacts of California's GHG policy package is of paramount importance. These impacts will depend on three primary drivers, the course of fossil fuel energy prices, energy efficiency trends, and renewable energy development. This study assesses these three factors and their impact on California's economic growth prospects.

Methodology

Using the Berkeley Energy and Resources (BEAR) model, a state-of-the-art, economy-wide forecasting tool, the study analyzes six energy price and source scenarios and tracks complex market interactions across key elements of the California economy.

To date, official and unofficial economic assessments of state policies have been informed by relatively conservative and now dated fossil fuel price trend estimates. Unlike any previous study on the impacts of California's GHG policies, this study uses up-to-date U.S. Department of Energy (DOE) fossil fuel projections.

The fundamentals of global energy markets strongly support DOE projections. Despite the recent recession, over the last six months, with national unemployment at 25 year highs, retail U.S. gasoline prices have risen 40 percent, lifting an additional half a billion dollars per day from driver's pockets in the process. Crude oil is also rising steadily despite a persistent global recession, and today is over 60 percent above its lows at the beginning of the year. Emerging market demand will continue to exert pressure on existing resources, and new resources will only be available at ever higher marginal cost. Unfortunately, a significant amount of public policy has been informed by unduly optimistic fossil fuel price trend estimates.

To assess the economic impact of increased RPS implementation, we sequence projects according to the most recent Renewable Energy Transmission Initiative report (RETI, June 2009) following the Rank Cost standard for drawing renewables into the system.

Findings

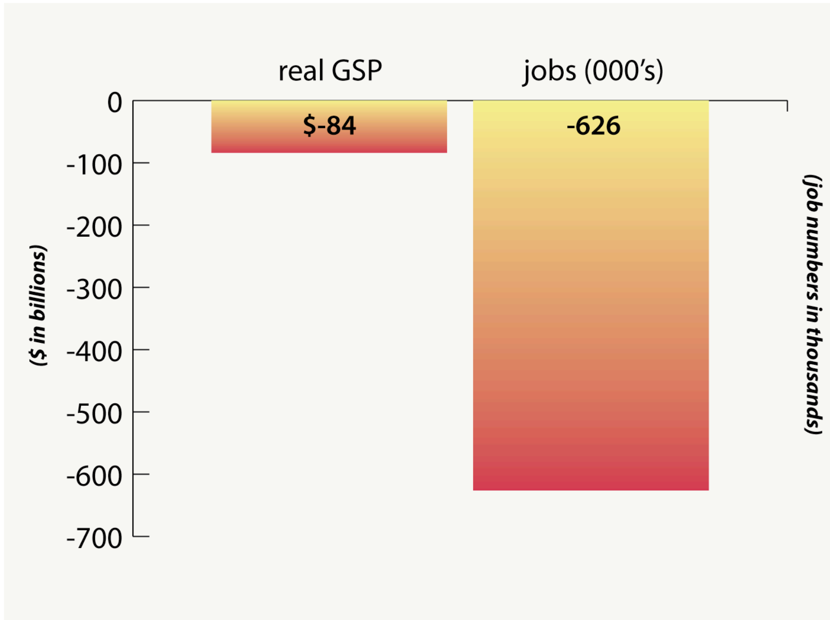
Without implementation of State GHG policies, likely Increases in Fossil Fuels Will Hurt California's Economy

- Projecting California's growth with U.S. Department of Energy official price trends (***Figure 1***) finds that in 2020 GSP will be over **$80 billion lower.**

- An energy price handicapped economy will also offer more than half a million fewer jobs.

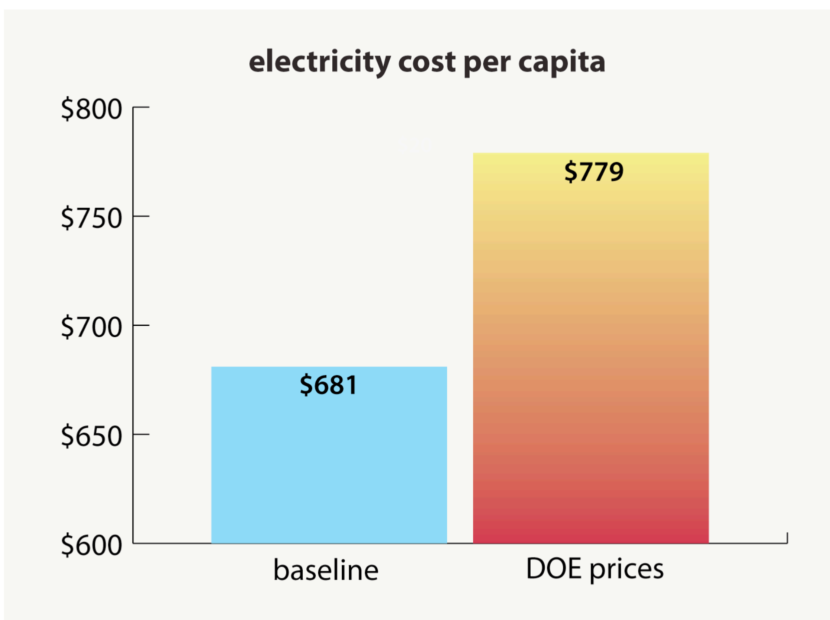
- Between now and 2020, without implementation of GHG policies, private electricity costs in California will be up to $100 per person higher in 2020, which would rise $100 above today's costs in any case, making electricity 33 percent more expensive (***Figure 2***). Higher energy prices force California enterprises and households to take a dollar away from in-state labor and labor-intensive goods and services and spend that dollar on capital-intensive fuel imports.

Figure 1: Higher Fossil Fuel Prices Handicap the Economy
(Difference from 2020 Baseline in 2008 billions, Thousands of FTE Jobs)



Source: Author estimates.

Figure 2: Higher Fossil Fuel Prices Drive Up Electricity Bills
(Difference from 2020 Baseline in 2008 billions)



Source: Author estimates.

More Aggressive RPS & Energy Efficiency Protect Consumers & Grow California's Economy

- Our forecast shows that combining AB 32, a 33 percent RPS, and enhanced energy efficiency (EE) will more effectively insulate California from external energy price shocks and stimulate economic growth and job creation.

- The impact of AB 32 combined with a 33 percent RPS mitigates GSP loss from higher energy prices by $71 billion and reduce job losses by 352,000 (fourth bar in ***Figures 3 and 4***).

- Increasing energy efficiency by 1 percent, as proposed by the AB 32 scoping plan, combined with 33 percent RPS increases GSP by an additional $33 billion and jobs by 387,000 (fifth bar in ***Figures 3 and 4***).

Conclusion

Aggressive Renewable Portfolio Standard & Energy Efficiency Will Help Protect California from Higher Energy Prices & Promote Economic Growth

Energy efficiency and renewables offer a valuable hedge against the risks of higher fossil fuel prices, quite apart from the fact that fossil fuel consumption generates over 80 percent of global GHG emissions.

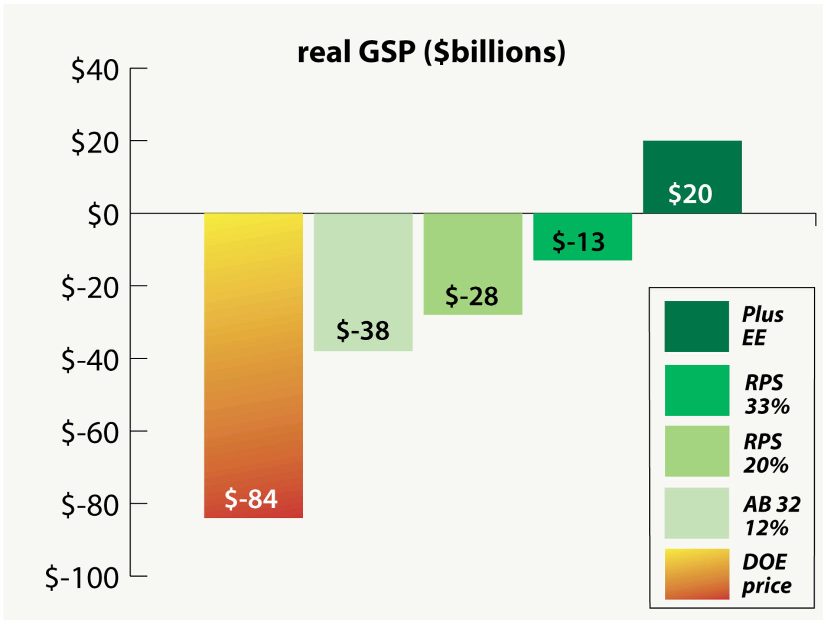
California's ambitious program will create dramatic opportunities for emergent technologies and green job creation, while setting a standard for other state and national governments to watch and consider emulating.

Uncertainly is Endemic to Innovation, but its Potential Rewards Justify Adaptive Policies

Available recent evidence on renewable deployment has very large uncertainty bands. Such uncertainty is endemic to any innovation process, but this does not mean renewable policy should be deferred. Instead, we need to promote research to elucidate and reduce this uncertainty and attendant risks, and design policies that promote and capture further innovation.

Figure 3: Climate Policy Protects the Economy

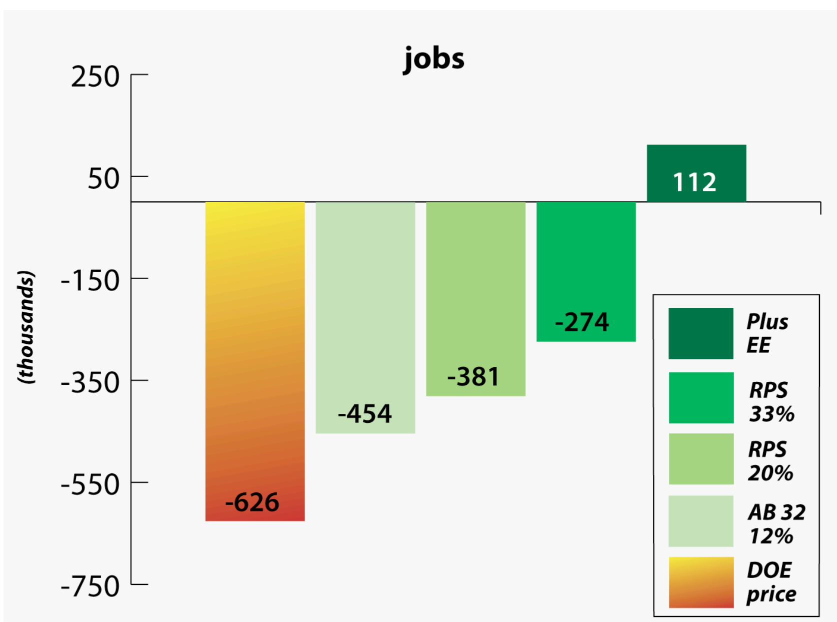
(Differences from 2020 Baseline, Real GDP 2008B$)



Source: Author estimates.

Figure 4: Climate Policy Promotes Growth

(Differences from 2020 Baseline, Thousands of FTE Jobs)



Source: Author estimates.

Research Papers on Energy, Resources, and Economic Sustainability

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

For this project on Energy Prices & California's Economic Security, financial support from Next 10 is gratefully acknowledged. Thanks are also due for outstanding research assistance by Elliott Deal, Fredrich Kahrl, and Mehmet Seflek.

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

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INTRODUCTION

Augmenting the state's current Renewable Portfolio Standard (RPS) for the electric power sector offers California much more than a lower carbon future. Because it is closely tied to technological change, bold promotion of the renewables sector promises to change the dynamics of long-term energy costs. The aggregate stock of three primary renewables (solar, wind, geothermal) is essentially fixed at a capacity far exceeding foreseeable energy needs. The economic cost of these resources is thus determined more by technology than by scarcity, and recent technical progress in these sectors suggests that a version of Moore's Law could apply as renewable energy development advances, lowering costs from these energy sources monotonically over time. This stands in sharp contrast to the long-term scarcity of fossil fuel supplies which, despite the current temporary demand failure, will become ever more expensive in the long-term.

In its path breaking AB 32 climate initiative, California has committed to a wide array of measures for direct and indirect GHG emission mitigation. In addition to the obvious benefits of reducing global warming pollution, the effects of this policy package on the state's economic growth prospects are of paramount interest. These effects will depend on three primary drivers, the course of fossil fuel energy prices, energy efficiency trends, and renewable energy development. In this brief, we begin with an assessment of how these three factors can influence California's growth prospects.

Energy Prices – Thanks to a strong economic cycle in recent years, energy prices are subject to almost unprecedented medium-term uncertainty. After a prolonged boom that shattered oil price records two years ago, we are currently experiencing sharply lower demand for energy because of the global recession. As the below ***Figures 5-11*** indicate, official forecasts for traditional fuel types are highly discordant across the last two years and between institutions. This uncertainty makes energy-related policy unusually risky, since appropriate technology choices under one scenario may be completely inappropriate under others. For example, consensus estimates released by the California Energy Commission (CEC) in 2007 suggest that fuel prices will rise on very moderate or even declining trajectories from 2009 to 2020, while the DOE Annual Energy Outlook (AEO) of January 2009, as well as International Energy Agency (IEA) trends, suggest that gasoline, diesel, and Liquid Natural Gas (LNG) prices will rise much more substantially.

