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Energy Pathways for the California Economy

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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 global economy. In addition to disseminating original research findings, these studies are intended to contribute to policy dialog and public awareness about environment-economy linkages and sustainable growth. All opinions expressed here are those of the author and should not be attributed to their affiliated institutions.

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Executive Summary

Over the last four years, California has taken unprecedented initiative to cap and reduce greenhouse gas emissions. Governor Arnold Schwarzenegger signed Executive Order #S-3-05 (Schwarzenegger 2005), calling for a 30 percent reduction below business-as-usual of greenhouse gas emissions by 2020 and a long term, lower carbon future with emissions 80 percent below 1990 levels by 2050. In September 2006, the California legislature passed and Governor Schwarzenegger signed into law the Global Warming Solutions Act (AB 32), which mandates a first-in-the-nation limit on emissions that cause global warming. To promote implementation of its path breaking climate strategy, in December 2008, the California Air Resources Board (CARB) adopted the "AB 32 Climate Change Scoping Plan" – a 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.

Now, as the state moves to implement its landmark plan, the world is in the grips of a global financial crisis, and Californians face an unprecedented multibillion-dollar state budget deficit. The short- and long-term implications of this state fiscal situation are daunting – some predict a dramatic exodus of businesses, loss of jobs and erosion of academic prowess.

Within this context, *Energy Pathways for the California Economy* evaluates the state's energy demand and supply horizons, and the economic impact of accelerating deployment of renewable energy resources and energy efficiency trends in California.

Top Findings

- From electricity to transportation, projecting status quo demand and supply horizons portends ever greater reliance on out-of-state fuel sources, and therefore greater exposure to fuel price volatility.
- Five alternative forecasting scenarios show that the faster and farther California can improve household and enterprise energy efficiency, while accelerating deployment of renewable energy resources, the faster the state economy will grow and create jobs. The most ambitious scenario (50 percent renewable energy; 1.5 percent annual efficiency increases) produces the largest number of additional jobs and income -- generating half a million new FTE jobs with over $100 billion in cumulative payrolls over 40 years.
- Renewable energy generation is more job-intensive than the traditional carbon fuel supply chain, captures more benefits within the state economy, and reduces our vulnerability to uncertain global energy markets.

Demand Horizons

California has made exemplary progress in demand-side management of electricity use; per capita energy use has remained flat for decades while rising over 60% in the rest of the country. For example, the California Energy Commission (CEC) estimates that Californians saved $40 billion in 2006 due to increases in space heating efficiency while air conditioning efficiency improvements saved $30 billion.

Nevertheless, the explosive growth in population, inland development, home size, rate of installation and total number of operating air conditions, has driven total electricity consumption even higher.

From 1976 to 2007, the average size of new homes grew 55 percent, from 1,560 to 2,390 square feet (CEC 2008) and a greater number of new homes are being built with central air conditioning. The increase in total number of operating air conditioners has increased total peak demand attributed to them from five percent in 1976 to over 24 percent in 2006 (CEC 2008). And the rate of installation in new homes has skyrocketed from 25 percent in 1976 to 95 percent in 2007. On current trends, the CPUC estimates that total California electricity demand could double by the middle of this century.

Transportation

In California, transportation is the largest energy consumer. There are more motor vehicles registered here than any other state – over 28 million – and worker commute times are among the longest in country. Commuters consume the largest share of total vehicle fuel. Two-thirds of all the state's imported oil is used for transportation, and 58 percent of overall energy expenditures in California fuel transportation. According to California Energy Commission projections, transport fuel demand could double by 2050 or fall by 25%, depending on regulatory policies and fuel prices.

Supply Horizons

Petroleum

California produces one-tenth of the national share of crude oil production with drilling operations concentrated primarily in Kern County and the Los Angeles. Overall current production in California has been steadily declining as no new terrestrial oil reserves have been discovered in the past two decades.

California is a top petroleum refiner with the third largest petroleum refining capacity in the U.S. producing over two million barrels a day. Refinery capacity has been increasing in California since 2000, with an average growth rate of .5 percent or about half as fast as the U.S.[1]

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[1] California's strict environmental standards are the primary constraint on refinery expansion.

With declining in-state production and Alaskan supply, California refineries are increasingly reliant on imports, with leading suppliers like Saudi Arabia and Ecuador making up 40 percent of offshore refining supply.

California fuel prices are significantly higher than the U.S. national average, and motorists are particularly vulnerable to short-term price spikes. Declining in-state production of petroleum and growing reliance on foreign crude only increases the state's vulnerability to external price and supply shocks.

Coal

Coal plays a small role in California's electricity sector – with only a few operating small coal fired power plants in the state due to strict emissions standards and restrictions on the use of coal fired generation within its boundaries. While low coal reliance is consistent with California's rigorous air quality standards, it narrows the state's options among traditional carbon fuels.

Natural Gas

California has substantial natural gas depositions in geological basins in the Central Valley and Pacific Coast, but production accounts for less than two percent of total annual U.S. production and meets less than one-fifth of state demand.

Historically, state natural gas supplies have remained relatively stable, with increasing supply from Rocky Mountains and nearly a dozen storage facilities to smooth supply fluctuations. Recently, however, but Washington and Oregon's rising natural gas demand has forced California to compete for a dwindling regional supply.

Although California leads the nation in hydroelectric and other renewable power generation like solar and wind, the state still relies significantly on natural gas and imports for its electricity. In fact, California imports more electricity than any other state, including hydroelectric-based power from the Pacific Northwest and coal and natural gas-fired power from the Southwest. With greater demand and limited domestic production, natural gas prices have been continuously rising, with particularly steep increases since 2000.

California's natural gas prices are higher than other states in the region. Following historic prices trends and with growing demand from the electricity sector, natural gas prices are forecasted to continue rising in coming years.

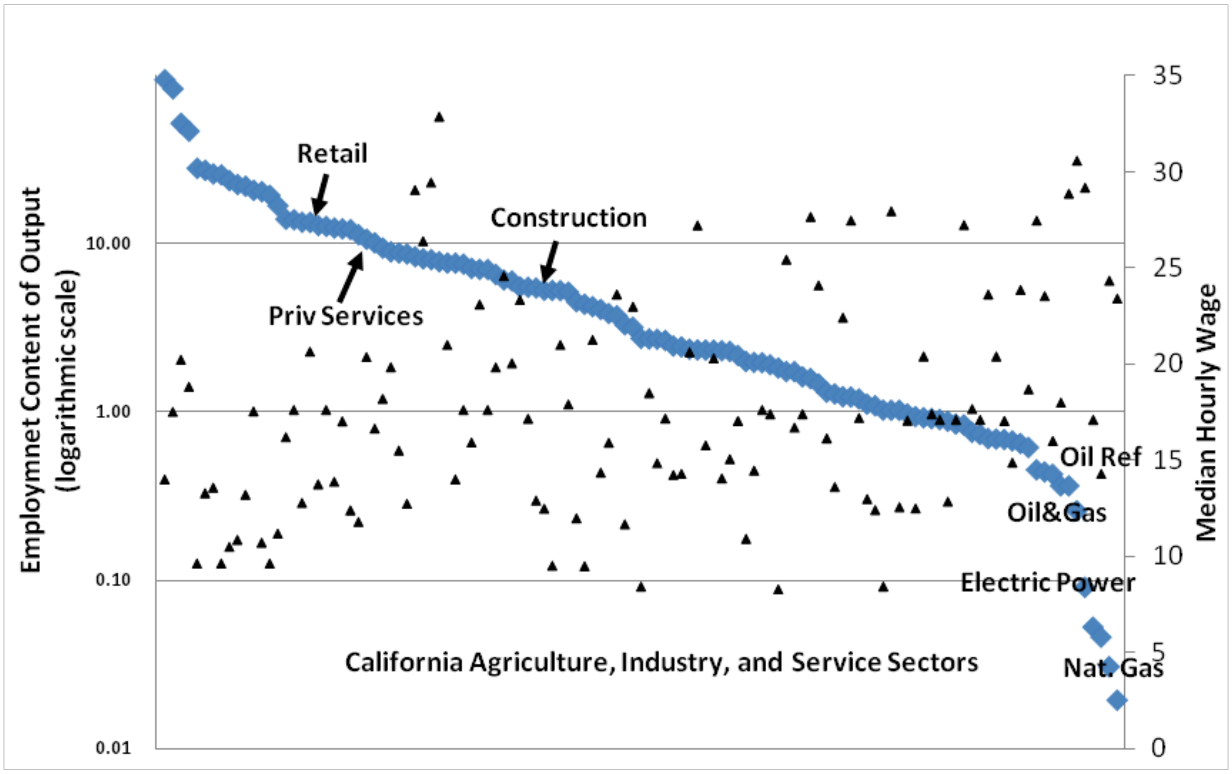
Demand & Supply Horizon Core Findings

Overall, from electricity to transportation, greater reliance on fuel imports means California will become even more vulnerable to external price and supply shocks.

The carbon fuel supply is among the very least employment intensive economic activities, even before considering how these expenditures leak outside the state and national economies to foreign energy sources.

Energy efficiency saves money and stimulates the economy through expenditure shifting, away from import-dependent carbon fuels and toward employment intensive in-state goods and services. Comparing the employment content of output across over a hundred different economic activities (Figure 1) reveals this expenditure shifting can have a dramatic net effect on job creation. The disparity between job growth from a dollar spent on fossil fuels and one spent on services is so great that a logarithmic scale is needed to display it. **Simply put, a dollar saved on traditional energy is a dollar earned by 10-100 times as many new workers.**

Figure 1: Employment Intensity and Median Wage by Sector
(labor/output ratios for 124 primary, secondary, and tertiary activities)



Source: California Employment Development Department dataset.

Economic Impact of Increased Renewable Energy and Efficiency

Methodology

For the last three years, University of California at Berkeley's Center for Energy, Resources, and Economic Sustainability (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.

BEAR is a 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 and over time, of new economic and technology policies.

Using BEAR, we evaluated the economy-wide impacts of five new energy scenarios, three degrees of Renewable Portfolio Standards (20 percent, 33 percent, and 50 percent) and new energy (NE) efficiency (with RPS50) improvements of 1.0 percent and 1.5 percent annually.

Renewable & Energy Efficiency Core Findings

- Renewable fuel generation is more job intensive and less price volatile than traditional carbon fuel supplies.
- Modeling five scenarios shows that the faster and farther California improves the efficiency of household and enterprise energy use while accelerating the deployment of renewable energy resources, the faster the state economy will grow and more jobs will be created. The most ambitious scenario (50 percent renewable fuels; 1.5 percent efficiency increase) produces the greatest number of jobs and largest payroll -- generating half a million additional jobs with over $100 billion in cumulative payrolls over 40 years.
- Employment creation outweighs employment reduction in every scenario.

Table 1: Employment Results
(change from Baseline in 2050, thousands)

	RPS20	RPS33	RPS50	NE1.0	NE1.5
Agriculture	0.154	0.353	0.611	9.686	14.645
Oil and Gas	-2.203	-5.062	-8.789	-46.004	-62.058
Electricity	-0.183	-0.433	-0.777	-17.642	-23.807
Renewables	10.184	23.429	40.730	6.061	5.301
Natural Gas Dist.	0.035	0.079	0.138	-17.051	-22.865
Construction	1.701	3.925	6.847	112.404	167.689
Food Processing	0.047	0.107	0.183	9.120	15.312
Oil Refining	-0.120	-0.276	-0.480	-10.650	-14.336
Chemicals	0.242	0.555	0.960	4.126	6.238
Pharmaceutical	0.063	0.145	0.253	-0.288	-0.222
Cement	-0.134	-0.308	-0.535	3.658	5.636
Metals	1.017	2.326	4.019	-2.640	-3.270
Machinery	2.070	4.761	8.276	-60.240	-86.992
Elec App and Semi	5.021	11.514	19.955	4.207	5.164
Vehicles	0.044	0.099	0.171	1.352	2.652
Other Industry	-1.783	-4.108	-7.156	2.193	7.045
Wholesale Trade	0.055	0.120	0.199	10.489	12.526
Retail Trade	1.202	2.745	4.738	57.037	73.017
Transport Serv	-2.077	-4.773	-8.291	23.994	38.778
Other Private Serv	-0.999	-2.373	-4.266	218.095	280.295
Total	14.335	32.826	56.785	307.907	420.747
New Jobs	21.834	50.159	87.078	462.422	634.298
Job Reduction	-7.499	-17.333	-30.293	-154.516	-213.551

Note: Employment results given in Table 1 for the five scenarios are stated in thousands of jobs against Baseline levels. All results are differences against a dynamic (2008-2050) baseline in which all sectors of the California economy grow.