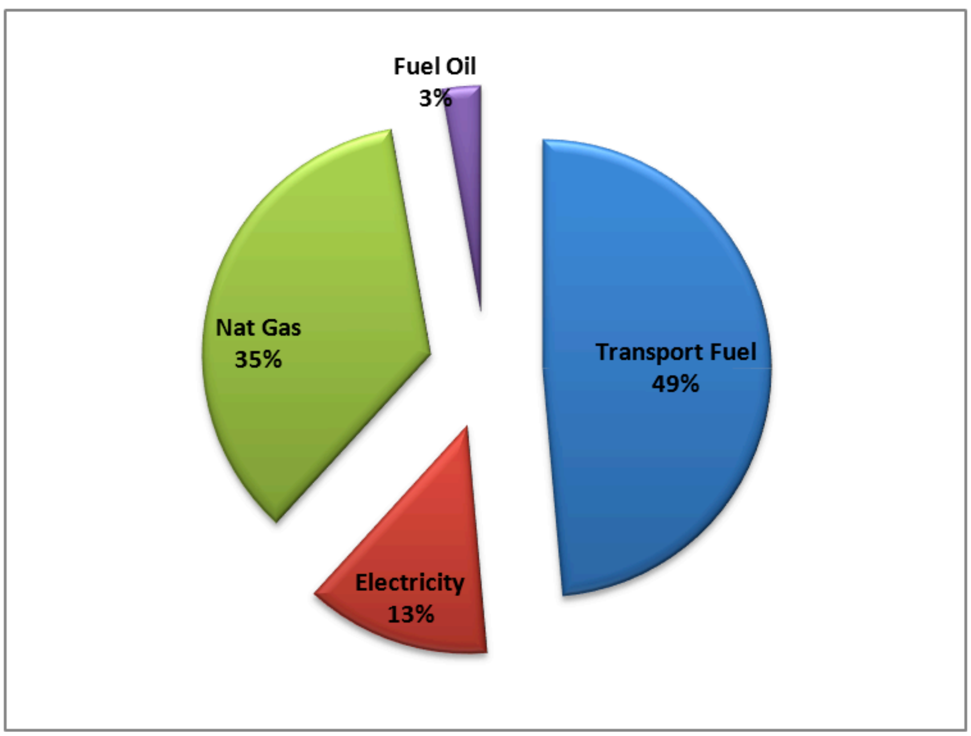
Energy Efficiency – Because energy consumption accounts for over 80 percent of GHG emissions, improving energy efficiency is essential to climate action. Efficiency can also achieve rapid and decentralized savings that stimulate economic growth.

Development, diffusion, and adoption of more efficient technologies, however, depend on complex interactions between policies and market incentives. California has relied heavily on the latter to establish national leadership in electricity efficiency. For market forces to accelerate efficiency improvements, sustained increases in fossil fuel prices, with and without price corrections for carbon pollution associated with fossil fuel combustion, will probably be required. The scenarios we evaluate here consider both these component effects, and show how higher efficiency can realize growth dividends from climate action.

The concept of energy efficiency is more general than might be suggested by the literature on individual energy sources. For example, the energy efficiency policy dialogue focuses on electricity use when appliance standards are being discussed, natural gas for heating when building insulation is debated, and on gasoline use when vehicle mileage standards are discussed. In reality, households exploit very diverse patterns of energy sources, both directly in their own uses and indirectly in the making of the goods and services they consume. The following figure shows the estimated average U.S. household energy direct energy consumption by source, measured in annual energy units (Giga Joules) for 2006.

Figure 5: Household Energy Use by Source

(annual use in Giga Joules, 2006)



Source: DOE.

For this reason, when we model scenarios for household energy efficiency improvements, it is important to be specific about the source of energy being economized. For example, California's AB 32 currently specifies over 40 different component measures, many covering energy fuels (e.g. gasoline and LNG) and many covering energy carriers (electricity). A recent statement of these measures is listed in ***Annex 2***, but we incorporate all of these in our AB 32 scenarios. For enhanced energy efficiency measures, we assume efficiency improvements across all household sources, in equal percent of energy content.

Renewable Energy Development and Integration – Recent studies have revealed extensive potential for developing renewable energy resources within and in proximity to California. If these can be effectively integrated into the state's energy grid, the RPS could achieve its dual purposes of mitigating climate damage and tempering long-term energy costs. This process will succeed only if it is innovation driven, developing and deploying new technologies that lower the cost of clean and green energy. Establishing global standards in this, the next breakout knowledge-intensive sector, would confer substantial economic benefits.

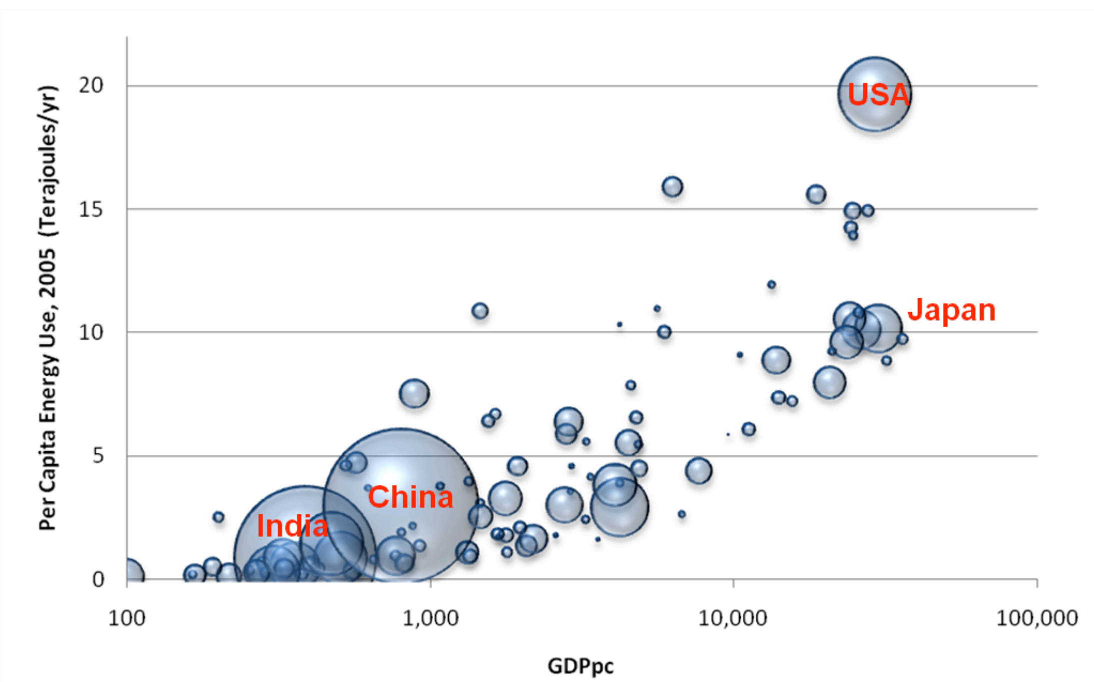
1 Energy Price Risk and the California Economy

"Our reliance on oil poses a threat to our economic security. Over the last few decades, we have watched our economy rise and fall along with the price of a barrel of oil. We must commit ourselves to an economic future in which the strength of our economy is not tied to the unpredictability of oil markets. We must make the investments in clean energy sources that will curb our dependence on fossil fuels and make America energy independent."

– U.S. Council of Economic Advisors

Carbon fuels have served humanity since prehistory, for most of this time providing simple heat and cooking service, accompanied by simple protective and utilitarian uses. About two centuries ago, however, Western economies began developing technologies to domesticate carbon fuel energy for mechanization of production and transportation. The result, usually referred to as the Industrial Revolution, has conferred living standards on us today that are beyond the imagining of these ancestors. Unfortunately, the same process also created an environmental liability that threatens to undo our progress by climate damage.

Figure 6: Per Capita Income and Energy Use, 2006



Source: Vertical axis measures energy use per capita from all sources. Author estimates from International Energy Agency and World Bank data. Bubble diameter is proportional to population.

In any case, we have prospered mightily by exploiting the relatively low cost energy potential of fossil fuels. The process of industrialization continued smoothly until the early 1970's, when the industrialized economies were awakened to their energy price vulnerability by the exercise of monopoly power among oil producing nations. A commodity that had become embodied in modern society's every good and service suddenly rose in price, triggering a sharp and sustained economic downturn. Since that time, the advanced economies have adapted by technical innovation and changing energy use patterns, yet the most prosperous economies remain the most energy intensive on a per capita basis (***Figure 6***).[1]

1.1 Energy Price Uncertainty

In light of the risks that energy price uncertainty poses for economic growth, it is reasonable to ask how reliable are public and private expectations regarding fossil fuel costs. From an energy user perspective, long-term declining prices would of course be most appealing, stable prices second-best, rising prices least so. Once committed to a given fossil fuel, however, real world users have little control over prices and can at best hope for accurate expectations. This would enable them to adapt to trends with rational investments in inventories and alternative technology. Unfortunately, today's fossil fuel prices fail on all of these counts, being neither low, stable, nor predictable. For these reasons, the best strategy in the long run is to reduce our dependence on fossil fuels through efficiency and substitution.

While it is true that a global recession significantly reduced growth of demand for energy over the last year, this had little or no effect on supply, and as the global economy recovers energy prices are bouncing back rapidly. Gasoline, for example, has recovered more than 60 percent of its decline since last January. Even though policymakers are reluctant to call the beginning of an economic recovery, both gasoline and oil prices have already risen well above decadal averages. In addition to this, we must recognize that the large emerging economies in ***Figure 6*** (China and India) are coming out of recession ahead of the OECD and, over two decades, they have established growth rates three times higher than the U.S. or California. Thus it is reasonable to expect prices well above historical averages, and indeed these may escalate to unprecedented levels.

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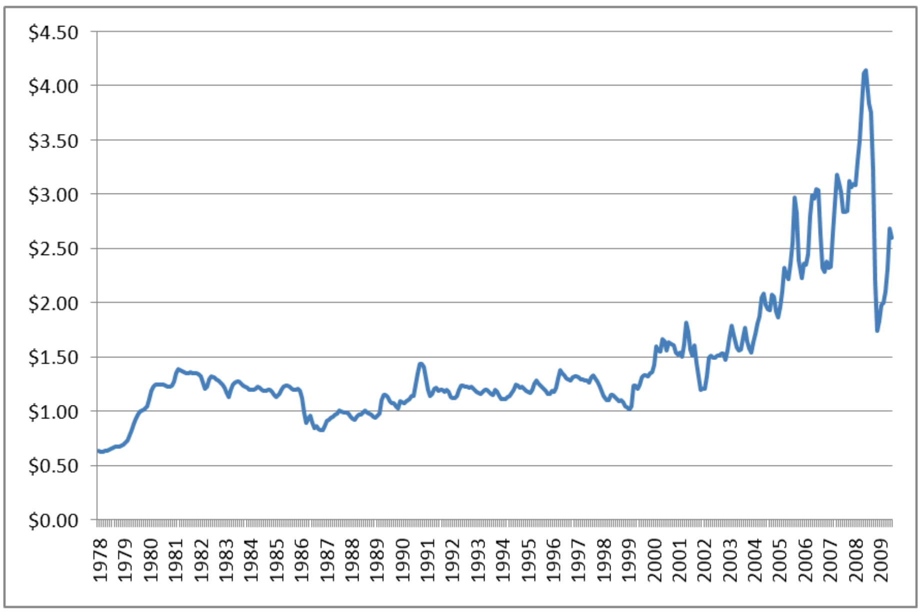
[1] Although its energy intensity is still high by global standards, the example of Japan suggests that U.S. living standards might be attainable with more moderate energy dependence. Japan has the highest levels of household and enterprise energy efficiency in the world.

While long-term oil prices suggest ever escalating economic scarcity of fossil fuels, recent trends have mitigated the fears of many.[2] It must be understood, however, that the demand side failure represented by a global recession is already reversing itself, and provides little reliable guidance regarding long-term energy needs. As ***Figure 8*** suggests, recent oil prices have been more pronounced in their volatility than in establishing any downward or even level trends.

Figure 7: US Retail Gasoline Prices

(national, all grades, 2008 dollars)



Source: Bureau of Economic Analysis, Series APU00007471A.

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[2] There have been several recent announcements of large oil and natural gas discoveries, particularly from Brazil and Australia. It is important, however, to recognize that these new resources are below several thousand feet of seawater, and their costs of recovery will likely establish new standards for the industry. In other words, physical abundance does not necessarily alleviate economic scarcity.

Figure 8: Crude Oil Prices

(1970-2008, $/barrel)

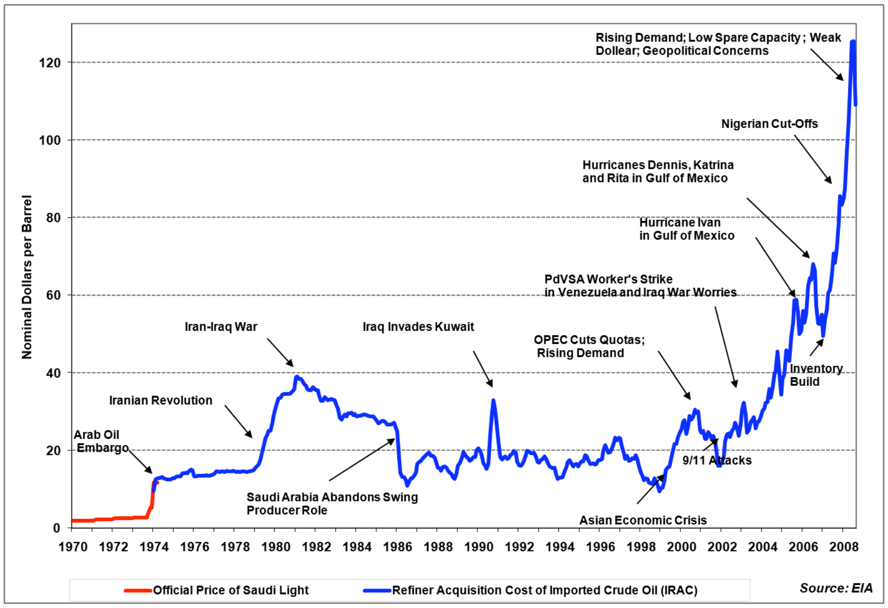
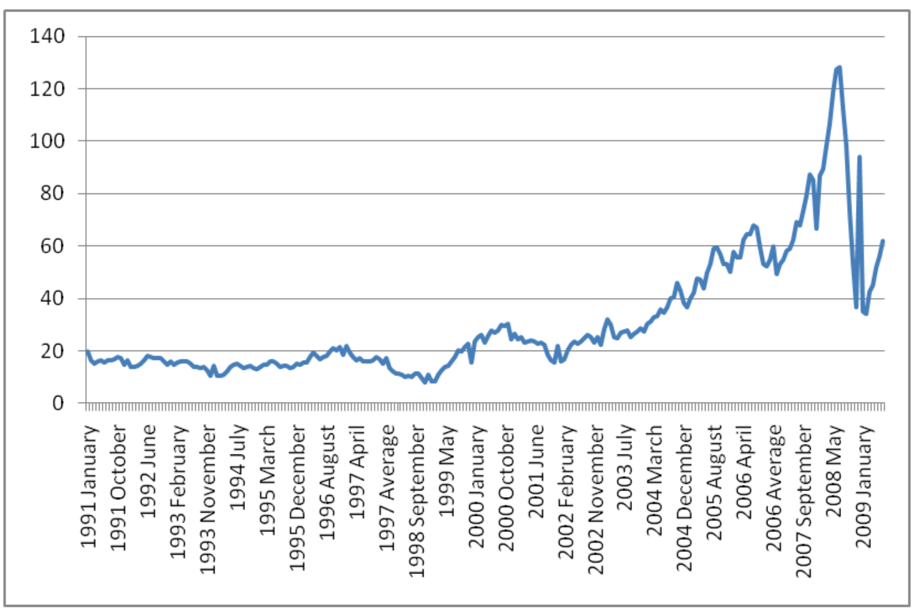


Figure 9: More Recent Crude Oil Prices

(1991-Present, $/barrel)

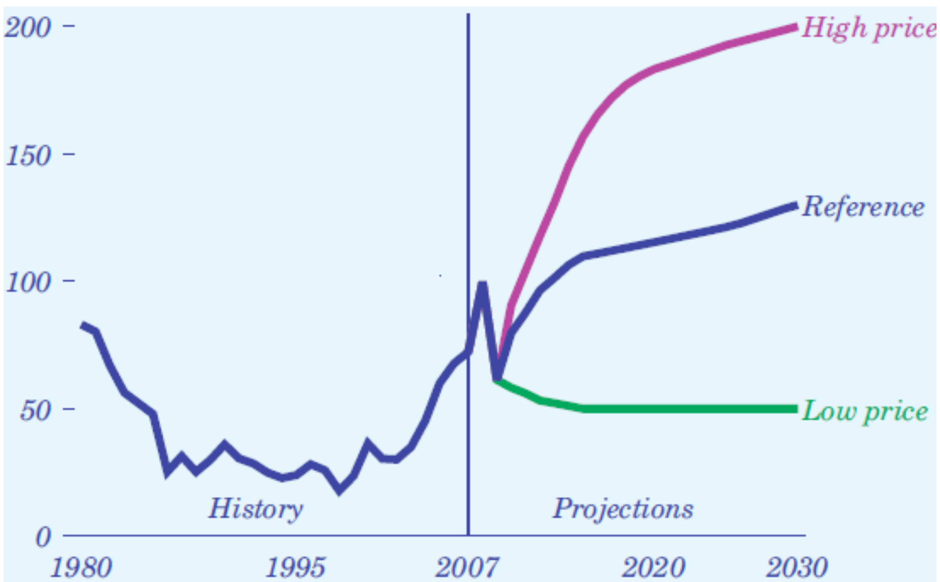


Source: Bureau of Economic Analysis.

If we won't get our wish for low prices, can we at least form reliable expectations that would permit us to use hedging strategies, including inventories, long-term exploration investments, and other supply-side solutions? The answer here too appears to be negative. The most recent official U.S. expectations regarding oil prices are depicted in ***Figure 10*** below, comprising Low, Reference, and High scenarios. Not only are all three scenarios well above 10-20 year historical averages, their variation (fourfold difference between low and high) shows that the best available official information is essentially unreliable. In light of history, however (sixfold increase between 2002 and 2008), it is also inevitable.

Figure 10: Future World Oil Prices in Three Cases, 1980-2030

(2007 dollars per barrel)



Source: DOE, 2009.

At the global level, energy price expectations are set by the International Energy Agency. While they have a wider ranging perspective and detailed supply and demand reporting from over one hundred countries, the IEA has also acknowledged substantial uncertainty. Moreover, recent revisions of their energy price forecasts have been increasingly pessimistic, as reflected in the following three extracts from their most recent public statements:

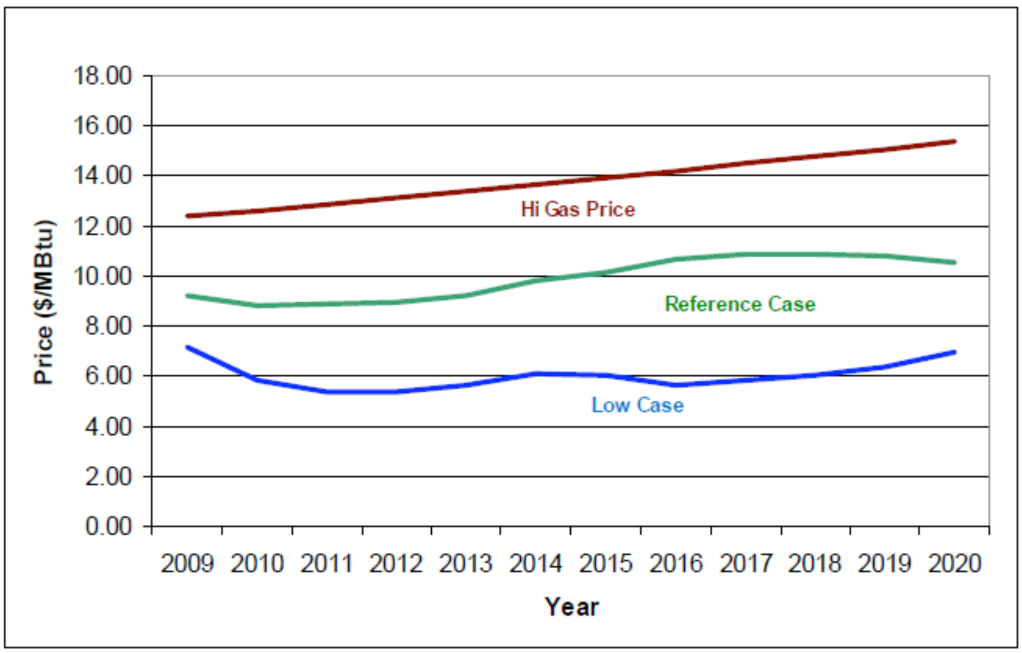
> *"The public and many governments appeared to be oblivious to the fact that the oil on which modern civilization depends is running out far faster than previously predicted and that global production is likely to peak in about 10 years – at least a decade earlier than most governments had estimated."*

"…the first detailed assessment of more than 800 oil fields in the world, covering three quarters of global reserves, has found that most of the biggest fields have already peaked and that the rate of decline in oil production is now running at nearly twice the pace as calculated just two years ago."

"…we estimate that the decline in oil production in existing fields is now running at 6.7 percent a year compared to the 3.7 percent decline it had estimated in 2007, which we now acknowledge to be wrong." - Dr. Fatih Birol, IEA Chief Economist

At the state level, most official work has been based on price trends set forth in the 2007 edition of the California Energy Commission's Integrated Energy Policy Report (IEPR). An example is the Renewable Energy Transmission Initiative (RETI) price trends, which combine CEC IPER (Ref and Low), Nymex 2007 (High), and a carbon adder for prices after 2012. These encompass more than doubling of prices between high and low trends to account for system uncertainty in fuel markets.

Figure 11: RETI Reference Energy Price Trends (CEC)



Source: RETI Final Report, January 2009.

What we see in national and international price uncertainty for gasoline and oil is also reflected at the state level and for all fossil fuels. The following figures summarize official trends from a variety of official sources, and the most arresting feature of these is their discord. ***Figures 12 and 13*** show gasoline prices and price indexes as predicted by DOE and CEC, with the former being the DOE 2009 reference case and the latter comprising three trends estimated in 2007. In fairness, CEC probably used the same data available to the DOE authors (U.S. Department of Energy), but their estimates were made two years earlier. Thus we see that long-term expectations have a very short half-life, and within one or two years the most pessimistic expectations can become reference trends.

Figures 14 and 15 provide comparable trends for diesel fuel, but in this case 2009 DOE reference projections are below CEC's most pessimistic projections. Whether this reflects different market fundamentals or challenges the reliability of both sources is an open question. What remains uncontroversial is the huge variance in long-term outcomes between high and low, i.e. the systemic risks for buyers in this market.

Meanwhile, there is always a private alternative to official statistics on future price trends for economically important commodities, namely established futures markets where participants bet billions of dollars on the hope of predicting trends. Unfortunately, in the case of energy it is apparent that markets offer little more in terms of reliable expectations. ***Figures 16 and 17*** show projected prices and price indexes for natural gas, including futures prices from the New York Mercantile Exchange (NYMEX). Depending on whether the latter are sampled in 2008 or 2009, expected future prices can differ by more than 50 percent. Again, this kind of volatility might present an opportunity for speculators, but not for main street business and households.

Thus it is apparent that fossil fuel price uncertainty is endemic to both public and private decision making, and indeed its magnitude appears to be rising sharply. Recall that we are also talking about a commodity that is embodied in the costs of producing every single good and service in the modern global economy. Cost uncertainly of this magnitude would be intolerable to most businesses, and given that these prices are largely outside the control of consuming countries, the only rational defense against it is again to reduce reliance on these commodities.

For their part, policymakers (e.g. the White House) have begun to recognize that reducing fossil fuel dependence is not just an environmental priority, but an economic one. In light of history, energy will likely remain essential to prosperity, but we must find ways to avoid the environmental and price risks associated with fossil fuels. This has led to more determined efforts in Washington, Sacramento, and a growing list of state capitals to reduce the fossil fuel intensity of economic activity. Promotion of renewable energy and energy efficiency are the two primary strategies to achieve this.

Figure 12

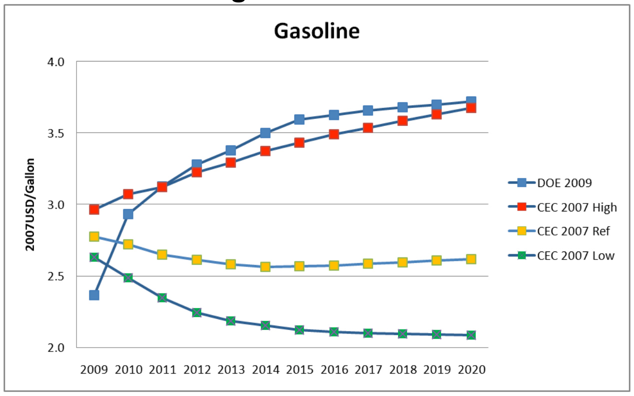


Figure 13

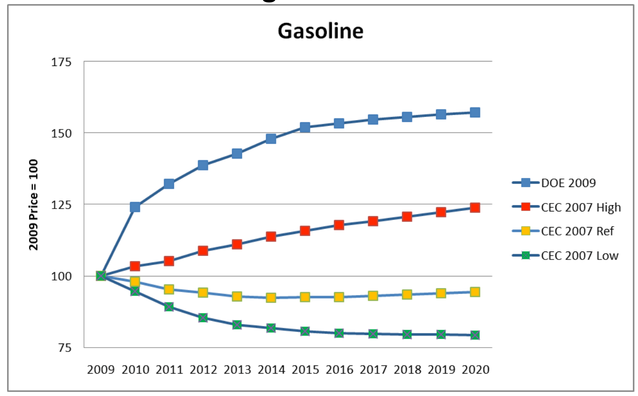


Figure 14

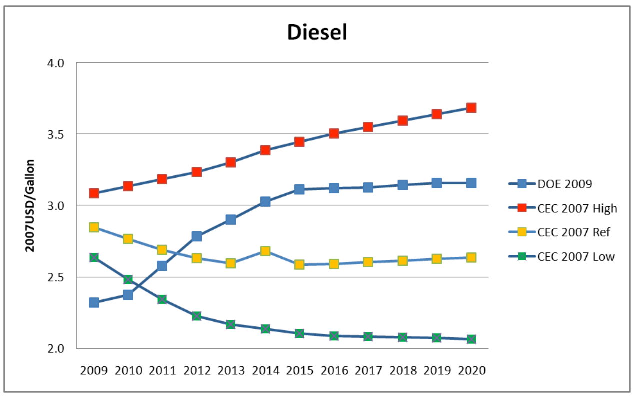


Figure 15

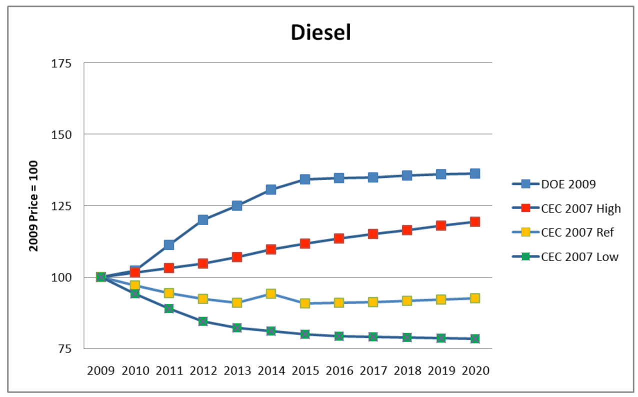


Figure 16

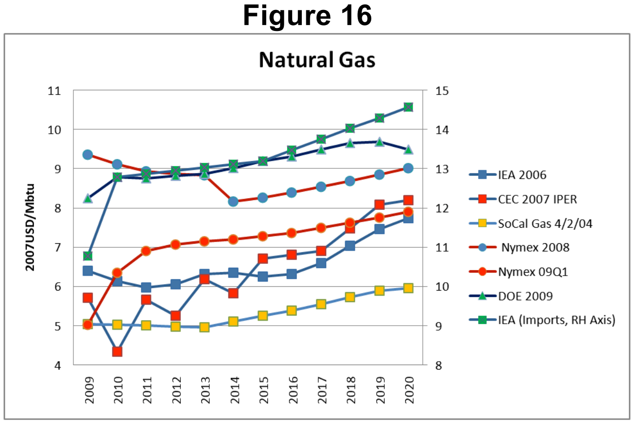
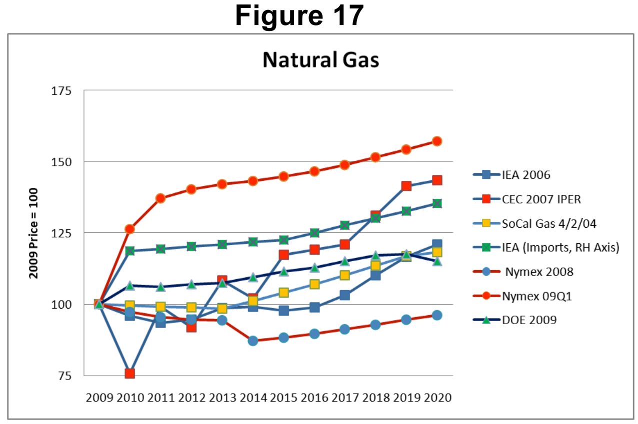


Figure 17



Sources: DOE 2009, CEC 2007, NYMEX, IEA, Southern California Gas.