- Over the time period we consider, the renewables industry increases in-state employment to about half the size of California's biotech sector, but meanwhile up to twice as many jobs are created in upstream and downstream sectors.
- When renewables are the primary new energy strategy, employment growth is concentrated in that sector, in electronics, and in machinery.
- Depending on the degree of renewable deployment, direct job creation would be between 10,000 and 40,000 FTE jobs, though our estimates suggest that total "green jobs" attributable to RPS (including up and downstream) would be closer to column totals, or 14-57,000 jobs for California. Even these figures are net of employment reductions against the baseline. Adding up the new jobs only, green job creation becomes 22-87,000.

- **By comparison with renewables alone (RPS50), integrating energy efficiency measures increases statewide job benefits almost tenfold.** Employment gains are more widespread, particularly in construction and services, with the former responding to new building standards and the latter benefiting from expenditure diversion. Note, however, that the energy efficiency component moderates the growth of RPS, since efficiency applies both to traditional and new energy sources.

- In terms of relative income effects, renewables deployment generates 2-3 times as many new payrolls as it displaces in traditional carbon fuel supply chains.
- Renewables generate jobs with **relatively high wages** and obvious new technology appeal. Even when a significant portion of green tech manufacturing is outsourced (we assume about 25 percent of value), California still captures significant employment and payroll benefits from greater renewable deployment.
- In addition to direct renewable technology sector ("green-collar") employment, significant indirect income benefits travel up and down supply chains, increasing payrolls in construction, manufacturing, and services.
- These jobs, particularly those in services related to marketing, installation, and maintenance, cannot be outsourced, and are a lasting dividend accruing to the large domestic market adopting these new technologies.
- Finally, household energy efficiency savings translate, via expenditure shifting, into even greater income growth for consumer sectors, including more diverse, bedrock in-state employment in food, services, etc.

Table 2: Cumulative Income Results
(change from Baseline over 2010-2050, in 2007 USD millions)

	RPS20	RPS33	RPS50	NE1.0	NE1.5
Agriculture	34	77	134	1,767	2,554
Oil and Gas	-575	-1,322	-2,295	-10,012	-13,858
Electricity	-87	-206	-370	-5,742	-7,984
Renewables	3,444	7,924	13,774	2,203	1,952
Natural Gas Dist.	11	25	43	-4,513	-6,264
Construction	41	95	165	5,762	8,529
Food Processing	12	28	48	2,732	4,068
Oil Refining	-41	-94	-164	-2,803	-3,906
Chemicals	71	162	280	1,303	1,872
Pharmaceutical	26	59	102	0	-16
Cement	-13	-31	-54	169	259
Metals	224	513	886	41	29
Machinery	548	1,262	2,196	-9,311	-13,649
Elec App and Semi	1,765	4,046	7,005	2,173	2,466
Vehicles	12	27	46	604	928
Other Industry	-407	-938	-1,633	2,085	3,270
Wholesale Trade	10	21	33	2,187	2,650
Retail Trade	226	515	885	9,218	11,809
Transport Serv	-517	-1,187	-2,061	4,906	7,966
Other Private Serv	-374	-886	-1,586	44,834	58,529
Total	4,409	10,089	17,436	47,604	61,204
New Payroll	6,424	14,753	25,600	79,986	106,882
Reduction	-2,014	-4,664	-8,164	-32,382	-45,678
New/Old	3.2	3.2	3.1	2.5	2.3

Conclusion

Our economic assessment strongly supports the notion that a new California energy agenda, emphasizing efficiency, renewables, and infrastructure, can be a potent catalyst for economic growth in both the short- and long-term.

We find that dramatically increasing energy efficiency and renewable energy's share of electricity generation can be a powerful source of job creation, and that this employment is diverse and attractive in terms of average skill content and wages.

It is clear from this research that "green job" creation goes far beyond "green collar jobs". That is, green job creation is much more widespread than direct employment in green technology sectors. This fact is often ignored in the enthusiasm surrounding green/clean energy. Although direct employment in such new energy technologies may be significant, it is not the primary source of job creation arising from greater energy efficiency or renewable development. Indirect employment benefits from these innovation trends are much greater, more diverse and income-equitable, and in-state job retention is much higher. In addition, most of these jobs are in the services bedrock of the state's labor force and cannot be outsourced.

Energy efficiency measures offer much more potent growth leverage to the economy than renewable energy deployment alone. Only a fraction of the employment benefits of a new energy agenda are on the supply-side, as our results demonstrate that energy efficiency measures offer strong multiplier effects through expenditure shifting.

As California looks to a future of dramatically increasing energy demand, dwindling traditional energy supplies, and greater fuel price volatility, it is clear from this analysis that pursuing an aggressive schedule of renewable fuel and energy efficiency deployment now is the most prudent economic course of action if we are to avert even greater financial crises in the future.

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Energy Pathways for the California Economy

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1. Introduction

Higher material living standards, and the economic growth that delivers them, is a nearly universal aspiration, and one that the California economy has long excelled in fulfilling. Today, however, we have entered an age of new uncertainty about the state's capacity to sustain ever higher real per capita output and personal incomes. Beyond the current economic downturn, a recession unlikely to last more than a few years, trends of resource scarcity and climate change extend well into this century. In a separate study, we estimated that California faces potential losses that would seriously undermine economic growth unless action is taken.[3] At the same time that we make defensive investments to limit the damages from climate change already under way, we must transition to a lower carbon future to offset risks from further temperature increases. Finally, we need to reduce dependence on increasingly scarce carbon fuels, particular from import sources whose prices are subject to forces outside our control.

These challenges are very diverse, yet they have essential commonalities. As Figure 2 indicates, the overwhelming majority of greenhouse gases (GHG) arise from one activity, consuming carbon-based energy. For this reason, understanding our climate future, as well as its economic implications, is to a significant extent synonymous with understanding our energy future. For California, this means understanding the complex interplay of energy demand,

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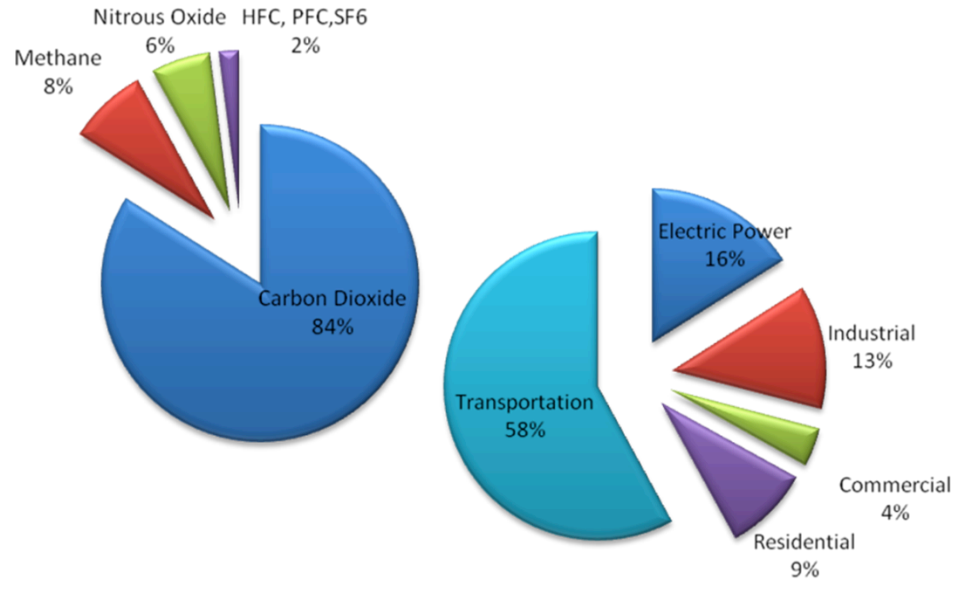
[3] See Kahrl and Roland-Holst: 2008.

supply, and market/technology linkages between the two. This report is intended to elucidate California's energy pathways to the future. We review an extensive body of existing evidence on patterns of the state's energy consumption and production, including official and independent projections of how these patterns might evolve under alternative futures for resource availability, market conditions, and policy regimes. We also discuss the state of California's energy transmission infrastructure and the prospects for development of a new generation of grid architecture. Dubbed the SuperGrid, this network would represent a mega-project on the scale of a TVA for the Digital Age. Finally, we present a new set of independent estimates of the economic growth effects of new energy scenarios for California, including strategies for deploying renewable energy and alternative energy efficiency programs.

Figure 2: California GHG Emissions by Source



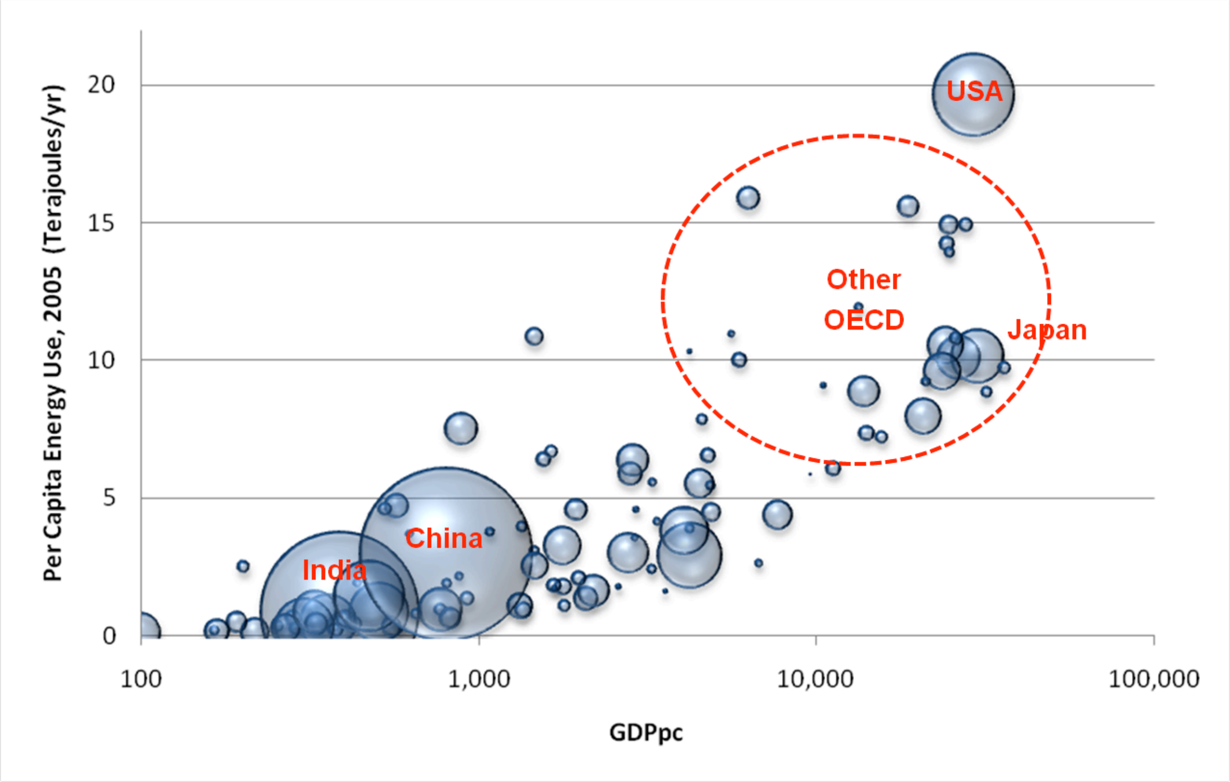
Source: CEC (2006)

2. Sustainable Economic Growth in an New Energy Economy

Energy and Growth

As the world's eighth largest economy and one it's most diverse, California's energy future offers many important examples to others, particularly higher income economies who wish to remain so. Generally speaking, an important insight from this and related work is that the general premise of an environment-growth tradeoff is fallacious, and with the right policy leadership, higher environmental standards are fully compatible with sustained economic growth. In California we have already proven this with the growth dividend we reaped from electricity efficiency.[4] Climate risk poses very diverse challenges but, because of the dominance of energy use in emissions, they are unified in a challenge to improve energy efficiency.