Notes and abbreviations:

1. IEA – International Energy Agency, World Energy Outlook, November 2008
2. CEC – California Energy Commission
3. Nymex – New York Mercantile Exchange, Period average closing prices of commodity futures.
4. DOE – Annual Energy Outlook, U.S. Department of Energy, Report #:DOE/EIA-0383(2009), March
5. RH Axis – Units for prices of LNG imported into the U.S. are display on a separate, right-hand vertical axis

Notes on Renewable Deployment and Costs

The economic impact of the RPS will of course depend critically on the costs of technologies deployed, and the level of uncertainty regarding these is large enough to justify careful examination. Fortunately, California has recently made significant investments to improve the quality of available information on appropriate renewable potential. The hallmark RETI reports released in January, June, and August 2009 represent a high standard for this kind of information, detailing the logistical, cost, and environmental characteristics of scores of RPS eligible projects within and in proximity to the state's energy markets. In our assessment, we take advantage of this information for California climate projection work. In particular, we have used a statistical procedure to produce smooth adoption profiles from RETI project data. These were incorporated into BEAR to measure the cost of renewable energy deployment to meet the RPS and independent demand.

1.2 Deployment Ranking and Sequencing of Renewable Capacity

The relevant RETI information and estimated profiles are illustrated in ***Figures 18 and 19*** below. Of particular interest is the fact that negative or zero ranking cost options are estimated to be available, even in RETI's reference scenario. When full transmission development and operating costs are included, about 75TWh are available at negative or ranking cost relative to even moderate energy price scenarios (CEC Reference). If transmission development costs were financed by other means (e.g. Federal stimulus or other concessional pubic finance), over 110TWh would be available at relatively low cost.

Figure 18: Weighted Average Rank Cost (2009 $/MWh) for Competitive Renewable Energy Zones (CREZ) and Resource Areas

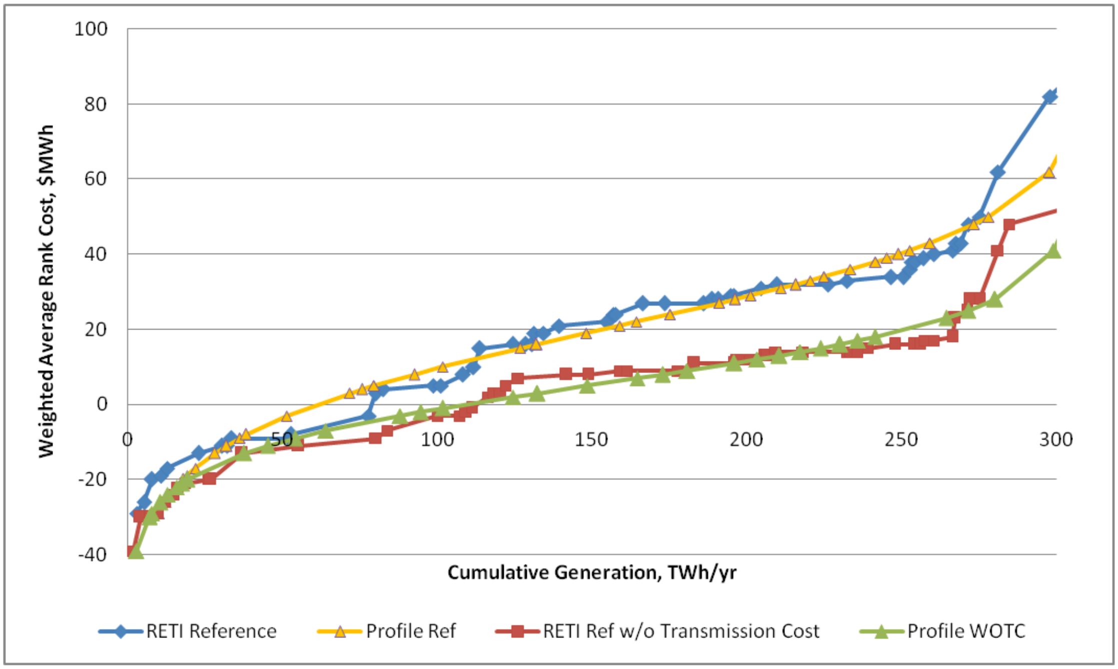
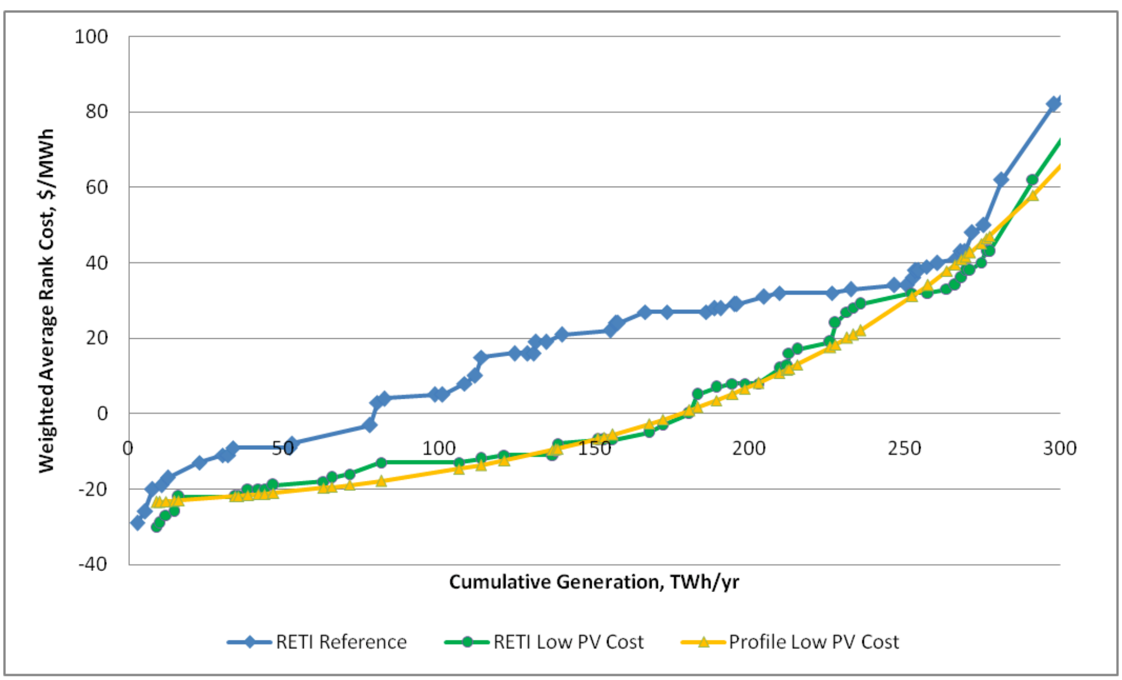


Figure 19: Weighted Average Rank Cost (2009 $/MWh) for CREZs and Resource Areas



Source: Author estimates and data from RETI (2009ab).

The most arresting results, however, come after taking account of RETI's lower solar technology cost scenario (RETI, 2009bc). In their June report, RETI simply discounts existing projects for lower PV costs, leaving them in place in the same adoption sequence as Figure 18. If PV prices fall as they predict (and emerging evidence suggest they may fall much more so), then deployment should be reordered to take advantage of this. Figure 19 assumes that the projects set forth by RETI are re-sequenced to take full account of lower PV costs, and the result is that about three times the state's baseline "Net Short" RPS position (~60TWh) could be covered with relatively low Rank Cost renewable sources, again by comparison to unrealistically lower energy price trends.

The relationship between Net Short and PV capacity is illustrated in ***Figure 20***, where we see how residential deployment of solar technology reduces the potential for a gap in RPS fulfillment.

Figure 20: RETI Estimates of Net Short RPS Requirements or Varying Residential PV Adoption

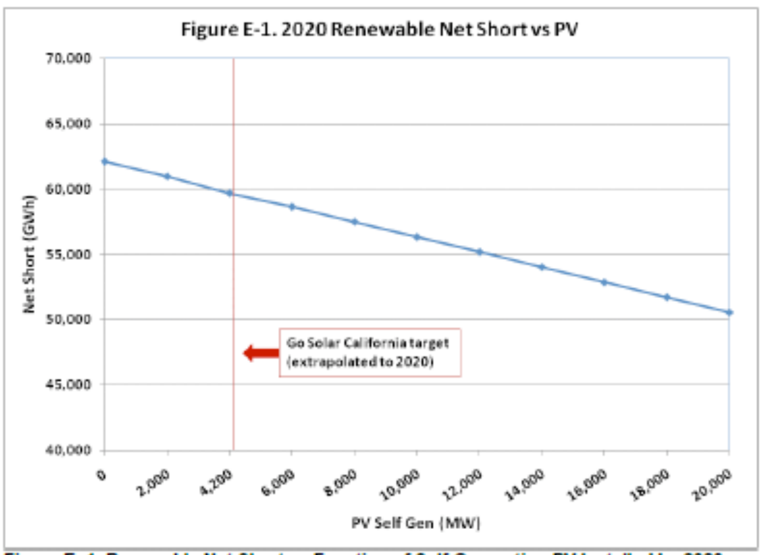


Figure E- 1 Renewable Net Short as Function of Self-Generation PV Installed by 2020.

Source: RETI (February, 2009).

Some clarification of the Rank Cost concept is appropriate, as it is easily misinterpreted and subject to varying application. To be explicit, Rank Cost is defined by RETI as follows:

Rank Cost = Generation Cost + Transmission Cost - Energy Value - Capacity Value

Where Generation Cost refers to the renewable technology under consideration and Transmission Cost is specific to grid conveyance for the same renewable source.

Energy Value measures to economic value of electric power generated (usually a market valuation), and Capacity Value refers to the value of continuously reliable generation during a defined peak interval (usually summer peak hours). It is important to emphasize that Rank Cost is not the same as Generation Cost. In particular, the first two components measure Generation Costs, while Energy Value calibrates alternative technologies to an energy equivalent value basis for comparison. Finally, Capacity Value is a proxy for the economic value of system reliability, not an explicit Generation Cost. Technologies with higher continuous capacity (e.g. geothermal>solar>wind) will be ascribed higher values of Capacity Value, which lowers their Rank Cost and confers higher rating as projects will be selected on a lowest Rank Cost basis. Again, Rank Cost is an index for combining energy production costs and a financial proxy for reliability benefits. It does not measure actual deployment cost.

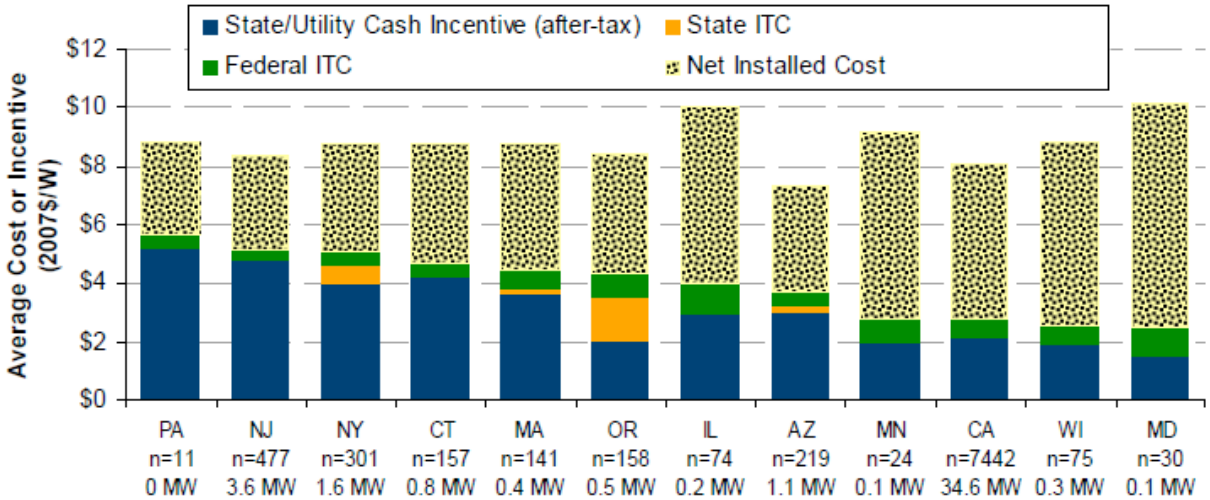
If PV price trends continue to be favorable, it appears that the economic potential for renewable energy deployment far exceeds the existing RPS commitment. If this is the case, the state may want to supplement RPS with hybrid policies that combine adoption and investment incentives to facilitate faster transition in the energy sector. These policies could significantly accelerate de-carbonization of the California's electric power sector and confer substantial savings on households. To estimate the latter benefits, we incorporate the RETI Reference and Low PV Cost profiles in separate BEAR scenarios.

1.3 Renewable Cost Estimates

To impute actual costs for RPS, we need to estimate the capital and Operation & Maintenance (O&M) costs of these systems over the time horizon under consideration, including costs of backstop technology that compensates for the intermittence of solar and wind power. There is very extensive research literature on this topic, and while there is significant variation in detailed estimates, a number of salient characteristics of renewable potential can be generalized. Firstly, there is a broad consensus that costs of renewable technologies are falling significantly, while efficiency and reliability are both rising.

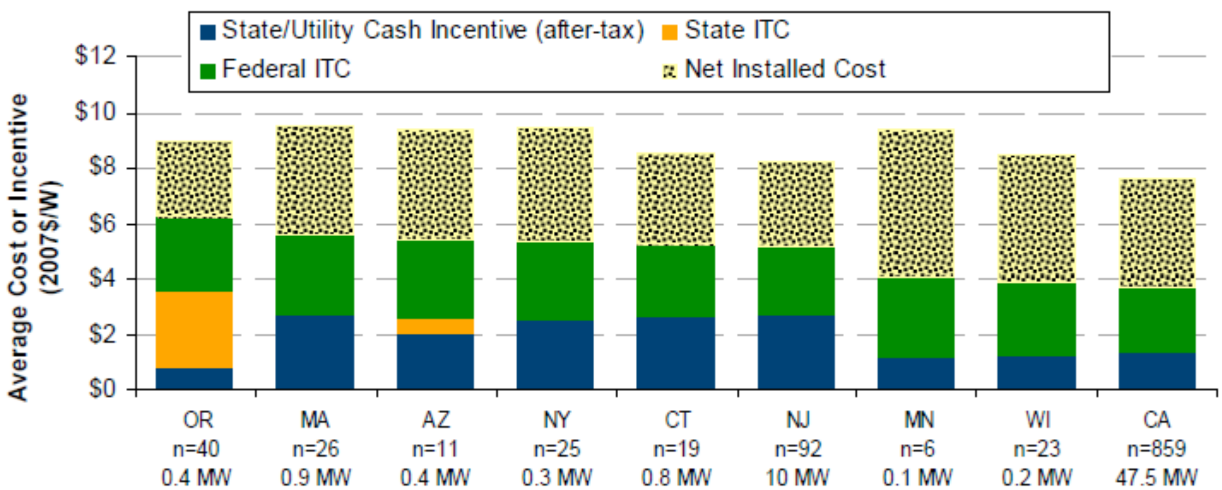
The most definitive recent study of costs is that of Lawrence Berkeley National Laboratory (2009), based on recent and detailed surveys of renewable costs across states. The estimates they obtained of most relevance to the present study are summarized in ***Figures 21 and 22***. In these figures, it is apparent that state incentives are very significant to adoption decisions for both households and businesses, but they are more generous to households and vary significantly from state to state. Federal incentives, by contrast, are more important to enterprises and of course more uniform across states.

Figure 21: Installed Cost and Incentives for Residential PV Systems, 2007



Notes: We assume that all systems <10 kW are residential (unless identified otherwise) and that state/utility cash incentives for such systems are non-taxable and reduce the basis of the Federal ITC. The value of state ITCs is calculated as described in Appendix C.

Figure 22: Installation Cost and Incentives for Commercial PV, 2007

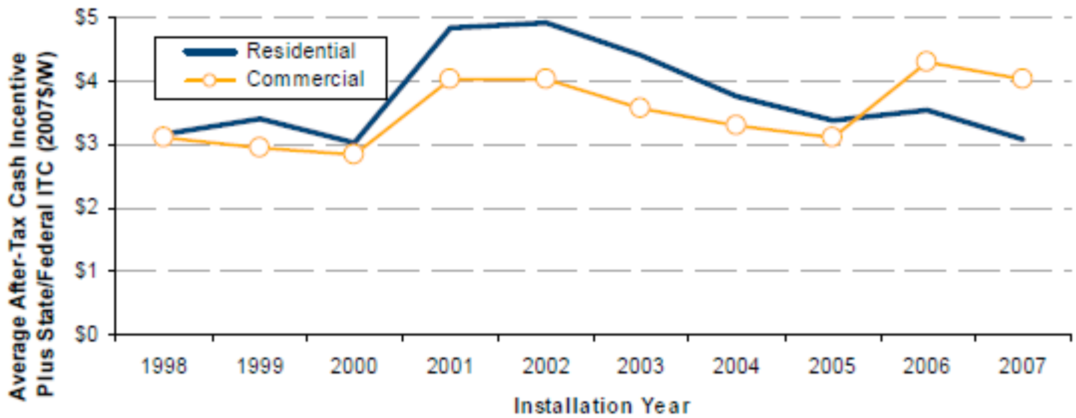


Notes: IL , MD , and PA are omitted from the figure due to insufficient sample size (<5 systems). We assume that all systems >10 kW are commercial (unless identified otherwise) and that state/utility cash incentives for such systems are taxed at a Federal corporate tax rate of 35% plus the prevailing state corporate tax rate, and do not reduce the basis of the Federal ITC. The value of state ITCs is calculated as described in Appendix C.

Source: Wiser et al, 2009.

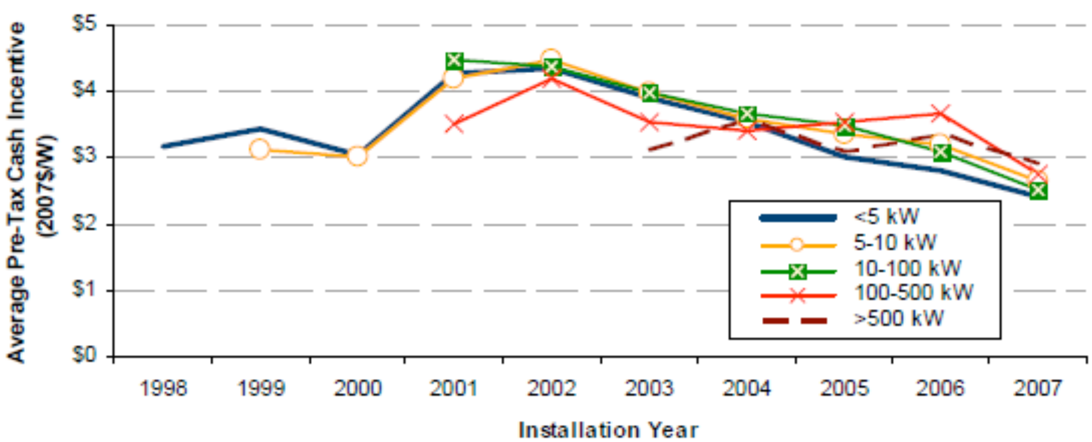
In any case, the result is substantial public stimulus for private renewable deployment, in many states covering more than half the total cost of installation. ***Figures 23 and 24*** show how this public support differs across users (residential/commercial), scale of generation, and time. Over time, subsidies have not varied too much nationally, nor do they differ across generators in pre-tax dollar terms. In terms of after-tax cost, however, households formerly benefitted more from PV subsidies, but recently commercial generators have reaped greater after-tax benefits.

Figure 23: After-Tax State/Utility Cash Incentives plus State & Federal Investment Tax Credits (Estimated)



Notes: We assume that all systems <10 kW are residential (unless indentified otherwise) and that state/utility cash incentives for such systems are non-taxable and reduce the basis of the Federal ITC. We assume that all systems >10 kW are commercial (unless indentified otherwise) and that state/utility cash incentives for such systems are taxed at a Federal corporate tax rate of 35% plus the prevailing state corporate tax rate, and do not reduce the basis of the Federal ITC. The value of state ITCs is calculated as described in Appendix C.

Figure 24: Pre-Tax State/Utility Cash Incentive Levels over Time

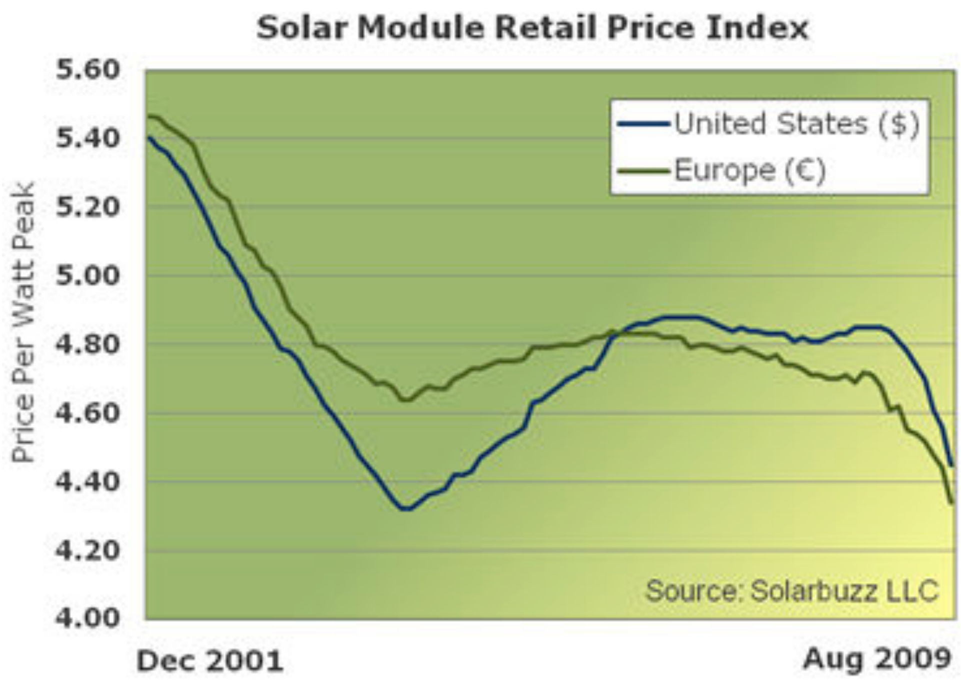


Note: Averages shown only if more than five observations available for a given size range in a given year.

Source: Reproduced from Wiser et al (2009).

Figure 25 provides higher resolution data on PV prices, and illustrates the current sharp downturn in these technology costs. Expert observers are somewhat divided, however, on the relative importance of technology driven cost improvements and demand-side fluctuations in this process. There is general agreement that the downward trend in the early part of this decade was driven by innovation, while the upswing was due to demand-induced scarcity. The recent downturn may be supported by continued cost and productivity improvements, but must at least partly be due to an adverse global economic cycle that has repressed some demand for PV but also made silicon much cheaper. In any case, to avoid reliance on these mixed interpretations, we chose median values for PV module prices in the cost calculations presented below, but it is worth emphasizing that long-term PV price trends are continuing down.

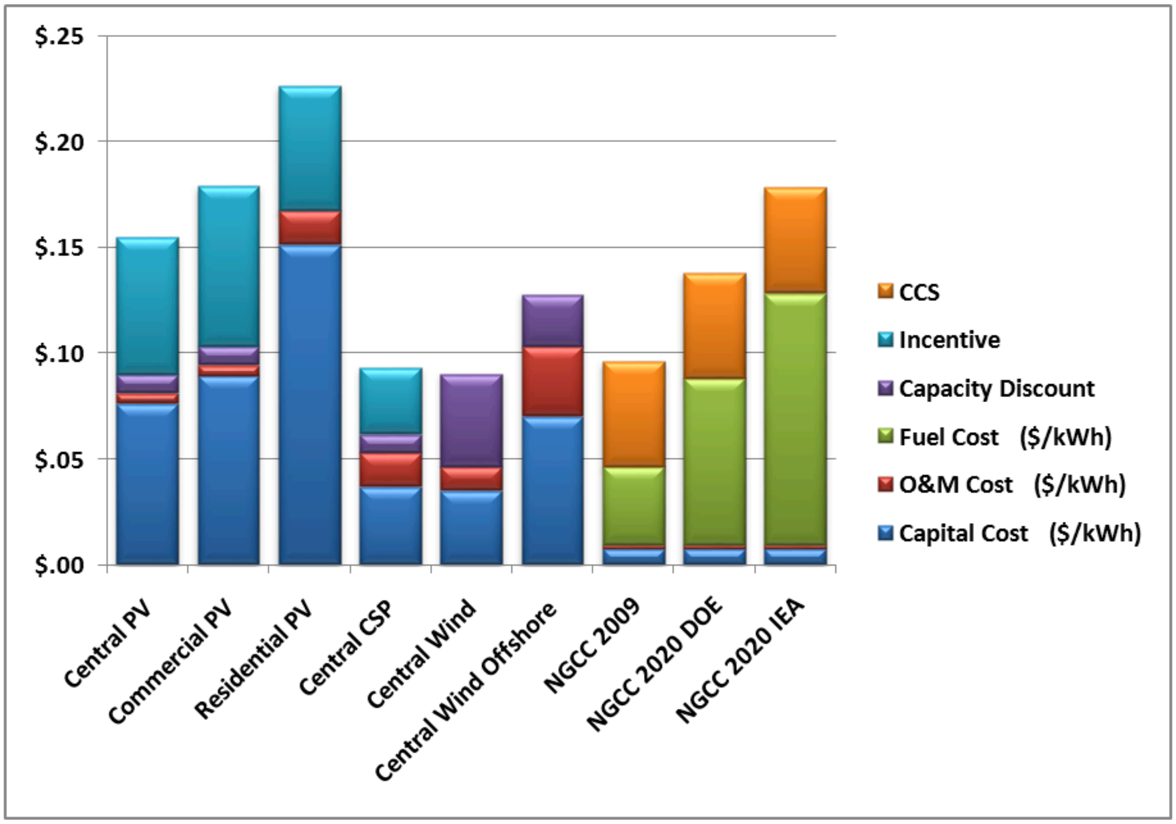
Figure 25: Recent Trends in PV Cost



Source: http://www.solarbuzz.com/Moduleprices.htm.

To calibrate our economic projection model, we combine this information with other data and assumptions regarding renewable and conventional energy alternatives. These are presented in ***Figure 26*** in terms of total cost per kWh of electricity, comparing the main intermittent renewable sources with a state-of-the-art Natural Gas Combined Cycle (NGCC) generation technology. Because fuel costs are an essential determinant of conventional costs, we present estimates under three LNG price scenarios, today (2009), DOE Reference 2020, and IEA Reference 2020. The last is an international LNG price, significantly higher than DOE because historically U.S. LNG prices have been buffered by domestic supply, regulation, and other conditions that kept domestic prices below world prices. Whether or not this price advantage can continue with sharply rising global demand is an open question, but we include IEA prices for comparison. In our projections of RPS deployment, the prices assumed for LNG are taken from the DOE reference case.

Figure 26: Renewable and Conventional Cost Estimates



Source: Author estimates from industry data (see Annex 1 below).