Figure 3: Energy and Income, by Country, Income, and Population (2005)



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[4] See Roland-Holst: 2008a, for detailed estimates.

Source: Author estimates from International Energy Agency and World Bank data. Bubble diameter is proportional to population

As Figure 3 vividly illustrates, energy use and prosperity go together, with (e.g.) per capita energy use in the United States over five times that in China or India. As the latter economies grow, their demographics suggest a challenging future for global energy availability. Even if this were not a commodity with adverse climate effects, energy efficiency would be a reasonable economic goal under such conditions. How far can we go in this direction? Again, Figure 3 is suggestive. Note that Japan, with roughly equal per capita income, consumes about half as much energy per person as the United States. Even discounting for less intensive residential life, much of this difference is a result of behavior regarding technology adoption and conservation practices. While U.S. living habits is not, and never will be, Japanese, this comparison demonstrates that efficiency levels can differ, and it is reasonable to ask what would be the economic consequences of significant reductions in U.S. per capita energy use.

Simply correlating income with energy use offers little insight into the fundamentals of energy dependence. In reality, the primary drivers of energy needs arise from two main sources: production structure and consumption patterns. To understand the latter, we have found that most economies experience a three-step transition in development from subsistence economies to modern, Organization for Economic and Co-Operation and Development (OECD) members. In the first stage, agriculture (primary) dominates the economy, succeeded by industry (secondary), and finally by services (tertiary) in a long established succession from subsistence to post-industrial societies. The implications of this for the past, present, and future of development and the climate are profound, as suggested by Figure 3. Here we see post-industrial societies on the right, with the highest per capita emissions, agrarian societies on the right, and emerging industrialists in the middle. Given the cumulative population of the latter two groups, the climate implications of further “progress” by conventional economic standards are ominous.

For the last 300 years, we have been using carbon fuel technologies to take us beyond this, passing through an Industrial Revolution to achieve living standards unimaginable by our ancestors. At the same time, however, we set the stage for today’s challenges, laying down 75 percent of the stock of GHG by 1950, before most of the world’s population even began to industrialize. With our miraculous energy fuels increasingly scarce, and half of humanity still living on less than $2/day, it is clear that we need a different economic growth model.

If you ask economic and energy experts where to look for answers, the vast majority will agree. Whether we are trying to overcome the dual challenges of climate risk and energy scarcity in California or China, the solution lies in technology innovation, diffusion, and adoption (IDA). The Promethean gift of carbon technology vaulted the western economies to unprecedented prosperity. So too can technology oversome limited natural endowments with ever greater productivity, conferring higher living standards at more sustainable rates of resource use. While the three stages of technological change (IDA) are always uncertain, we have learned to trust human ingenuity and commitment for solutions to our pressing problems. Now that we recognize the challenge of climate/energy sustainability, public and private resources can focus on overcoming it.

New Energy and Employment

“Green jobs” has become a mantra in both the energy policy dialogue and the venture technology community. New primary technology sectors do not come along very often, and when they do they usually animate significant public and private commitments, including support all along the R&D supply chain and new educational and training programs. Because of the scope of climate the climate challenge and the scale of the energy industry, it is clear that new energy, including both renewable supplies and new ways of using energy, will create the next break out technology sector. By revenue, energy is the world’s largest industry, and new energy can be to this sector what IT was to management, and biotech to healthcare – a family of innovations to revolutionize traditional practices around the world. For California, new energy can join these knowledge-intensive industries to once again establish new innovation at home and global technology standards for export leadership.

Having said this, it is important to recognize how such technologies will affect employment within the state. Job creation in the three main new energy innovation areas considered in this study, renewables, efficiency, and transmission is more complex than often imagined. First consider the energy supply technologies, renewables and transmission. The basic point about these sectors, already observed by several authors (e.g. Kammen et al: 2004) is that they are not particularly labor intensive, but more so than the traditional carbon fuels and their energy carriers (e.g. electricity). Relatively high current adoption costs also undermine the job creation benefits of energy efficiency. For these reasons, shifting supply toward renewables will occasion job growth, even for fixed total supply, but modestly. Green job expectations need to be better informed by the facts of technology employment. The technologies we are discussing create jobs in four phases:

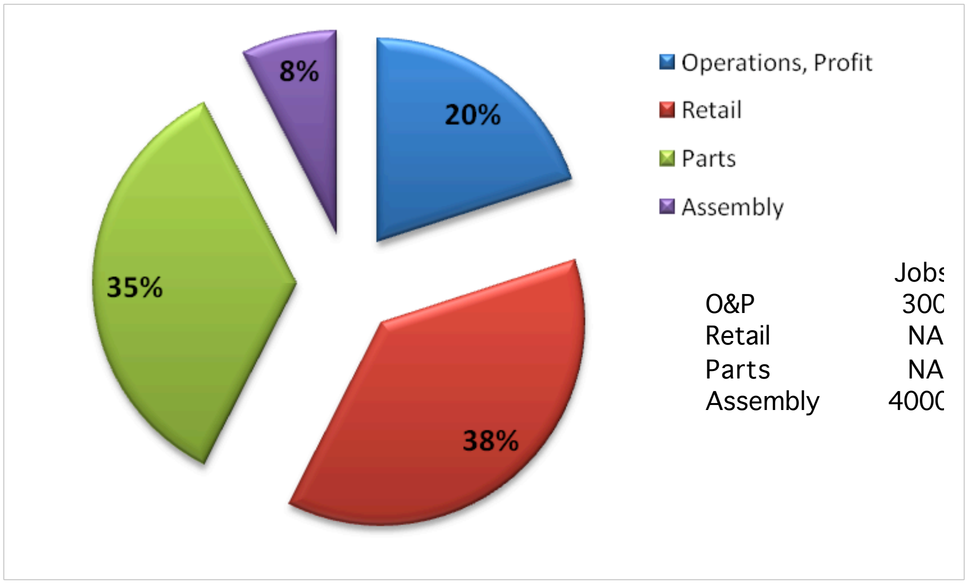
1. Technology research and development
2. Product fabrication
3. Marketing and adoption (installation, operation, and maintenance -- IOM)
4. Income effects on other expenditure

The first three of these job creation impacts is direct, and these can be called “green collar” jobs. The fourth impact is indirect, usually resulting from the economic dividend of energy efficiency. While these jobs are a result of new energy or the green economy, they are not “green collar” and are dispersed across all consumption and business expenditure categories. We shall discuss indirect green jobs later, but for the moment we focus on the three product cycle phases of direct, or “green collar,” jobs.

As a state with a reputation for technology leadership, California can be expected to capture a significant number of Phase 1 green jobs. Because of the very capital-intensive nature of technology R&D, these will have a big impact on the state labor market.

Phase 2 jobs are a different matter, and depend critically on the nature of the new energy product and its production technology. To the extent that this is a technical hardware project, we must acknowledge from experience with hardware IT that direct employment benefits within California will be limited. Realistically, electronic new energy technologies will probably be manufactured in traditional workshop economies like China. To the extent that the innovation is more information oriented, like the many energy process innovations being considered by Google, Apple, and other enterprises working on “Smart” energy use, job creation will more closely resemble software and biotech, with high rates of in-state retention for highly skilled workers that can be legitimately called “green collar.”

Figure 4: A Mouse Called Wanda
(percentage of sale price or retail value)



Finally, Phase 3 employment will have two components, management/marketing in domicile markets (i.e. where the company operations are located), and marketing/adoption in destination markets. Here again, other technology sectors offer guidance. A case in point is shown schematically in Figure 4, which displays value composition for a real-life computer mouse made by a prominent hardware firm (during product development, its name was Wanda). This mouse is fabricated in a Chinese assembly plant employing about 4,000 people, while the corporation employs about 300 people in its U.S. and European management. As the figure indicates, over 90 percent of Phase 2 jobs only capture 8 percent of the product's value. Components, made all over the world, take another 35 percent.

More significantly, 20 percent of value goes to management and stockholders, with former earning much higher salaries than do the 4,000 outsourced jobs. Finally, 38 percent of total value goes to workers and firms in destination markets. Wages here depend on the market, but for new energy, these jobs would likely be higher paid service sector jobs because of skill requirements for marketing and installation of the technologies. In any case, Wanda offers two important lessons about green job creation:

1. Home production of green technology may be neither efficient nor desirable, particularly if it renders these technologies unprofitable.
2. Globalization can make products more profitable and create high wage payrolls at home that far exceed manufacturing payrolls abroad.

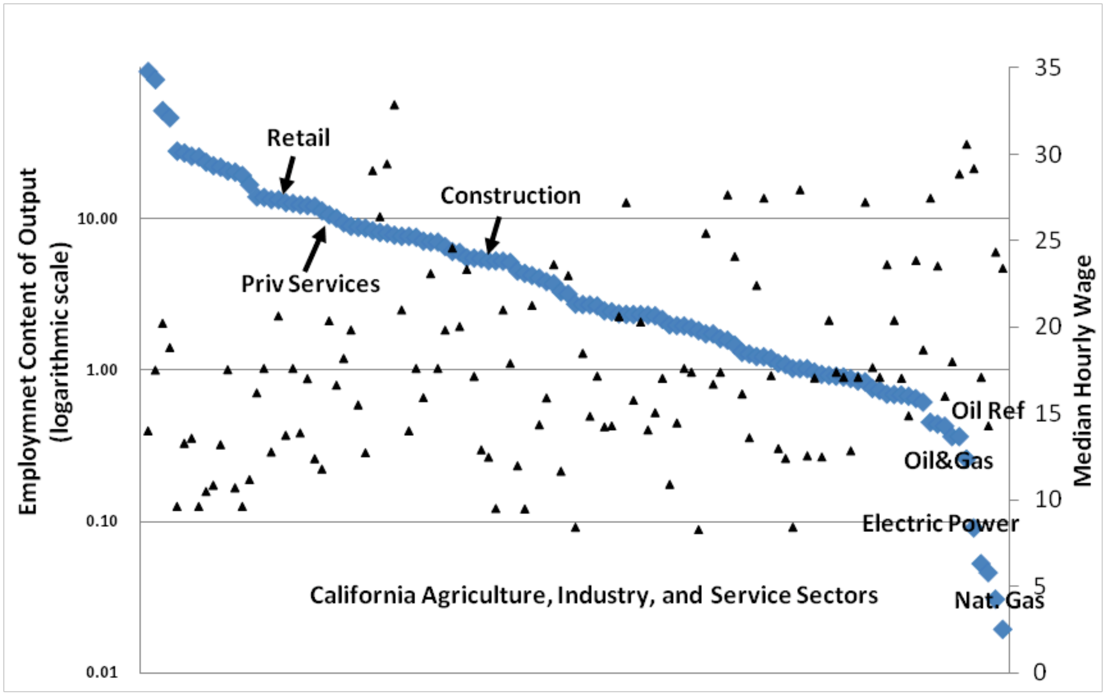
Thus the basic message is to capture innovation, develop and market it at home, but fabricate it efficiently. For new energy, the latter is particularly essential to make new technologies price competitive and enlarge their markets. This approach will accelerate the diffusion and adoption of new energy, creating more jobs and raising incomes in the higher wage Phase 1 and 3 categories. By contrast, expecting or even insisting that all Phases take place in a single market may betray the "Holy Trinity" of technological change: innovation/diffusion/adoption, and seriously retard the emergence of new energy and its essential environmental and growth benefits.

Energy Efficiency and Job Creation

Now we consider the fourth category of new energy job creation, induced or indirect employment resulting from efficiency. We shall see in this study, as we have in its predecessors, that energy efficiency is a potent catalyst for economic growth and job creation. This is true not only because it realizes more value from existing resources, but also because it saves money that can stimulate other economic activities. The predominant source of energy today is a complex array of carbon fuels. Despite their diversity and high energy content, however, they have three major drawbacks. First and foremost is carbon content, which occasions environmental damage or additional mitigation costs. Second, the majority of carbon fuels are non-renewable, and those that are renewable (biofuels) remain highly uncertain in their economic and environmental costs.