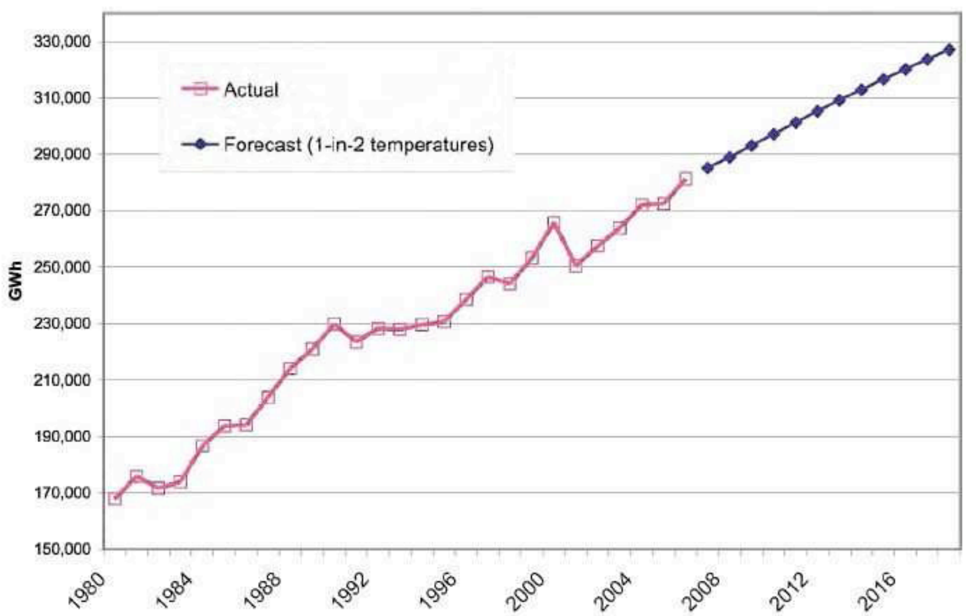
The actual estimation procedure, data, and assumptions are described in ***Annex 1***, but several components of these estimates still require elaboration. Each energy technology has a capital cost (dark blue) for installation, as well as recurrent Operations and Maintenance (O&M, red) costs. Conventional (NGCC) energy is generated from fossil fuels (LNG, green), whose cost depends on market price assumptions. For renewables, intermittency imposes an additional cost for backstop technology (purple), higher for wind than for solar. Assuming that state and federal government continue historic trends of providing incentives (at least for solar, light blue), we have a significant cost component that is not borne by the adopter. Finally, assuming a primary objective of renewable deployment to be carbon mitigation, we include for the conventional source an estimate of sequestration (CCS, yellow) costs.

Taken together, these unit cost estimates are used by the projection model to price RPS strategies, assuming renewable adoption for California follows a pattern dictated by the Rank Cost criteria of RETI and by the residential targets set forth in the California Solar Initiative.

2 Electricity Demand

For the sake of consistent comparison, we have used California Public Utilities Commission/California Energy Commission estimates of residential and non-residential electricity demand in our baseline. These assume that California is able to maintain a constant per capita level of consumption going forward (***Figure 27***).

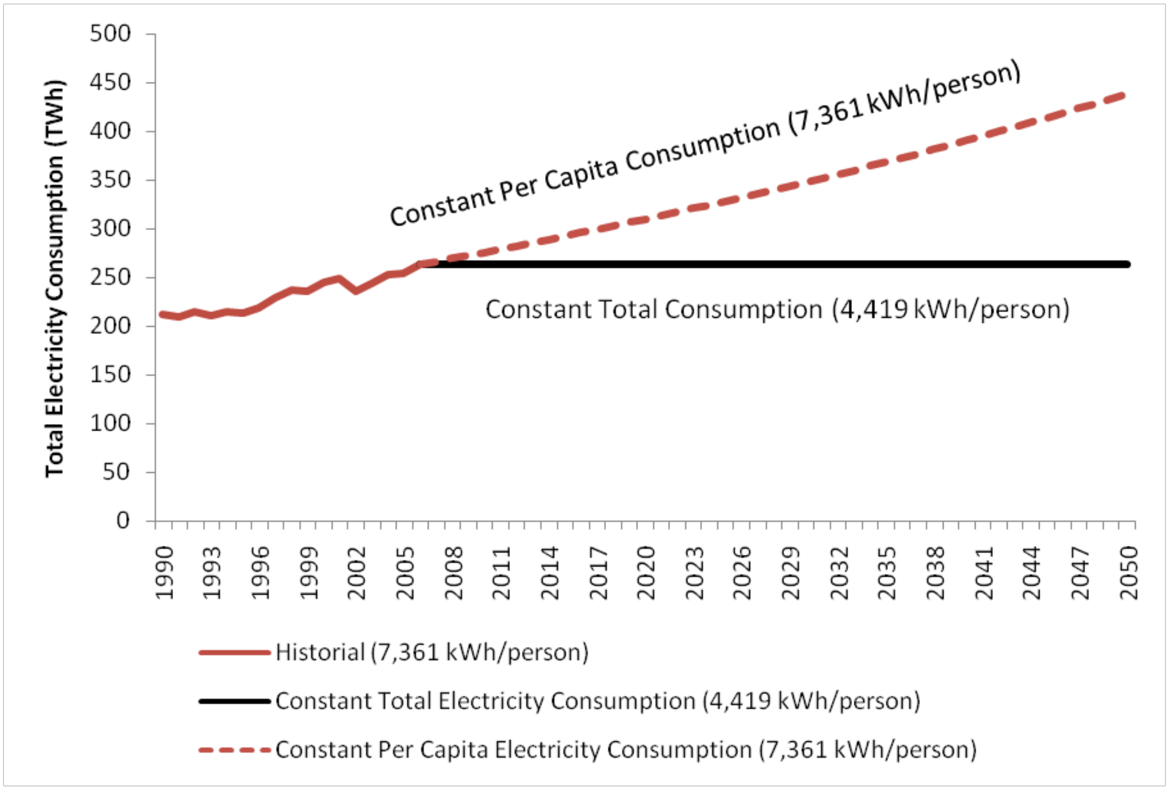
Figure 27: Past and Projected California Electricity Demand



Source: CEC (2007).

It should be emphasized, however, that these trends are uncertain and probably conservative for several reasons. Despite its historical successes in per capita electricity efficiency, a business-as-usual future for the state would probably reverse this trend because of rising air conditioning use that results from inland migration and rising average temperatures. Intensive econometric analysis by Aroonruengsawat and Auffhammer (2008, ***Figure 28***) suggests that the combination of these two trends could increase in the state's per capita electricity consumption by 2050, more than doubling of the state's total electricity demand, even in scenarios where the earth's climate can be stabilized.

Figure 28: California Electricity Demand Trajectories, with either Constant Per Capita Electricity Consumption or Constant Total Consumption



Source: Aroonruengsawat and Auffhammer (2008), with historical data are from the EIA website, http://www.eia.doe.gov.

3 Scenarios

Using the Berkeley Energy and Resources (BEAR) economic forecasting model, the following scenarios were evaluated to assess the interactions described above.[3] To facilitate transparency and comparability, we have attempted in each case to implement price trends supported by official state, national, or international estimates.

Scenario 1: *Baseline*. Baseline Comparison Trend - Assume no climate policies, efficiency improvements stay at 2009 trends. For this scenario, we use CEC Reference case prices, estimated by them in 2006 and reported in the 2007 IPER.

Scenario 2: *DOE Prices*. Assume no climate policies, global economy recovers and demand from emerging markets (e.g. India and China) creates global energy demand competition, which drives prices faster than CEC Reference trends. This and the remaining scenarios use the most recent (2009, January DOE) price forecasts.

Scenario 3: *AB 32/12*. Assume climate policies that place limits on carbon per AB 32 beginning in 2012, evenly distributed improvements in efficiency and other measures targeted by the CARB Scoping Plan (see ***Annex 2***). One policy is omitted in this case, where RPS is limited to the initial share of 12 percent.

Scenario 4: *RPS 20*. This scenario is the same as the previous, but expands RPS to 20 percent.

Scenario 5: *RPS 33*. The same as Scenario 3, but expanding RPS to 33 percent.

Scenario 6: *Plus EE*. Assume Scenario 5, but accelerate energy efficiency (across all energy and fuel sources) by 1 percent per year. DOE Reference prices.

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[3] The BEAR model, described in Section 5 of this report, is the preeminent climate policy model for California. Its results have been quoted in the Executive Order establishing AB 32 and this model was used to produce comparison scenario analysis for CARB's Scoping Plan.

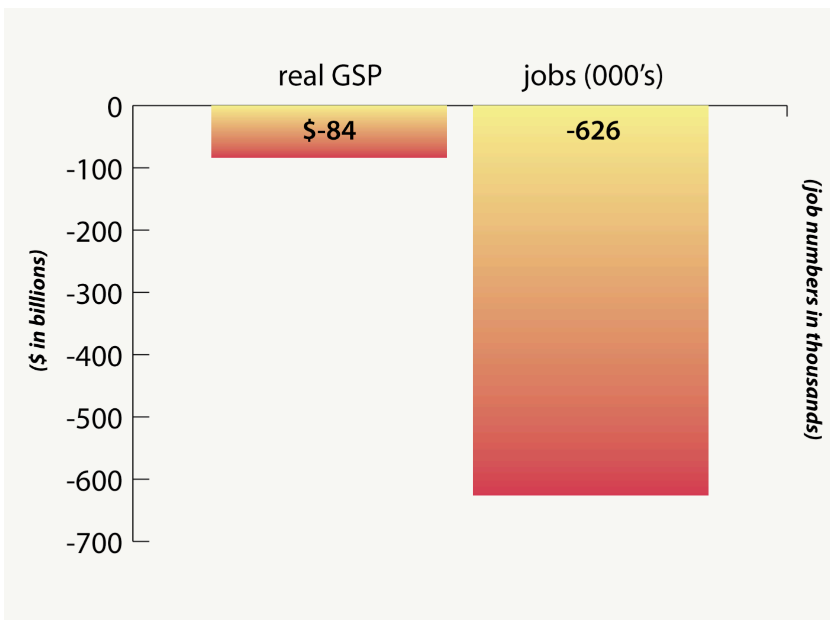
In the scenarios for incremental RPS implementation (Scenarios 4-6), we sequence projects according to the most recent RETI report (June, 2009), following the Rank Cost standard for drawing renewables into the system (***Figure 18***). Given the capacity required to meet the "Net Short" or new RPS need, the most cost-effective resources may include assets outside California but in market proximity to the state. The extent of these "spillovers" depends on both the Rank Cost sequence and the total (Net Short) requirement. In the context of the new mandate of 33 percent RPS, we estimate that less than 10 percent of new capacity would be sourced out of state using the existing Rank Cost profile

4 Economic Projections

Our initial estimates suggest that today's California economy is highly vulnerable to fossil fuel price uncertainty, but energy efficiency and the renewable substitutes offer potent sources of risk reduction. ***Figures 29 and 30*** *below* support the first observation, while the results in ***Table 1*** below provide insight into the second. By reducing external energy dependence, AB 32 climate policies and extended RPS both confer long-term savings on households and enterprises that can be channeled into more employment-intensive and sustainable growth patterns. In addition to GHG mitigation, then, efficiency and renewable energy development offer economic security and new sources of domestic demand stimulus.

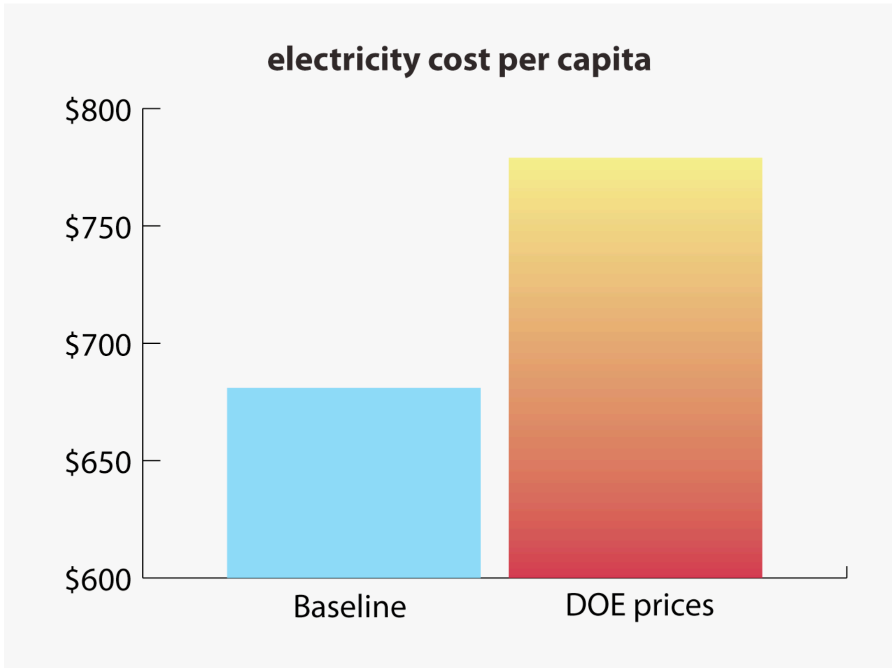
Figure 29: Higher Fossil Fuel Prices Handicap the Economy

(Difference from 2020 Baseline in 2008 billions, Thousands of FTE Jobs)



Source: Author estimates.

Figure 30: Higher Fossil Fuel Prices Drive Up Electricity Bills
(Difference from 2020 Baseline in 2008 billions)



Source: Author estimates.

Our forecasts for Scenarios 2-6 indicate that higher energy price trends could result in significantly lower real GSP, reduced state employment, and higher electric power rates. In particular, revising fossil fuel prices trends from the CEC projections used for the AB 32 assessment to the DOE prices suggest increases of over 40 percent by 2020 (Scenarios 3-5). If the DOE trends prove to be more accurate, California's real GSP will be over $80 billion lower in 2020 with over half a million fewer jobs, and a reduction in cumulative state income over the period 2009-2020 totaling over $500 billion. The effect of AB 32 in Scenario 3 (adding AB 32 with 12 percent RPS) is to mitigate these adverse effects modestly.[4] This is consistent with CARB's own estimates suggesting that the diverse AB 32 package is largely growth-neutral, but both analyses rest on fairly pessimistic assumptions about renewable costs.

When more aggressive (1 percent per year) energy efficiency improvements are added (Scenario 6), the California economy is significantly shielded from higher energy price

[4] Note that price trends from DOE (2009) significantly exceed the sensitivity threshold for CPUC (June, 2009) assessments assessing cost effectiveness of a 33 percent RPS (Figure A13).

trends, as suggested by prior work on the stimulatory effect of efficiency.[5] When we allow for more cost effective renewable development, the savings from efficiency are channeled into higher growth for the economy. In this case, we see that complementary climate policies, such as energy efficiency and renewable deployment, provide both greater economic security against uncertain energy prices and new stimulus from more diversified demand.

At the same time, efficiency lowers trend energy requirements and the magnitude (and cost) of the required RPS deployment ("Net Short") falls with energy prices. Our RPS system costs are lower than those of CPUC, for example, because we have computed the Net Short endogenously with an economywide model and the result is smaller than their estimate of 76TW of new capacity. Even though we assume the same transmission cost increments ($8 billion for 20 percent RPS and $12 billion for 33 percent), we deem this system more affordable than their estimate of $112 billion.

Table 1: Estimates of Macroeconomic Impacts
(Differences from 2020 Baseline)

Scenario	2: DOE Price	3: AB 32/RPS 12	4: RPS 20	5: RPS 33	6: Plus EE
Real GSP (2008B$)	-84	-38	-28	-13	20
Jobs (thousands)	-626	-454	-381	-274	112
Electricity per Capita					
Demand (2008B$)	6,403	6,236	6,143	5,992	5,303
Cost (2008$B)	$1,089	$935	$891	$869	$716
Percent of Income	5%	4%	4%	4%	3%
Total Use (TWh)	315	306	302	294	261
New RPS Power (TWh)	64	61	59	56	40
Cost (2008B$)	$78	$74	$72	$68	$49

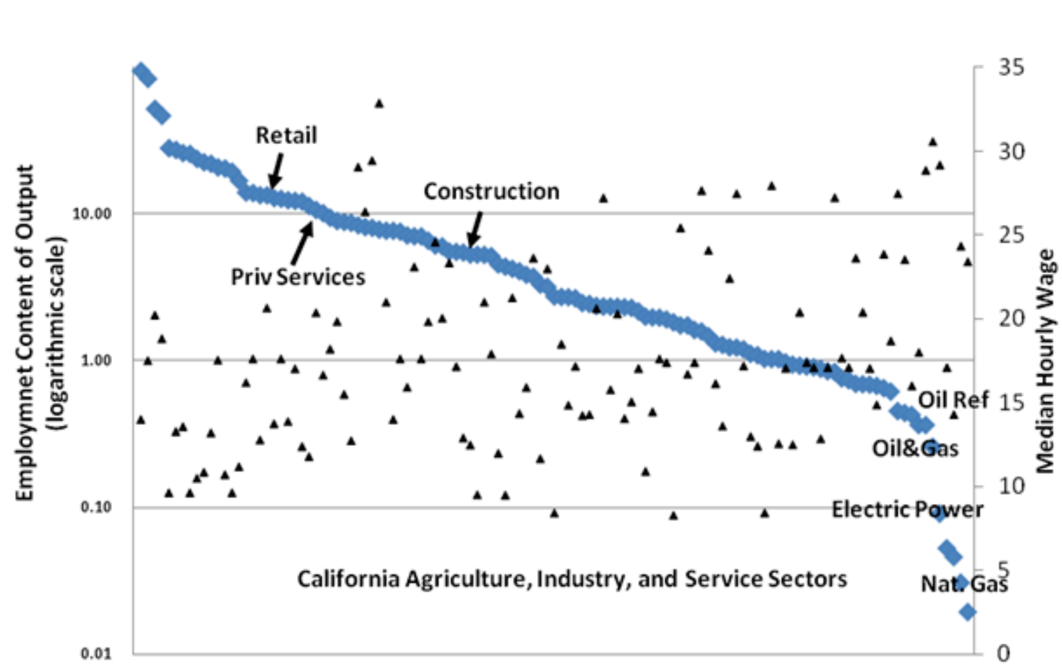
Source: Author estimates from the BEAR model.

The employment impacts above are worthy of more discussion. Job losses are much greater in percentage terms than GSP losses in each scenario. The reason for this is

[5] Roland-Holst (2008). In this study, California was shown to create over 1.4 million additional jobs as a result of savings on electricity use. In an environment like that being considered, where energy prices are much higher, the stimulatory effect of energy savings is significantly greater.

that, at the margin, a dollar moving from the carbon fuel supply chain to more conventional household and enterprise spending generates much more employment. Households, for example, would allocate 2 percent less of their income to electricity in Scenario 6, and these savings would be diverted to other customary expenditures. As ***Figure 31*** makes clear, carbon fuels and other conventional energy are among the least job intensive activities in the state economy. Consumers, by contrast, spend over two-thirds of their income on services, which generate 10-50 times as many jobs per million dollars of demand as carbon fuels.[6]

Figure 31: Employment Intensity and Average Wages by Sector (2002)



Source: Author estimates from BEA, IMPLAN, and BLS data.

Simply put, if energy prices rise, enterprises and households have to take a dollar away from labor and labor-intensive goods and services and spend it on this essential, but capital and import intensive commodity, net in-state demand and job creation, are reduced, dollar for dollar.

[6] This difference in labor intensity also explains how California's legacy of energy efficiency has created more than 1.4 million additional jobs over the last 30 years.

Another issue raised in the latest RETI report is dramatic reductions in the market cost of PV panels. This can be expected to have two important effects on the RPS, and may be quite significant in light of these sharp cost reductions. Firstly, project costs for PV based RETI renewables will decline appreciably. Secondly, sharp price declines in PV prices will accelerate residential adoption and thereby reduce the Net Short and concomitant RPS requirement. To assess the significance of this, we have reproduced Scenarios 2-6 with 40 percent lower PV prices.

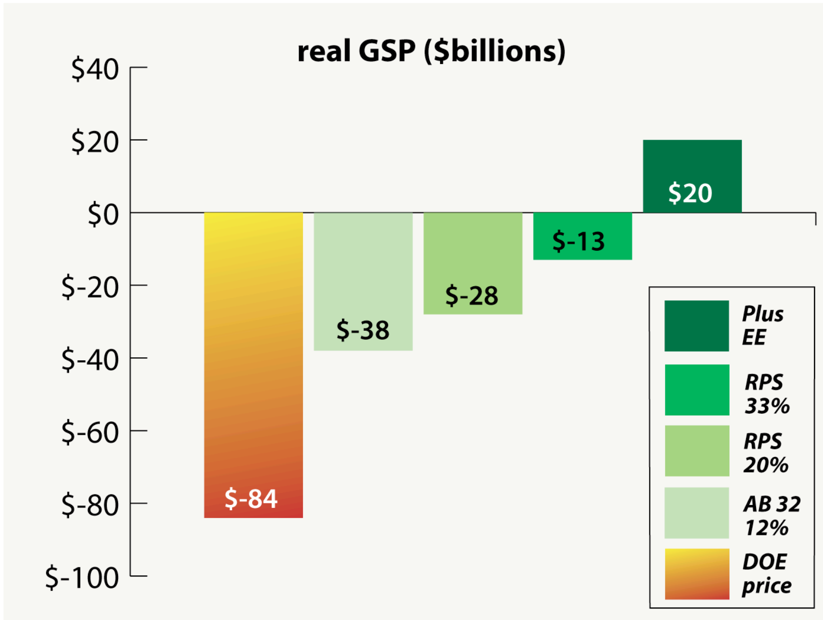
The basic stimulus patterns arising from AB 32 and the RPS stages are broadly comparable, but of course significantly lower PV prices increase these benefits by reducing the costs of mandated commitments and acceleration of private solar adoption. A few more points are noteworthy, however. Firstly, accelerated residential PV further reduces the Net Short via greater “privatization” of energy supply via distributed adoption. More intensive private adoption displaces demand for utility-based electricity, lowering the Net Short and reducing new RPS deployment costs to less than one quarter of those projected by CPUC. Finally, the Net Short under this scheme would put all of the new RPS capacity requirement well within the scope of assets inside California.

Table 2: Low PV Scenarios

Scenario	2: DOE Price	3: AB 32/ RPS 12	4: RPS 20	5: RPS 33	6: Plus EE
Real GSP (2008B$)	-84	-38	-27	-11	23
Jobs (thousands)	-626	-454	-362	-247	129
Electricity per Capita					
Demand (2008B$)	6,403	6,236	6,284	6,358	4,507
Cost (2008$B)	$1,089	$935	$846	$782	$716
Percent of Income	5%	4%	4%	4%	3%
Total Use (TWh)	315	306	309	312	221
New RPS Power (TWh)	64	61	62	63	24
Cost (2008B$)	$78	$74	$75	$77	$30

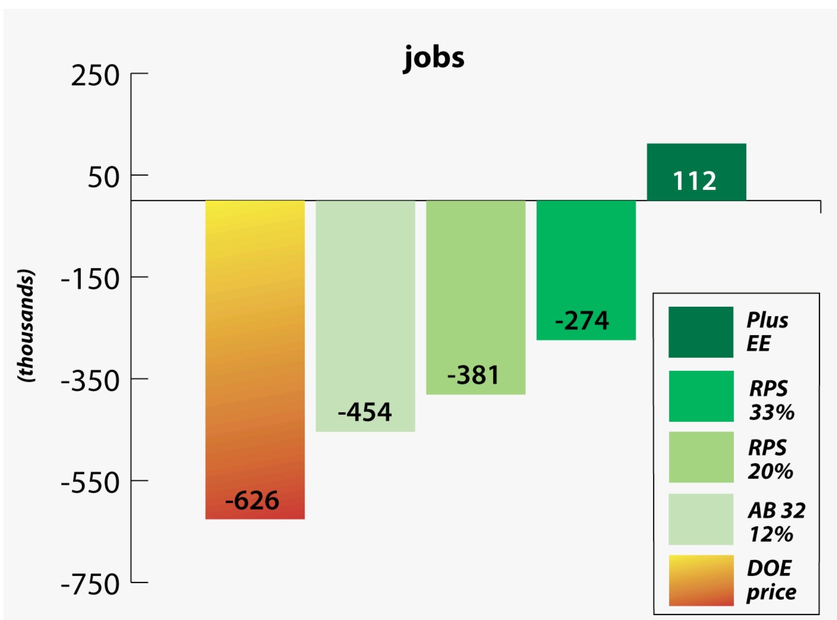
Sources: Author estimates from RETI, CPUC, DOE, and data cited in annex. Note: Costs do not include residential adoption. For capacity cost, we assume CPUC estimate of $12 billion transmission cost increment in all cases.

Figure 32: Climate Policy Protects the Economy & Promotes Growth
(Differences from 2020 Baseline, Real GDP 2008B$)



Source: Author estimates.

Figure 33: Climate Policy Protects the Economy & Promotes Growth
(Differences from 2020 Baseline, Employment in thousands)



Source: Author estimates.

5 Description 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 34 and 35*** 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.[7] 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 20 activity sectors and ten households aggregated from the original California SAM. The equations of the model are completely documented elsewhere (Roland-Holst: 2008), and for the present we only discuss its salient structural components.

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

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

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

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

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.[8] The result is a single economy model calibrated over the fifteen-year time path from 2005 to 2020.[9] Using the very detailed accounts of the California SAM, we include the following in the present model:

5.1.1 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.

In each period, the supply of primary factors — capital, land, and labor — is usually predetermined.[10] 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.[11]

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

5.1.2 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

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

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

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

[11] 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.

demand for the other commodities, the price of saving being set arbitrarily equal to the average price of consumer goods.

The government collects income taxes, indirect taxes on intermediate inputs, outputs and consumer expenditures. The default closure of the model assumes that the government deficit/saving is exogenously specified.[12] 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.

5.1.3 Trade

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

5.1.4 Dynamic Features and Calibration

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

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

5.1.5 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.

5.1.6 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.

5.1.7 Dynamic Calibration

The model is calibrated on exogenous growth rates of population, labor force, and GDP. In the so-called Baseline scenario, the dynamics are calibrated in each region by imposing the assumption of a balanced growth path. This implies that the ratio between labor and capital (in efficiency units) is held constant over time.[13] When alternative scenarios around the baseline are simulated, the technical efficiency parameter is held constant, and the growth of capital is endogenously determined by the saving/ investment relation.

[13]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.