Finally, and more germane to the present analysis, the supply chain for conventional carbon fuels has very low employment intensity. This fact is the primary reason energy efficiency stimulates economic growth. If efficiency investments save one dollar for a household or enterprise, their alternative spending of that dollar is nearly certain to create more jobs. As Figure 5 makes clear, carbon fuels and their downstream energy carriers (electricity) have among the very lowest labor/output ratios in the California economy. This figure shows employment intensity or labor/output ratios for 124 sectors of the California economy, displayed along the horizontal axis in order of employment intensity. Because the disparities are quite wide across sectors, a logarithmic scale is used. For the same value of total output, some service sectors have more than 100 times as many employees as electric power or natural gas sectors.

Figure 5: Employment Content of Output by Sector in California
(labor/output ratios for 124 primary, secondary, and tertiary activities)



Source: California Employment Development Department dataset.

The fundamental insight about energy efficiency and employment growth has already been emphasized in an earlier report (Roland-Holst:2008). The figure below makes this point graphically, comparing employment content of output across over a hundred different economic activities. When households save money on traditional energy, they shift this expenditure from the carbon fuel supply chain to more customary spending categories, of which about two thirds are services. As the figure shows, this expenditure shifting can have a dramatic net effect on job creation. The carbon fuel supply is among the very least employment intensive economic activities, even before considering how these expenditures leak outside the state and national economies to foreign energy sources. The disparity between job growth from a dollar spent here and one spent on services is so great that a logarithmic scale is needed to display it. Simply put, a dollar saved on traditional energy is a dollar earned by 10-100 times as many new workers.

Also displayed in Figure 5 is the median hourly wage (triangle markers and right axis) for each sector. These data suggest that, although energy supply jobs pay above average across the economy, there are plenty of high wage jobs in more employment intensive sectors, and in any case the former represent a small portion of the state's total wage bill. Expanding demand for sectors on the left side, even at lower median wages, would generate so many more jobs that aggregate net income gains are inevitable. This is precisely what happens as a result of energy efficiency, which diverts expenditure across a wide spectrum of alternative goods and services. For households in higher income countries, this expenditure is concentrated (over two thirds) in tertiary sectors, those on the left side of Figure 5 with the highest employment content.

Supply-side policies, like an RPS that changes the sources and carriers of energy available to the economy, have more complex effects on employment. As we shall see in the next sub-section, employment content for new energy sources, including biofuels and other renewables, varies by source and still remains uncertain with respect to emerging technologies. Having said this, however, it is apparent from Figure 2.3 that virtually any economic activities that play role in new energy development will be more job intensive than exhaustible carbon fuels. With the added advantages of renewability and domestic sourcing, this employment dividend also has a more certain future and more extensive multiplier effects.

Scenarios for New Energy and Economic Growth

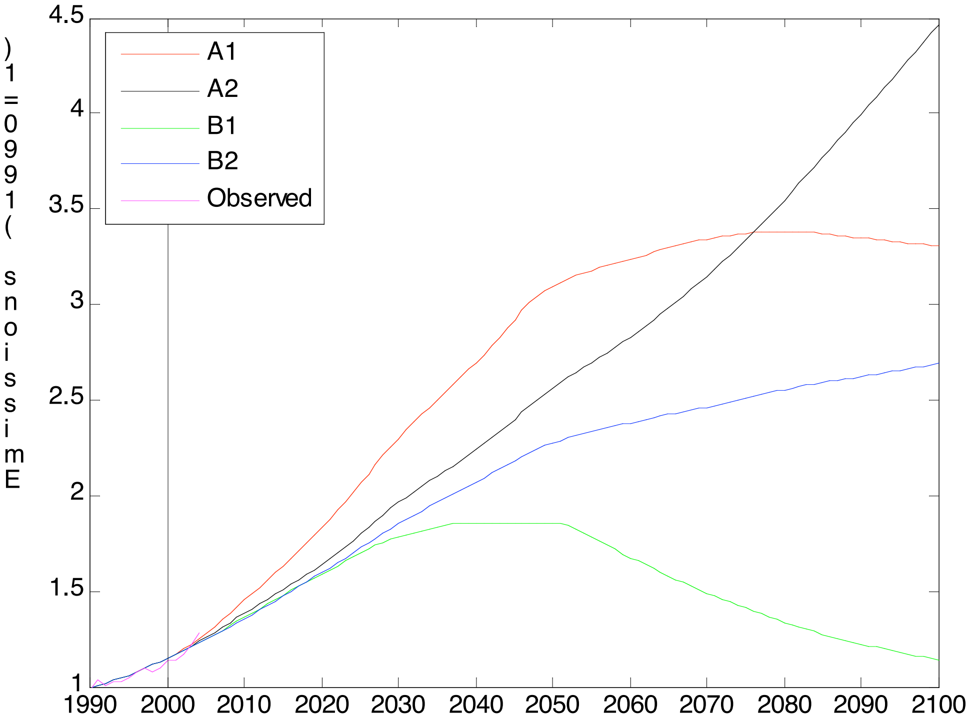
In this section we consider California's energy future to 2050, examining how policies on both the demand- and supply-side of the state's energy economy will affect its prospects for growth and employment. As discussion in later background sections of this report, as well as a large body of current research suggest, there are many uncertainties over this time period, including climate change, global energy resource availability, technological opportunities, policy regimes, and private responses to all these. For this reason, we look at the future with a scenario approach, using a state-of-the-art economic forecasting model and a variety of prospective trends based on consensus among independent researchers regarding the uncertainties just mentioned. Much more detailed analysis of each of these background characteristics is available elsewhere and cited later in this study, but for the present discussion we focus on median cases with respect the main issues.

Warming Trends

The physical science of climate change is a subject far beyond the scope of this report. Thus we rely on the leading scientific research in this area for our baseline scenario. Since California cannot substantially affect the global climate with its own policies, we consider the climate scenarios depicted in Figure 6 as exogenous to our modeling exercise. These represent estimates of alternative trends for global GHG emissions, with two steadily rising and two "stabilization" scenarios, indicating optimistic and pessimistic adaptation assumptions in each case. The more pessimistic A scenarios assume that global emissions respond slowly (A1) or not at all (A2) to mitigation priorities. The B scenarios assume more rapid response, but that response is more (B1) or less (B2) inclusive. Either of the stabilization scenarios is preferable in the very long run, but Scenario B1 is the only one that yields emissions stabilization at levels with reasonable estimated temperature increases (1-3 degrees centigrade). Even in this case, extensive adaptation will be required to contend with rising sea level and many other climate damages, but tripling emissions by 2100 would be catastrophic.[5]

Given that scenario B1 is really the only tenable one for realistic projection work, we adopt it and assume California responds accordingly.

Figure 6: IPCC/NCAR Global GHG Emission Trends



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[5] See Stern: 2006 for a discussion of global effects, and Kahrl and Roland-Holst (2008) for discussion of California climate damage.

Notes: IPCC refers to the Intergovernmental Panel on Climate Change, a UN institution awarded the 2006 Nobel Peace Prize for its climate research. NCAR is the National Center for Atmospheric Research, a leading U.S. climate research institution.

Energy Demand

This study is focused on the linkage between energy use and the state economy, so for the present we leave aside forecasting of complex adaptation strategies, such as targeted infrastructure investment. Instead we focus on the energy demand responses of private actors and alternative energy supply/availability trends. As we have seen historically, and emphasize in the background analysis below, households play a major role in statewide energy consumption through uses of electricity and transport fuel. For electricity demand, we adopt the findings of Aroonruengsawat and Auffhammer (AA, 2008), whose intensive econometric analysis indicates that the B1 scenario warming would (in a neutral policy environment) lead to reversal of California's four-decade stability of per capita electricity use.[6] From 1960 to the early 1970's, this usage grew at about 7 percent per year. Then, as a result of determined policies to improve efficiency, California's economy continued to grow from 1975 to the present time at about 2.6 percent per year, but per capita electricity grew at only 0.3 percent annually. Now, largely because of home and workplace air conditioning requirements in central and southern California, AA estimate that per capita usage will rise about 0.5 percent annually to 2050. Combined with low range estimates for state population growth (0.9 percent/year), this would lead to doubling of total household electricity use from 2010 to 2050. This rate of growth is incorporated in our baseline projection. For transport fuels, we assume constant per capita use in the baseline.[7]

Energy Supply

For the baseline scenario, we assume that California maintains its present energy mix of energy, facing average global carbon fuel prices that rise by 1 percent per year, or roughly doubling between now and 2050. Given the volatility

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[6] These new estimates are a very important contribution to our understanding of future electric power needs, but it should be borne in mind that estimates based on historic billing data may not be robust against price dynamics from emerging renewable and efficiency technologies.

[7] Actual patterns of future transport use, in California and elsewhere, are a matter of intense interest and debate, but projecting these is outside the scope of this study.

in today's energy prices, this assumption is of course open to alternatives. For this reason, our baseline energy prices begin from a ten-year average.

It is worth emphasizing that the current turmoil in global energy markets is completely demand driven, and long-term scarcity of exhaustible carbon fuels is a certainty. Despite identification of new sources, the marginal costs of exploration and exploitation have remained on monotone rising trends for decades. The reason for this is that technology can only exert a limited role in cost efficiency for developing increasingly remote and inaccessible resources.[8] This can be contrasted with solar energy, for example, where it has been estimated that 100 percent of the country's electricity needs can be met by 100 square miles of panels in California's own (50,000 square miles) Mohave Desert.

In any case, variational analysis of our results indicates that our conclusions about employment-efficiency linkages are robust against baseline fuel prices, but of course would influence the price competitiveness of new energy sources. For the latter, we do not model a market driven adoption process, but only standards-driven implementation, discussed in the next sub-section.

Scenarios and Results

Against a relatively passive baseline, including optimistic assumptions about climate change and population growth, we now evaluate the economic consequences of transition to new and renewable energy sources and higher levels of energy efficiency. Most research on these topics suggests that California must make significant progress in both areas, and our findings strongly support this two-pronged approach to reducing fossil fuel dependence. Even with determined policy leadership, renewables are likely only to displace a significant fraction of traditional energy in the medium-term, and demand-side policies will remain important to reducing a large residual of carbon fuel dependence. At the same time, energy efficiency can save money regardless of the source of that energy, and save ever more money as the source becomes more expensive. We shall see below that renewables substitution increases state employment, but combining this with energy efficiency multiplies the job gains.

To assess the economic growth potential of new energy for California, we consider the following five scenarios to 2050:[9]

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[8] For example, Brazil recently discovered a vast marine petroleum deposit, far exceeding its current reserves. Unfortunately, this oil lies under 5,000 feet of seawater.

[9] Of course the universe of policy options with respect to renewables and efficiency is vast indeed. We have chosen a set of generic policy scenarios that contrast the essential components being discussed for California. For a wider array of options, applied in other regions, see e.g.

1. RPS20 – California is assumed to achieve a 20 percent renewable portfolio standard (RPS) for electric power by 2020, and to maintain this through 2050.[10]
2. RPS33 – Like the previous scenario, but with a 33 percent RPS.
3. RPS50 – Like the previous scenario, but with a 50 percent RPS.
4. NE1.0 – RPS50, combined with household and enterprise energy efficiency improvements of 1.0 percent annually over the period 2008-2050.[11]
5. NE1.5 – RPS50, combined with household and enterprise energy efficiency improvements of 1.5 percent annually over the period 2008-2050.

Table 3: Employment Results
(change from Baseline in 2050, thousands)

	RPS20	RPS33	RPS50	NE1.0	NE1.5
Agriculture	0.154	0.353	0.611	9.686	14.645
Oil and Gas	-2.203	-5.062	-8.789	-46.004	-62.058
Electricity	-0.183	-0.433	-0.777	-17.642	-23.807
Renewables	10.184	23.429	40.730	6.061	5.301
Natural Gas Dist.	0.035	0.079	0.138	-17.051	-22.865
Construction	1.701	3.925	6.847	112.404	167.689
Food Processing	0.047	0.107	0.183	9.120	15.312
Oil Refining	-0.120	-0.276	-0.480	-10.650	-14.336
Chemicals	0.242	0.555	0.960	4.126	6.238
Pharmaceutical	0.063	0.145	0.253	-0.288	-0.222
Cement	-0.134	-0.308	-0.535	3.658	5.636
Metals	1.017	2.326	4.019	-2.640	-3.270
Machinery	2.070	4.761	8.276	-60.240	-86.992
Elec App and Semi	5.021	11.514	19.955	4.207	5.164

Eldridge et al. (2008a and 2008b). In the context of long-term efficiency potential, see e.g. the Expert Group on Energy Efficiency (2007) and Geller et al (2006).