Figure 34: Component Structure of the Modeling Facility

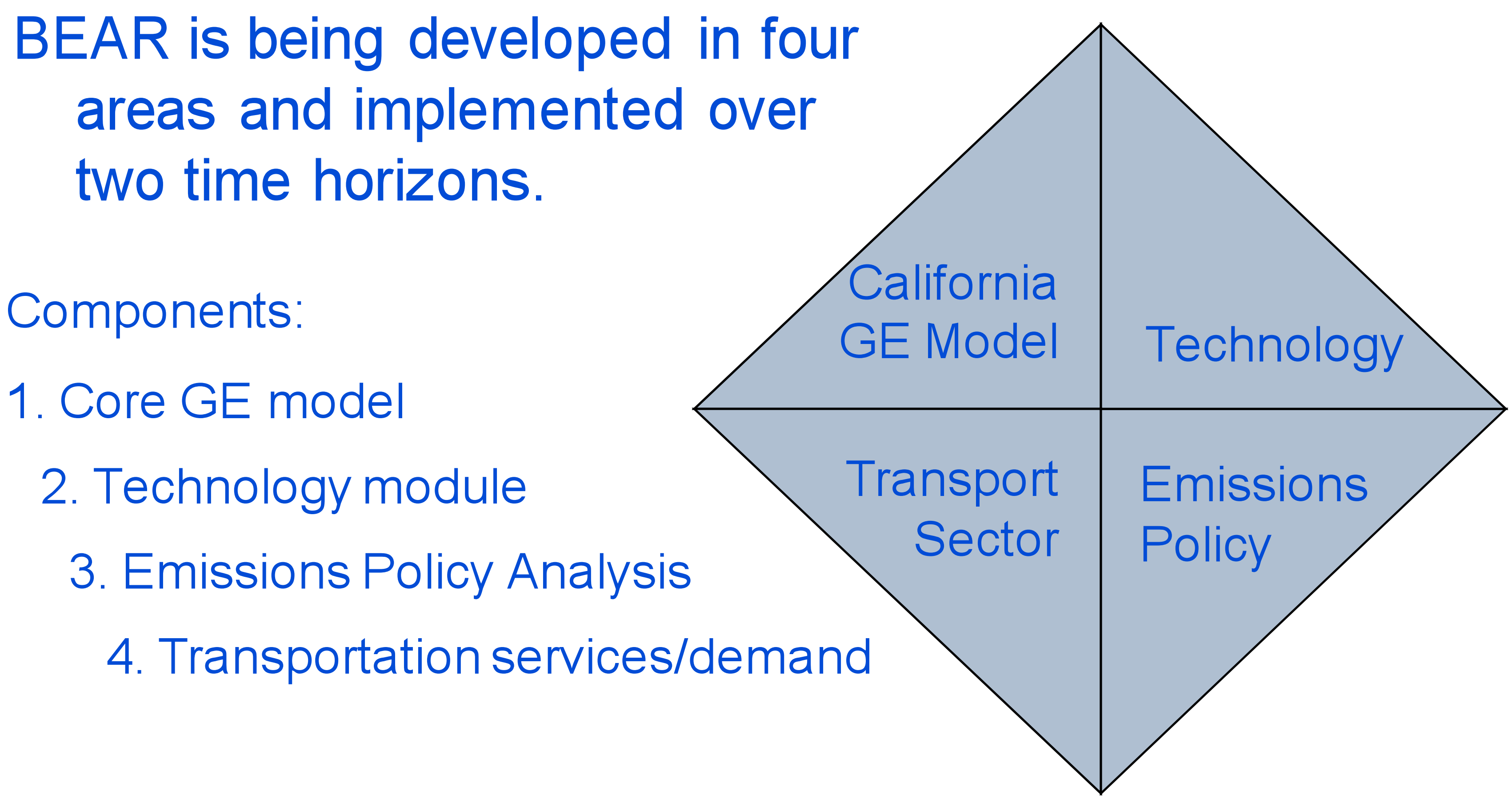
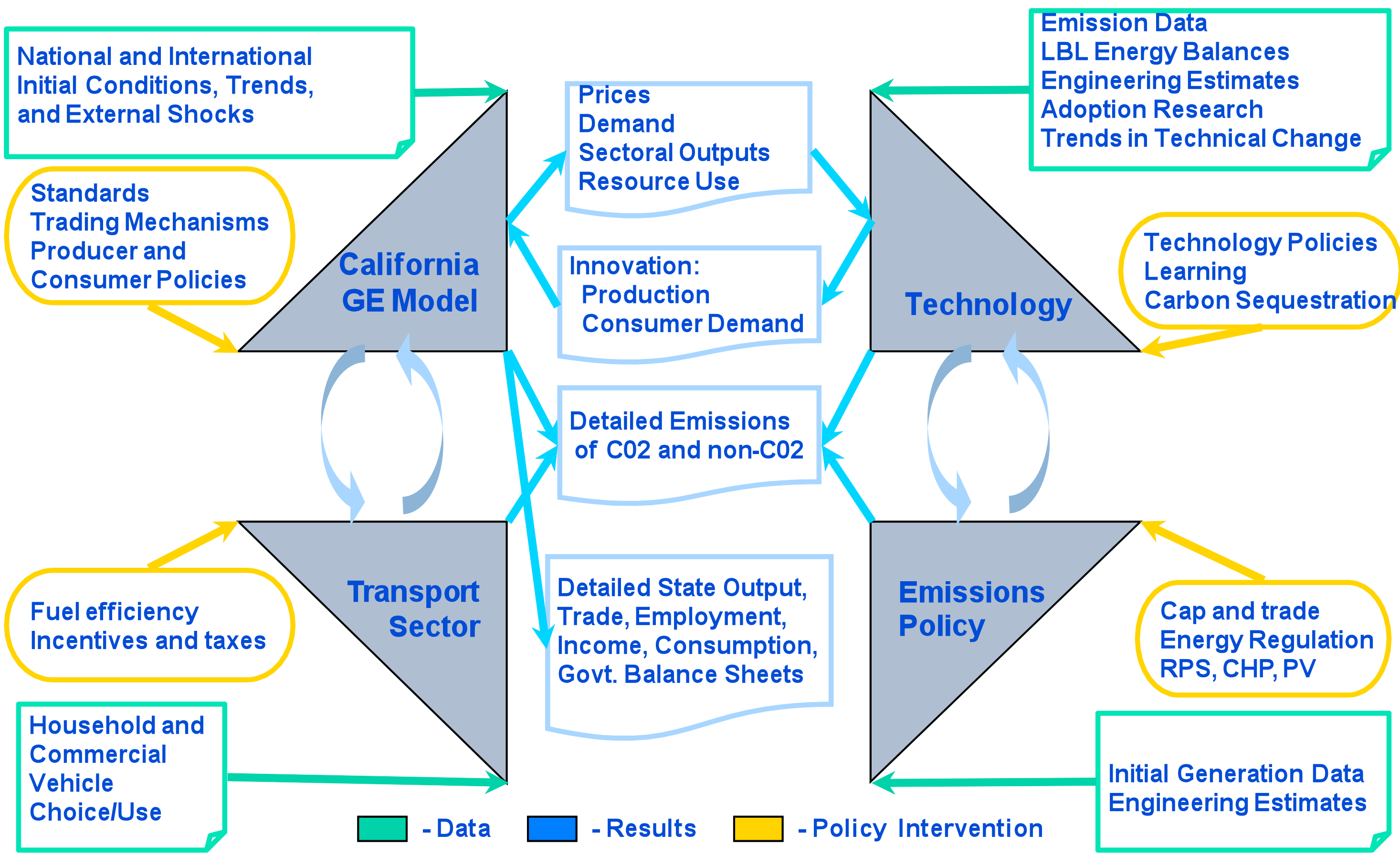


Figure 35: Schematic Linkage between Model Components



5.1.8 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.[14] 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. In some of the policy simulations we evaluate sectoral emission reduction scenarios, using specific cost and emission reduction factors, based on our earlier analysis (Hanemann and Farrell: 2006).

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

Table 3: 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
8.	Carbon Dioxide (CO_2)	
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

The model has the capacity to track 13 categories of individual pollutants and consolidated emission indexes, each of which is listed in ***Table 3***. Our focus in the current study is the emission of CO2 and other greenhouse gases, but the other effluents are of relevance to a variety of environmental policy issues. For more detail, please consult the full model documentation.

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

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7 Annex 1 – Renewable Cost Estimates

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

Table 4: Data and Assumptions for Renewable Cost

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

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

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

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

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

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

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

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

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

Annualized capital costs (ACC) are thus

$$ACC = CC \times CRF$$

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

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

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

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

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

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

Fuel costs can be calculated with the following formula

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

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

8 Annex 2 - AB 32 Measures Recommended and Under Evaluation

Recommended Greenhouse Gas Reduction Measures						
Measure #	**MEASURE DESCRIPTION**	**REDUCTION ($MMTCO_2E$ in 2020)**	**COST ($Millions)**	**SAVINGS ($Millions)**	**Comments on Costs of Major Measures above 1% of total cost**	**Comments on Savings of Major Measures above 1% of total Savings**
					($ million) unless noted	**($ million) unless noted**
	Transportation					
T-1	Pavley I Light-Duty Vehicle GHG Standards	31.7	1,372	11,142	Fleetwide aggregate cost per vehicle of $33-$1,910, 2009-2020. Approximately 1.3 million vehicles per year; annualized over 16-19 years = $1,236; times 1.10 CPI = 1,372	3 billion gallons at $3.67 per gallon = $11,142
	Pavley II - Light-Duty Vehicle GHG Standards		594	1,609	$2,010 cost per vehicle	438 million gallons at $3.67 per gallon = $1,609
T-2	Low Carbon Fuel Standard	16.5	(11,000)	(11,000)		
T-3	Low Friction Oil	4.8	520	954	$20 per vehicle O&M for 26 million vehicles = $520	260 million gallons at $3.67 per gallon= $954
	Tire Pressure Program		49	69		
	Tire Tread Program (Low resistance)		0.6	119.7		
	Other Efficiency (Cool Paints)		360	370	$250 capital costs per vehicle annualized over 14 years = $26 per vehicle, approximately 14 million vehicles = $360	101 million gallons at $3.67 = $370

T-4	Ship Electrification at Ports	0.2	0	0		
T-5	Goods Movement Efficiency Measures	3.5				
	Vessel Speed Reduction		0	86	Need explanation	
	Other Efficiency Measures		0	0		
T-6	Heavy-Duty Vehicle GHG Emission Reduction (Aerodynamic Efficiency)	1.4	1,136	973	$12,000 capital cost per truck annualized over 10 years = $1,600 per truck; 730,000 trucks = $1,136	265 million gallons of diesel at $3.68 per gallon = $973
T-7	Medium and Heavy-duty Vehicle Hybridization	0.5	93	163		
T-8	Heavy-Duty Engine Efficiency	0.6	26	133		
T-9	Local Government Actions and Targets	2.0	200	858	$100 per ton of CO2 reduced = $200	234 million gallons at $3.67 per gallon = $858
T-10	High Speed Rail	1.0	0	0		
	Building and Appliance Energy Efficiency and Conservation					
E-1	Electricity Reduction Program 32,000 GWH reduced	15.2	1,809	4,925	Cost of $119 per ton of CO2 reduced = $1,809	Savings of $324 per ton of CO2 reduced = $4,925
	Utility Energy Efficiency Programs					
	Building and Appliance Standards					
	Additional Efficiency and Conservation					
E-2	Increase Combined Heat and Power Use by 30,000 GWh	6.9	362	1,673	$5,560 capital cost annualized over 30 years = $362 million.	32,000 MWh at $86 per MWh = $2781savings; natural gas consumed for CHP 139,493,000 MMBTU at $7.94 per MMBTU = $1,107 cost. Net savings = $1,673
CR-1	Natural Gas Reduction Programs (800 Million Therms saved)	4.2	420	640	$100 per ton of CO2 reduced = $420	800 million at $0.80/therm $640

	Utility Energy Efficiency Programs					
	Building and Appliance Standards					
	Additional Efficiency and Conservation					
	Renewable Energy					
E-3	RPS (33%)	21.7	3,206	1,650	Cost of $274 per ton from CPUC/E3 modeling	Savings of $141 per ton from CPUC/E3 modeling
E-4	California Solar Programs (3000 MW Installation)	2.1	0	0		
CR-2	Solar Water Heaters (AB 1470 goal)	0.1	0	0		
	High GWP Measures					
H-1	MVACS: Reduction of Refrigerant from DIY Servicing	0.5	60.00	0.00		
H-2	SF6 Limits in Non-Utility and Non-Semiconductor Applications	0.3	0.14	0.00		
H-3	High GWP Reduction in Semiconductor Manufacturing	0.15	2.60	0.00		
H-4	Limit High GWP Use in Consumer Products	0.25	0.06	0.23	$450K Capital Cost for 10 years	
H-5	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	$6 capital cost annualized over 16 years = $0.78; + O&M cost of $220 = $220.78	
	Refrigerant Recovery from Decommissioned Refrigerated Shipping Containers					
	Enforcement of Federal Ban on Refrigerant Release During Service or Dismantling of MVACS					

H-6	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				
RW-1	Landfill Methane Capture	1.0	0.5	0	
A-1	Methane Capture at Large Dairies	1.0	156	0	$4 capital costs, 330 dairies, annualized over 20 years = $106; + O&M cost of $49.5 = $156
F-1	Sustainable Forest Target	5.0	50	0	
W-1	Water Use Efficiency	1.4	-	-	
W-2	Water Recycling	0.3	-	-	
W-3	Pumping and Treatment Efficiency	2.0	-	-	
W-4	Reuse Urban Runoff	0.2	-	-	
W-5	Increase Renewable Energy Production	0.9	-	-	
	Total Recommended Measures	***135.5***	***10,771***	***25,394***	

Measures Under Evaluation					
MEASURE DESCRIPTION	**REDUCTION ($MMTCO_2E$)**	**COST ($Millions)**	**SAVINGS ($Millions)**	**Comments on Costs of Major Measures above 1% of total cost**	**Comments on Savings of Major Measures above 1% of total Savings**
				($ million) unless noted	**($ million) unless noted**
Transportation					
Feebates for New Vehicles	4.0	594	1,609	Same as Pavley II	Same as Pavley II
Incentives to Reduce VMT	2.0	200	858	$100 per ton of CO2 reduced = $200	234 million gallons at $3.67 per gallon = $858
Subtotal	**6.0**	**794**	**2,467**		
Electricity					
Energy Efficiency (8000 additional to 32,000 GWh Reduced Demand)	3.8	678	1,231	Cost of $179 per ton of CO2 reduced = $678	Savings of $324 per ton of CO2 reduced = $1,231
Calif. Solar Initiative (including New Solar Homes Partnership) Additional 2000MW	1.4	1,348	339	$16,800 capital cost annualized over 20 years = $1,348	3,000,000 MWh at $113.12 per MWh = $339.37
Reduce Coal Generation by 12,800 GWh	8.5	850	0		
Subtotal	**13.7**	**2876**	**1571**		
Natural Gas					
Energy Efficiency (200 million Therms Reduced)	1	179	324	Cost of $179 per ton of CO2 reduced = $179	200 million therms at $0.80 = $324
Residential Solar Water Heater Installation (beyond AB 1470 goal) 2 million	1.2	0	0		
Subtotal	**2.2**	**179**	**324**		
Industrial					
Energy Efficiency and C0-benefits Audits	TBD			$250K for 54 facilities	
Carbon Intensity Standard for	1.9	19.4	22.8		

Calif. Cement Manufacturers					
Carbon Intensity Standard for Concrete Batch Plants	3.1	0.0	0.0		
Waste Reduction in Concrete Use	1.1	55.0	82.5		
Refinery Energy Efficiency Process Improvement	3.7	71.0	454.0	$762 capital cost annualized over 20 years $61; + $10 O&M cost = $71	56,900,000 MMBtu at $7.98 per MMBtu = $454
Removal of Methane Exemption from Existing Refinery Regulations	0.03	5.0	0.0	$5 O&M cost per year	
Oil and Gas Extraction GHG Emission Reduction	2.0	101.5	276.2	$357 capital cost annualized over 20 years = $23; + $23 O&M cost; + $55 electricity cost = 101.5	33,417,000 MMBtu at $7.98 per MMBtu = $267; + $8.75 O&M Savings = 276.2
GHG Leak Reduction from Oil and Gas Transmission	1.0	19.0	34.2		
Industrial Boiler Efficiency	1.0	22.9	149.7		
Stationary Internal Combustion Engine Electrification	0.5	17.9	30.6		
Glass Manufacturing Efficiency	0.1	14.6	8.5		
Off-Road Equipment	TBD				
Subtotal	**14**	**326**	**1,059**		
Total of Measures Under Evaluation	**36**	**4175**	**5421**		
Total	**172**	**14,947**	**30,815**	**Net costs of**	**(15,868)**