[10] This is a lower bound for policy fulfillment. In its recent Scoping Plan, California ARB calls for a 33% RPS. It should be noted that our Baseline scenario includes all AB 32 measures other than those related to energy efficiency, such as RPS, Pavley, building efficiency, etc. The latter policies are covered in the six alternative scenarios. Further, we assume for RPS and efficiency that, either as a result of market forces or policy interventions, alternative technologies enter markets at comparable adoption prices. After entry, prices fluctuate in response to competition.

[11] It should be noted that, although California has maintained 1% per capita efficiency gains over 1972-2006, we do not include these in the forward looking Baseline. This is done to isolate efficiency effects in the policy scenarios (4 and 5).

Vehicles	0.044	0.099	0.171	1.352	2.652
Other Industry	-1.783	-4.108	-7.156	2.193	7.045
Wholesale Trade	0.055	0.120	0.199	10.489	12.526
Retail Trade	1.202	2.745	4.738	57.037	73.017
Transport Serv	-2.077	-4.773	-8.291	23.994	38.778
Other Private Serv	-0.999	-2.373	-4.266	218.095	280.295
Total	14.335	32.826	56.785	307.907	420.747
New Jobs	21.834	50.159	87.078	462.422	634.298
Job Reduction	-7.499	-17.333	-30.293	-154.516	-213.551

Briefly, the first scenario mirrors AB 32's recommendation for renewables deployment, while the second and third consider more aggressive policies. Scenario 4 considers the consequences of improved household energy efficiency like that achieved in California over the four decades from 1970 to the present. We do not consider the source of this efficiency, i.e. regulatory or voluntary, but only the effects of such reductions in energy dependence. Given that the scope of AB 32 and most climate policy dialogue now reaches well beyond household energy use, we also consider (Scenarios 4 and 5) the implications of efficiency improvements by all energy users in the state. Given the proposals for Cap and Trade and even carbon fees being discussed, these are probably the most reflective of future adoption patterns. We further assume that efficiency gains of 1.0 percent or 1.5 percent are achieved.

Employment results are given in Table 3 for the five scenarios, stated in thousands of jobs against Baseline levels. All results are differences against a dynamic (2008-2050) baseline in which all sectors of the California economy grow. When a result in this table is positive, more jobs are created than in the Baseline, less when it is negative. In particular, negative results do not mean that a sector necessarily contracts or that existing jobs are lost. It is more accurate to think of these results as comparisons of shifting job opportunity across the economy. The last two lines decompose the employment impacts between new jobs in sectors that expand more rapidly, and "reduced" job creation in sectors that grow more slowly relative to the baseline. In the latter case, it is important to note that total employment in a sector may not fall in absolute terms (i.e. sector contraction) over the 2008-2050 period, but it will grow more slowly than in the baseline.

A few features of these estimates are particularly arresting. Firstly, employment creation outweighs employment reduction in every scenario, indicating that new energy stimulates aggregate economic growth in all cases.[12] Secondly, deployment of renewables increases employment both in its own sector and across the economy as a whole, but efficiency measures offer much more potent growth leverage to the economy. Finally, although both types of policies stimulate aggregate growth, the adjustment patterns they create are quite different.

Examining the results in more detail, we see that renewables employment creation is consistent with other independent estimates, including Kammen et al (2004) Greenblatt (2008), and many related contributions by Laitner and co-authors (2008abc). This fact is particularly significant because the present estimates were obtained by completely independent estimates. In non-technical terms, the other studies obtain employment effects with bottom up technology accounting in renewables sectors, while our approach is top down, imputing labor requirements from emerging supply and demand patterns induced by policies and prices. Depending on the degree of renewable deployment, direct job creation would be between 10,000 and 40,000 FTE jobs, which on a national scale would exceed 100,000 to 400,000 given the relatively lower initial national renewable portfolio. Having said this, our estimates suggest that total "green jobs" attributable to and RPS would be more like the column totals, or 14-57,000 jobs for California and 140-570,000 on the scale of the national economy. Even these figures are net of employment reductions against the baseline. Adding up the new jobs only, green job creation becomes 22-87,000, or at least 220-870,000 nationally.[13]

When renewables are the primary new energy strategy, employment growth is concentrated in that sector, in electronics, and in machinery. When energy efficiency measures are integrated with RPS, employment gains are more widespread, particularly in construction and services, with the former responding to new building standards and the latter benefiting from expenditure diversion. By comparison with renewables alone (RPS50), the energy efficiency (EE) measures increase statewide job benefits almost tenfold. Note, however, that the EE component moderates the growth of RPS, since efficiency applies both to traditional and new energy sources. Moreover, although statewide job growth is

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[12] In comparing dynamic baselines and scenarios, it is important to avoid misunderstandings about job creation. Negative numbers in (e.g.) Table 2.1 do not imply that the sector in question is losing jobs over time, but only that its employment is growing more slowly than it would in the Baseline. For sectors producing negative environmental externalities, this is an outcome that always makes good public policy sense, improving circumstances for many, without making others worse off. The sector's jobs might not shrink, but society will be better off under the scenario considered.

[13] Actual numbers at the national level will of course differ as do the structures of the US and California economies. Such an extension of this California work would be a valuable contribution to the energy policy literature.

significant and positive, substantial structural adjustments are implied by slower growth of jobs in other sectors. Over a 42-year time horizon, however, this kind of structural change is not at all unusual.

Year-to year job changes are gradual, but income benefits accumulate. To see the total income effect of new energy policies as an economic stimulus, Table 4 presents cumulative payroll changes for each scenario over the period 2010-2050. By this standard, we see that combined renewables and energy efficiency can create over 400,000 additional jobs by 2050, and would add over $100 billion in new payrolls in the process.

Table 4: Annual Wage Income Results
(change from Baseline in 2050, in 2007 USD millions)

	RPS20	RPS33	RPS50	NE1.0	NE1.5
Agriculture	3	8	13	210	318
Oil and Gas	-91	-208	-362	-1,894	-2,555
Electricity	-11	-27	-48	-1,087	-1,467
Renewables	627	1,443	2,509	373	327
Natural Gas Dist.	2	4	7	-893	-1,198
Construction	24	56	98	1,604	2,394
Food Processing	2	4	6	320	536
Oil Refining	-6	-15	-25	-563	-757
Chemicals	10	23	39	168	253
Pharmaceutical	3	6	10	-12	-9
Cement	-2	-4	-6	44	68
Metals	36	83	144	-94	-117
Machinery	81	185	322	-2,344	-3,385
Elec App and Semi	280	642	1,113	235	288
Vehicles	2	4	7	58	114
Other Industry	-66	-152	-265	81	260
Wholesale Trade	2	4	7	361	431
Retail Trade	41	94	163	1,961	2,510
Transport Serv	-82	-187	-326	942	1,523
Other Private Serv	-40	-95	-171	8,761	11,259
Total	815	1,869	3,236	8,231	10,794
New Payroll	1,113	2,557	4,439	15,118	20,282
Reduction	-298	-688	-1,203	-6,887	-9,488
New/Old	3.7	3.7	3.7	2.2	2.1

Thus we see that the new energy agenda can be a powerful source of job creation, and that this employment is diverse and attractive in terms of average skill and wage content. Renewables provide mainly “green collar” jobs in their own sector, but also indirect benefits to upstream suppliers and downstream marketing, installation, operations, and maintenance workers. This is an attractive enclave sector, with relatively high wages and obviously new technology appeal. Even when a significant portion of green tech manufacturing is outsourced (we assume about 25 percent of value), California still captures significant employment and payroll benefits from greater renewable deployment.

Only a fraction of the employment benefits of the new energy agenda are on the supply-side, however, and we find that energy efficiency measures offer strong multiplier effects through expenditure diversion.[14] The bottom line in this case is that most green jobs are not “green collar” jobs, but employment induced by the demand dividend of energy efficiency. This fact is often ignored in the (otherwise very just) enthusiasm surrounding new energy. Its implication is not negative, however. Although direct employment in new energy may be more modest, indirect employment benefits are much greater, more diverse and income-equitable, and in-state job retention is much higher. Spending by the California consumer is more than 70 percent of GSP, and a significant majority of this spending goes to services creating jobs that cannot be outsourced.

Table 5: Cumulative Income Results
(change from Baseline over 2010-2050, in 2007 USD millions)

	RPS20	RPS33	RPS50	NE1.0	NE1.5
Agriculture	34	77	134	1,767	2,554
Oil and Gas	-575	-1,322	-2,295	-10,012	-13,858
Electricity	-87	-206	-370	-5,742	-7,984
Renewables	3,444	7,924	13,774	2,203	1,952
Natural Gas Dist.	11	25	43	-4,513	-6,264
Construction	41	95	165	5,762	8,529
Food Processing	12	28	48	2,732	4,068
Oil Refining	-41	-94	-164	-2,803	-3,906
Chemicals	71	162	280	1,303	1,872
Pharmaceutical	26	59	102	0	-16
Cement	-13	-31	-54	169	259
Metals	224	513	886	41	29
Machinery	548	1,262	2,196	-9,311	-13,649
Elec App and Semi	1,765	4,046	7,005	2,173	2,466
Vehicles	12	27	46	604	928
Other Industry	-407	-938	-1,633	2,085	3,270
Wholesale Trade	10	21	33	2,187	2,650
Retail Trade	226	515	885	9,218	11,809
Transport Serv	-517	-1,187	-2,061	4,906	7,966
Other Private Serv	-374	-886	-1,586	44,834	58,529
Total	4,409	10,089	17,436	47,604	61,204
New Payroll	6,424	14,753	25,600	79,986	106,882
Reduction	-2,014	-4,664	-8,164	-32,382	-45,678
New/Old	3.2	3.2	3.1	2.5	2.3

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[14] Authors such as Ehrhardt-Martinez and Laitner (2008) have found energy efficiency is a primary driver of demand for new energy technologies and services, promoting a self-fulfilling cycle of adoption, savings, and job creation.

To more fully assess the economic impacts of these new energy scenarios, Table 6 presents 2050 payroll impacts, expressed in today's dollars and assuming average relative wages remain constant across sectors. These results indicate that new energy policies increase not only employment, but income for California, and significantly so. This outcome is not inevitable, since jobs reduced from the baseline might be higher wage than those created. In some cases this is true, but the total growth to employment far outweighs this, yielding annual payrolls by 2050 that are $1-20 billion higher in today's dollars. The last row in the table shows the ratio of new additional to baseline lost payroll, and these results are revealing. When renewables are deployed, payroll gains are 3.7 times losses because most of the jobs created are relatively high skill. When energy efficiency in included, total income gains are much higher, but only 2.1 times income reductions from the baseline because job growth is distributed across more diverse service sectors (compare Figure 3).

3. Demand Horizons

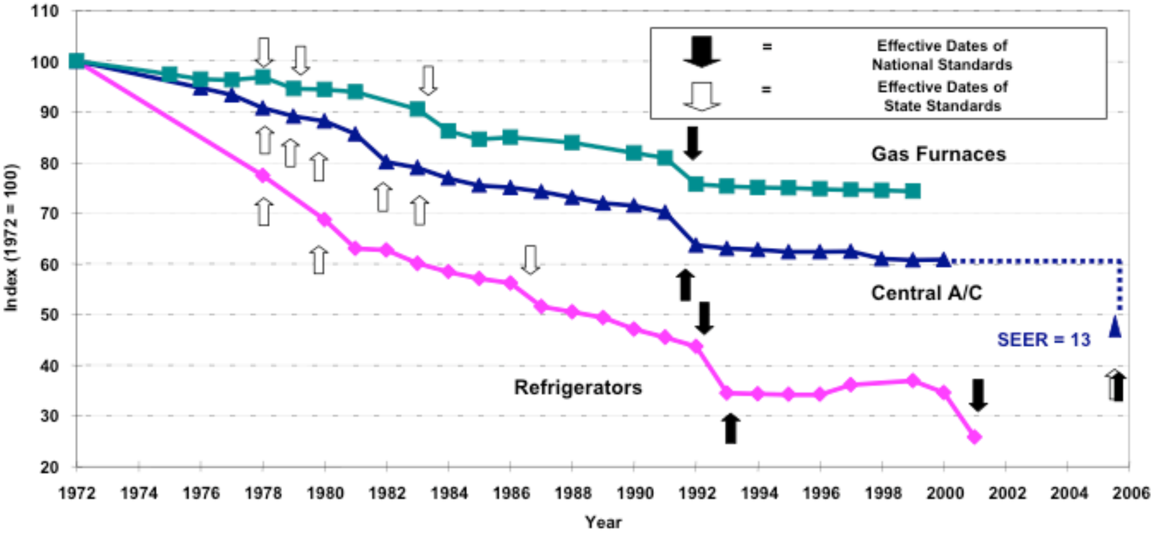
Home Energy Demand

“The average homeowner spends about $1,000 per year on heating & cooling their home, about half the home’s total energy bill.” –U.S. Dept. of Energy

Trends

California has made exemplary progress in demand- side management of energy use, particularly in ways that have promoted household energy efficiency, resulting in significantly decreased per capita energy consumption by HVAC systems. Average efficiency has been trending up from 10.3 SEER in 1999 to 11.2 SEER in 2005.[15] Recent legislation has increased the mandated rating from 10 to 13 SEER, resulting in a 23 percent increase in rated efficiency for new equipment. (CEC, 2008)

Figure 7: Efficiency Gains by for Leading Household Appliances



Source: (Rosenfeld, 2008)

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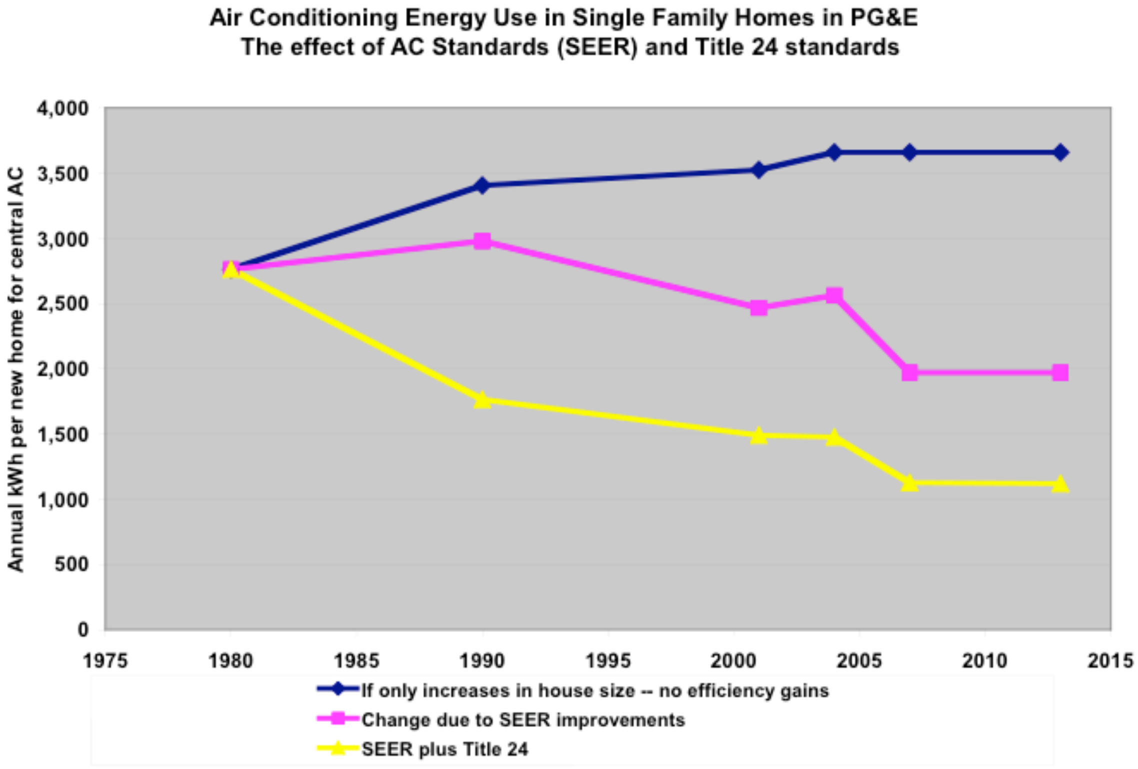
[15] SEER stands for Seasonal Energy Efficiency Rating. It is the most commonly used measure of the efficiency of consumer central air conditioning systems. (EER, or Energy Efficiency Rating is the most commonly used measure of efficiency for commercial air conditioning systems.)

In a recent report by the California Energy Commission (CEC), an estimated $40 billion was saved in 2006 due to increases in space heating efficiency; air conditioning efficiency improvements over the years saved the state $30 billion. (Rosenfeld, 2008) These calculations are based the subtraction of 1974 efficiencies from 2006 efficiencies. Federal and state standards have played a crucial part in improving efficiency. Figure 7 details the efficiency gains central air conditioning units and gas furnaces have experienced.

Figure 8 illustrates three important trends. First, the blue line demonstrates the increase in average house size. From 1976 to 2007, the average size of new homes built grew 55 percent, from 1,560 to 2,390 sq. ft. (CEC, 2008) Second, the pink line shows the importance of appliance standards—even with the increasing size of homes, improvement in the SEER rating of air conditioners decreased energy use by almost one-third. Last, the effect of Title 24, California's building code, coupled with the air conditioning standards illustrates the value of an energy efficient home with quality weatherization and so on.

Figure 8



Source: (Rosenfeld, 2008)

In addition to increasing home sizes, a greater number of these new homes are being built with central air. The rate of installation in new homes has skyrocketed from 25 percent in 1976 to 95 percent in 2007. Californians are also installing air conditioners for their existing homes at an increasing rate. (CEC, 2008)

Despite efficiency gains, the increase in total number of operating air conditioners has increased total peak demand attributed to them from 5 percent in 1976 to over 24 percent in 2006. (CEC, 2008) Additionally, the efficiency gains within production of HVAC systems can easily be negated by poor installation or maintenance. For instance, the rapid growth in housing starts from 1990 to 2002 resulted in proportionate demand for HVAC installation in the new houses. This led to low-quality installations being performed by an industry spread too thin, leading to decreases in observed energy efficiency and increased electricity demand. (CEC, 2008)

Heating

According to a 2000 survey by the Department of Energy, natural gas is used to heat 71 percent of Californian homes and businesses, a rate higher than the national average (51.2 percent). (DOE, 2008a) Most (22 percent) other homes are heated with electricity, and the remainder use liquefied petroleum gases or other sources. (DOE, 2008a) Space heating accounts for a total of 4 percent of end-use energy in the commercial sector.

A central heating unit is measured by its annual fuel utilization efficiency (AFUE) rating. It is defined as the “ratio of heat output of a furnace or boiler compared to the total energy consumed by a furnace or boiler.” (DOE, 2008d) However this does not take into account the heat losses through the duct system or piping, which can be up to as much as 35 percent of the furnace’s output. (DOE, 2008d) Current federal standards mandate AFUE ratings of at least 75-80 percent depending on the type of furnace or boiler manufactured. This is a significant improvement of energy efficiency over earlier low-efficiency heating systems with AFUE ratings in the fiftieth percentile.

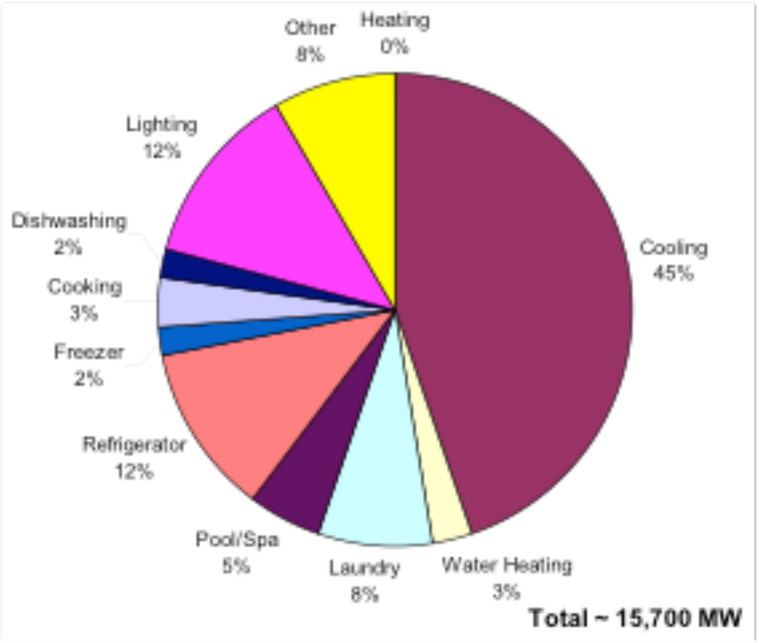
Electric resistance heating is another option. Extremely efficient (~100 percent) in the conversion of the energy in electricity to heat, but because the initial conversion to electricity from another fuel stock is generally only around 30 percent, it is a more expensive method of space heating. If electricity must be used, heat pumps are a more efficient alternative, using only half the electricity of electric resistance heaters. (DOE, 2008b) Unfortunately, heat pumps do not operate well in dry climates with either hot, or hot and cold temperatures, areas such as inland California.

Cooling

A fairly recent evaluation of California's residential energy-efficiency potential is a report examining the four major investor-owned utilities (IOUs), accounting for about 80 percent of the state's total electrical consumption and peak demand, and 99 percent of its natural gas consumption. The study found that the residential sector accounted for 29 percent of peak IOU demand, around 15,700 MW in 2000. Of these 15,700 MW, the largest portion of residential-sector summer peak demand for electricity came from cooling, 45 percent (see Figure 9). (Coito, 2003).

Figure 9

Breakdown of Residential IOU Summer Peak Demand by End Use



*Includes line losses. Source: CEC 2000 and XENERGY Inc. analysis.

Source: (Coito, 2003)

Air Conditioners

In 2006, 346,322 central air conditioning systems with a high potential for savings were installed as part of retrofits; 83,283 as part of newly constructed homes. (CEC, 2008)

A system of standards determined by the federal government is essential to maintain a reasonable level of energy expenditures. SEER ratings mostly range from 13 to 23, and have increased dramatically over the last two decades. (Consumer Energy Center) In 1992, the federal government established a minimum cooling efficiency standard of 10 for units installed in new homes. At the time, the typical SEER rating was 6.0. (Consumer Energy Center) The most recent standard, effective January 23, 2006, is an increase to a minimum 13 SEER rating. (CEC, 2007)

Because many areas in California are hot enough to necessitate an air conditioner, every effort needs to be made to maximize their efficiency. Air conditioners must first be engineered and built so that they are as efficient as possible, then installed properly, but finally they must also be monitored regularly to ensure they are working at the level to which they were designed. Incorrect airflow and refrigerant charge level are two common problems that are easily remedied, but can sap energy efficiency. When surveyed in 1999, the average air conditioner in California homes operated at a level at least 17 percent below what they were designed for. (Downey, 2004) This is equivalent to a 12 SEER air conditioner operating at 10 SEER. (Downey, 2004) Poor maintenance can easily defeat the purpose of appliance standards. Problems are not limited to residential air conditioners; a study commissioned by the Sacramento Municipal Utility District found that commercial air conditioners suffered refrigerant charge and airflow problems at least equivalent to residential systems. (Downey, 2004)

A recent attempt (Downey, 2004) to evaluate efficiency of installed California air conditioners surveyed 13,258 units and found that the majority of units, both residential (65 percent) and commercial (71 percent), were in need of repair, and that 92 percent of these units were able to be repaired successfully. Table 6 summarizes the findings.

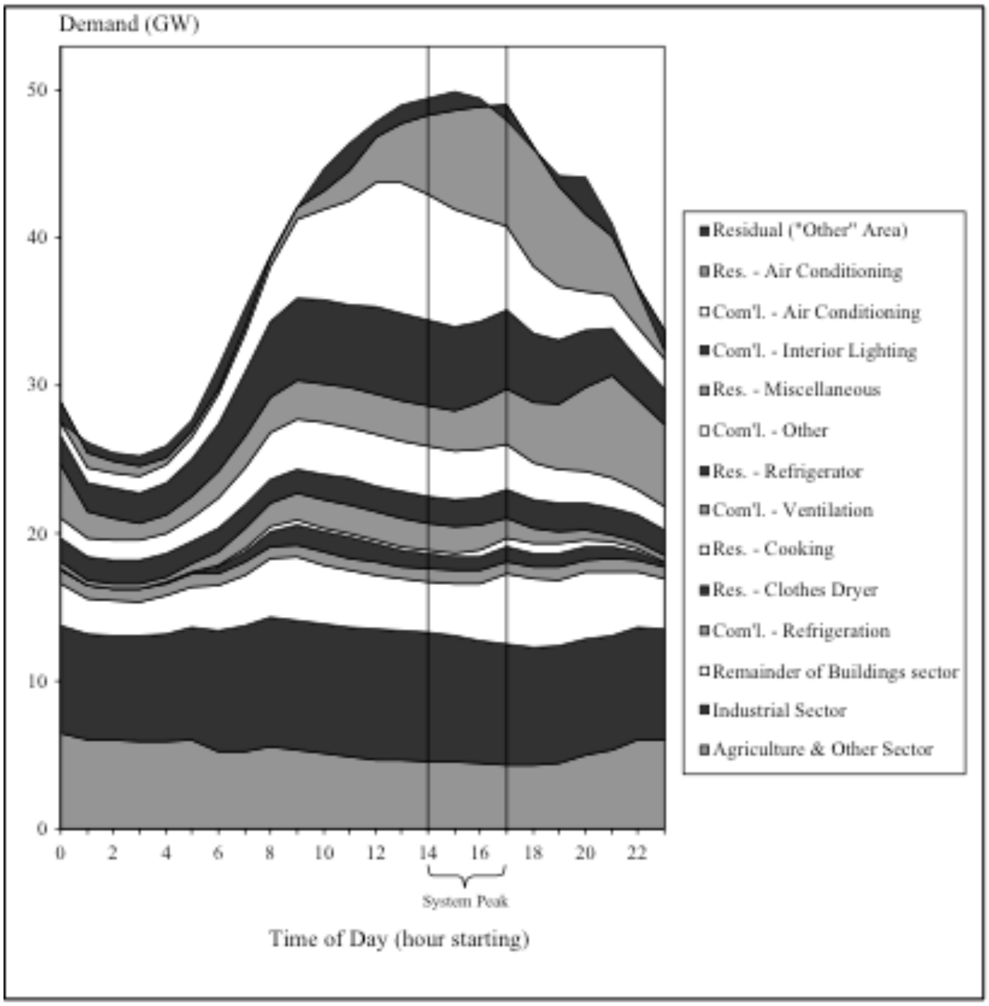
Table 6: California Air Conditioner Reliability Survey

	Systems	Systems in Need of Repair	Repairs Attempted (% of needed)	Successful Repairs (% of attempted)
Residential	8,873	5,776 (65%)	4,280 (74%)	3,924 (92%)
Commercial	4,385	3,100 (71%)	2,469 (80%)	2,257 (91%)
TOTAL	13,258	8,876 (67%)	6,749 (76%)	6,181 (92%)

Source: Downey: 2004

Electricity use during “peak hours” is an important concern, and air conditioning is an important contributor to peak demand. The peak demand period is simply the time when energy use is highest, occurring in California during summer weekday afternoons. Fred Coito and Mike Rufo, authors of *The California Statewide Residential Sector Energy Efficiency Potential Study,* found that air conditioning is the end use with the most potential for energy-efficiency gains, representing 40 percent of total savings potential by 2012. (Coito, 2003) Natural gas has similar energy-efficiency savings potential, 39 percent in terms of overall energy end use, not peak demand. Figure 10 shows a graphic representation of the major contributors to California peak demand; one can see that air conditioning is a prominent use. Electricity is much cheaper during off-peak hours, so any mechanism, such as efficiency gains, which decreases peak demand and will allow base level electricity generation to satisfy demand can be helpful.

Figure 10:
Largest Contributors to California Peak Demand



Source (Coito, 2003)

Opportunities to Reduce HVAC Energy Expenditures

Programs

Energy saving programs can take the form of federal or state mandates, such as efficiency requirements for air conditioners, or conservation campaigns, such as the “Flex your Power” program currently promoted by the CPUC.

Ventilation

Ventilation is the least expensive and most energy-efficient cooling system available. Natural ventilation requires no energy input to operate and can be sufficient in some areas. Equipment such as ceiling, window, or house fans can supplement natural ventilation and use small amounts of energy compared to air conditioners. Also, practices such as attic ventilation can help keep houses cool. Similarly, heating of a residence or business will be accomplished in the most efficient manner if a central heating system is supplemented with a well-functioning ventilation system and when appropriate, other methods of heating.

Evaporative Coolers

Evaporative coolers, also known as swamp coolers, are an alternative cooling solution to central air conditioning. The installation cost of evaporative coolers is about half that of central air conditioners, and they use about one-quarter as much energy. (DOE, 2008c) Evaporative coolers are only effective in areas with low humidity, and though installation and operational costs are lower, they require more frequent maintenance than central air conditioners.

Labor Force

One potential approach to reducing energy demands of HVAC lies within the installation industry and the group of technicians in charge of servicing the systems. Increased investment in education and training of contractors, inspectors, technicians, and installers is essential to improve overall efficiency. (CEC, 2008) Certification of technicians is a simple strategy that can easily grant gains in system productivity. According to a 2008 CEC study, systems installed by North American Technician Excellence-certified individuals achieve 10 percent (+/- 5 percent error) better field-adjusted energy efficiency than systems installed by technicians without certification. However, only 135 technicians receive NATE certification each year. (CEC, 2008) This is problematic because entirely uninformed installations can decrease efficiency by up to 50 percent, on average, 30 percent. (CEC, 2008)

Also, while there is currently a deficit of certified technicians, there is a deficit of technicians in general. In 2005, the Bureau of Labor Statistics estimated HVAC refrigeration jobs would increase by 29 percent. Additionally, 27,000 new skilled workers are needed each year to replace retirees. This totals to 35,000 new technicians annually. (CEC, 2008)

The Future

HVAC is an area of constant innovation, and if the past is any indication, efficiencies of existing technology will continue to improve alongside implementation and development of new technologies. One example is Low-Energy Cooling (LEC) Systems, currently under development at Lawrence

Berkeley National Laboratories. It is estimated that an energy savings of up to 40 percent could be garnered in non-residential buildings in California Climates. (PIER) Particularly, gains in efficiency can be made by developing HVAC systems that are tailored specifically for the California climate.

The CEC estimates that improved installation quality could equate to a potential savings of up to 1,100 MW by 2020. (CEC, 2008) If coupled with investment in alternative cooling technologies with reduced peak usage, up to 3,600 MW could be saved by 2020. (CEC, 2008)

Transport Energy Demand

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. There 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 U.S. Department of Energy. Thus, consumers would have recovered the up-front increased cost of the vehicle within less than three years (Hanemann, 2008).[16]

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 emissions standards. This is roughly the same cost that was incurred in the early 1980s, when emissions standards were far less stringent (Sperling et al. 2004). Sterling also notes that government regulations have accounted for about one-third 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.

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[16] Energy prices have fallen temporarily because of demand side failures, which would extend this payback period by up to three more years if the recession persisted that long. Most observers expect energy prices to recover quickly, however, in part because the downturn has reduced investment in energy supply.

CalEPA also addresses the job losses attributed to regulation by noting that according to their research 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.

Fossil Fuels and Employment Impacts

According to Kammen (2004) the fossil fuel industry provides little overall new employment, but generates huge economic externalities through pollution that somebody has to pay to clean up, or has to endure. These externalities become manifest in the loss of productive work days caused by illness due to pollution exposure, costs borne by industry (and eventually consumers) to clean up pollution, or costs borne directly by taxpayers for clean-up. Bailie et al. (2001) also note that on average if regulations on energy efficiency are enacted, then the national oil refining industry would lose 2,600 jobs by 2010 and 6,300 jobs by 2020. This is especially relevant with the signing of Executive Order 1-07 by California Governor Arnold Schwarzenegger in January 2007. The bill was signed to establish a greenhouse gas standard for fuels sold in the state. The new Low Carbon Fuel Standard (LCFS) requires a 10 percent decrease in the carbon intensity of California's transportation fuels by 2020. The state expects the standard to more than triple the size of the state's renewable fuels market while placing an additional seven million hybrid and alternative fuel vehicles on the road. Oil refineries may not lose nor gain jobs as more investments in technology are made in a relatively capital-intensive sector (Berman 2001). However, the technology implemented for alternative and renewable fuels required by the LCFS could increase employment in those sectors dramatically.

A low carbon fuel standard will promote the development of at least two important industries: a sustainable biofuels sector, and the evolution of the plug-in hybrid sector. Both of these are areas of potentially strong and sustained job growth. At present, however, Detroit automakers have expressed concerns about the job benefits of a clean energy economy. A study conducted by the University of Michigan found, in fact, that job losses could occur if Detroit does not become more innovative and competitive (McManus 2006). Job gains due to investments in fuel efficiency by the "Detroit Three" (GM, Ford, Daimler-Chrysler) cause employment gains in all scenarios except one (fuel at $2.00/gallon with a consumer discount rate of 7 percent). The largest gain would be 15,545 jobs assuming that the "Detroit Three" adopt more fuel-efficient technologies. McManus (2006) also notes that these investments in fuel efficiency can make the "Detroit Three", currently suffering from competition from foreign automobile manufacturers, much more competitive in the global market.

Biofuels have been deemed promising and able to reach LCFS goals by a U.S. Department of Energy report called *Breaking the Barriers to Cellulosic Ethanol*:

> "A biofuel industry would create jobs and ensure growing energy supplies to support national and global prosperity. In 2004, the ethanol industry created 147,000 jobs in all sectors of the economy and provided more than $2 billion of additional tax revenue to federal, state, and local governments (RFA 2005). Conservative projections of future growth estimate the addition of 10,000 to 20,000 jobs for every billion gallons of ethanol production (Petrulis 1993). In 2005 the United States spent more than $250 billion on oil imports, and the total trade deficit has grown to more than $725 billion (U.S. Commerce Dept. 2006). Oil imports, which make up 35 percent of the total, could rise to 70 percent over the next 20 years (Ethanol Across America 2005). Among national economic benefits, a biofuel industry could revitalize struggling rural economies. Bioenergy crops and agricultural residues can provide farmers with an important new source of revenue and reduce reliance on government funds for agricultural support. An economic analysis jointly sponsored by USDA and DOE found that the conversion of some cropland to bioenergy crops could raise depressed traditional crop prices by up to 14 percent. Higher prices for traditional crops and new revenue from bioenergy crops could increase net farm income by $6 billion annually (De La Torre Ugarte 2003)."

However, given the current global food crisis and biofuels possible link to it, biofuels may not be a viable large scale fuel substitution strategy for California.

Feebates

Feebates provide incentives 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 understanding how much GHG can be reduced and at what cost/benefit. McManus (2006) analyzed the potential benefits of a feebate program using fuel prices of $1.74 per gallon, and a 5 percent discount rate to estimate the present value of future savings to consumers due to the technology investments by automobile manufacturers. In each scenario considered, the author estimated a net increase in personal income for California residents. Also, retailers will also gain as their sales increase by up to 6 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.

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)

RAND (2005) argues that automobile manufacturers will be producing large numbers of partial-zero emission vehicles (PZEVs) over the next decade 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. 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, RAND 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.

RAND (2005) 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.

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. They assume three different scenarios for 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 ex. 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”).

Energy Efficiency in the broader U.S. context

A World Wildlife Fund (Bailie et al.) study in 2001 modeled the “Climate Protection Scenario”, a comprehensive environmental policy package that 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 study found that through their model they predicted sustained national employment benefits for 20 years, for a total of about 1.3 million jobs created by 2020 due to this scenario. For California, they predict that California will gain 141,000 jobs by 2020 due to this policy package (Bailie et al. 2001).

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 labor 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).

4. Supply Horizons

As the most populous state and second largest energy consumer after Texas, California has long been recognized for having one of the lowest per capita energy consumption rates in the country. This success, largely attributed to the state's successful energy-efficiency programs, is even more remarkable given that California is rich in both conventional energy resources like crude oil and natural gas deposits and renewable energy resources like solar and wind. An overview and analysis of California's traditional energy supplies and implications is presented below, followed by an analysis of California's renewable resources and potential for development.

Fossil Fuels Supply Trends

Petroleum

California produces one-tenth of the national share of crude oil production with drilling operations concentrated primarily in Kern County and the Los Angeles basin. Substantial offshore production in both state and federal-administered waters were common in the past but recent concerns about development impacts and marine oil spills have led to a permanent moratorium suspending new offshore drilling.[17] As a result, overall current production in California has been steadily declining as no new terrestrial oil reserves have been discovered in the past two decades.

Besides drilling, California is also a top petroleum refiner with the third largest petroleum refining capacity in the U.S. at 2,042,188 barrels/day. As seen in the figure below, California's refinery capacity growth has been increasing since 2000, with notable increases between 2001 and 2002. Although California's refinery capacity growth is below the U.S. and the rest of the world, it is nevertheless significant that the state has experienced an annual average growth rate of 0.5%, or nearly half as fast as the U.S.

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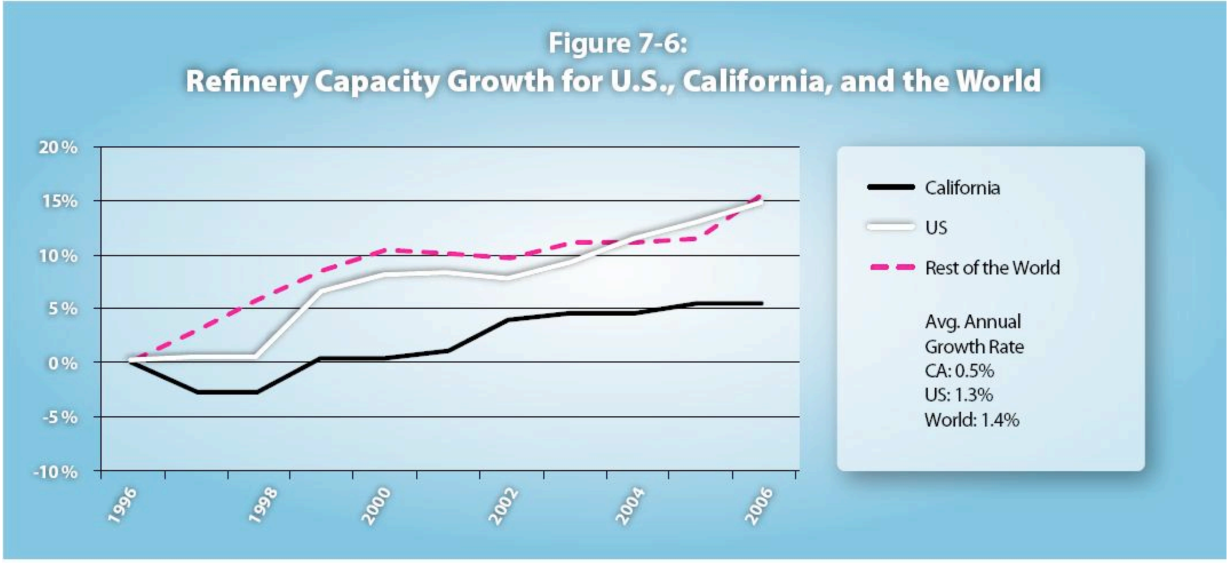
[17] Energy Information Administration (EIA), State Profile of California

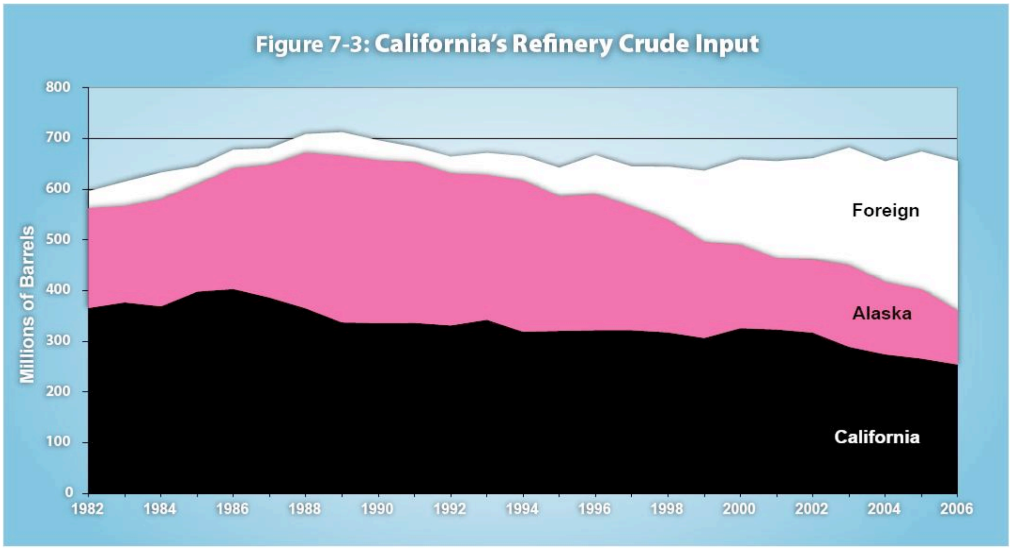
Figure 11: Refinery Capacity Growth, 1996 - 2006



Source: California Energy Commission; Media Briefing Presentation on Energy Commission Spring 2006 Price Spike Report to the Governor, CEC-999-2006-015.

Crude oil is transported within California via a network of pipelines that connects production areas to refining centers in the Greater Los Angeles area, San Francisco Bay Area, and Central Valley. In addition to processing in-state production, California refineries also process large volumes of Alaskan and foreign crude oil. With declining in-state production and Alaskan supply, California refineries are increasingly relying on foreign imports with leading suppliers like Saudi Arabia and Ecuador making up 40% of the refining supply (see figure below). Nevertheless, California's dependence on foreign oil remains below the national average.

Figure 12: California's Refinery Crude Supply



Source: California Energy Commission.

California's refineries are capable of processing a wide variety of crude oil types and are designed to yield a high percentage of light products such as motor gasoline. In order to meet strict federal and state environmental regulations, California refineries are configured to produce cleaner fuels, including reformulated motor gasoline and low-sulfur diesel.

Natural Gas

While California has substantial natural gas depositions in geological basins in the Central Valley and the Pacific Coast, its natural gas production accounts for less than two percent of total annual U.S. production and meets less than one-fifth of state demand. Due to its inherently low and continually declining in-state production, California meets most of its natural gas demand through pipelines from production regions in the Rocky Mountains, the Southwest, and western Canada.[18] California markets are served by two key natural gas trading centers: the Golden Gate Center in northern California and the California Energy Hub in southern California. In the past, state supply has remained relatively stable with increasing supply from the Rocky Mountains and nearly a dozen storage facilities to smooth supply fluctuations. However, Washington and Oregon's recent rise in natural gas demand has forced California to compete for a dwindling supply in the region. In response, several companies have proposed building liquefied natural gas (LNG) import terminals in southern California.

Coal

As a minor and extremely dirty local energy resource, coal has historically played a small role in California's electricity sector with only a few operating small coal-fired power plants in the state. Besides strict emission standards, the state also restricts the use of coal-fired generation within its boundaries. The Los Angeles Department of Water and Power (LADWP) remains the single exception, with operation of the coal-fired Intermountain power plant in Utah which delivers three-fourths of its output to LADWP and other California municipal utilities. However, Intermountain's existing contracts with southern California is set to expire in 2027 and a recent California law forbids utilities from entering into long-term contracts with conventional coal-fired power producers. Therefore, coal will be further displaced from California's electricity generation supply.

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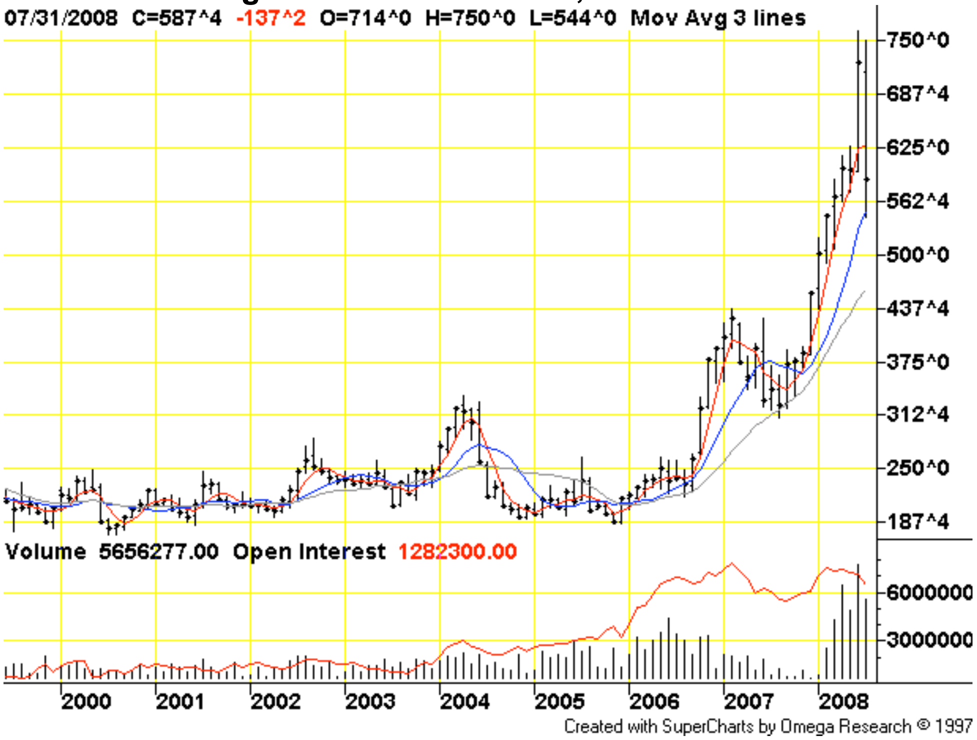
[18] California Energy Commission

Fossil Fuel Supply Prices & Outlook

Transportation fuels

Driven by high demand from California's many motorists, major airports and military bases, the transportation sector is the state's largest energy-consumer. For instance, California has more motor vehicles registered than any other state and its worker commute times are among the longest in the country. To mitigate the harmful health impacts of air pollution from transportation, California received an EPA waiver allowing the state to adopt stricter environmental standards. In particular, most California motorists are required to use a special motor gasoline blend called California Clean Burning Gasoline (CA CBG). Furthermore, motorists are required to use California Oxygenated Clean Burning Gasoline in the ozone non-attainment areas of Imperial County and the Greater Los Angeles metropolitan area, As of 2004, California also transitioned from methyl tertiary butyl-ether (MTBE) to ethanol as a gasoline oxygenate additive, making it the largest ethanol fuel market in the United States.[19] Despite four ethanol production plants in central and southern California, most of the state's ethanol supply is transported by rail from corn-based producers in the Midwest or imported from abroad (see Figure 13).

Figure 13: Corn Futures, 2000 - 2008



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[19] EIA, State Profile of California

As a result of the relative isolation and specific environmental requirements of the California fuel market, California motorists face some of the highest fuel prices in the country. Transportation fuel prices for California have been continually higher than that of the U.S. national average, with the state facing prices of $3.374 per gallon versus national average price of $3.297 per gallon in May 2008[20]. More importantly, California motorists are also particularly vulnerable to short-term spikes in the price of motor gasoline for two main reasons.

First, high demand for petroleum products often forces California refineries to operate at near maximum capacity. Coupled with the absence of pipelines to other major U.S. refining centers, the lack of reserve capacity increases the refineries' vulnerability to disruptions by unplanned refinery outages. Specifically, replacement supplies must be brought in via a marine tanker during an unplanned refinery outage. However, this further distorts gasoline market prices because takes two to six weeks to locate and transport replacement gasoline that conforms to strict state fuel requirements.

Second, the transition from MTBE to ethanol as a gasoline oxygenate additive has further exposed California's gasoline market to systematic risks in the global economy with recent price spikes in corn and grain feedstock for ethanol production. While the U.S. is a net exporter, grain prices like corn futures have nonetheless risen over 60% in the past three years with correspondingly high increases in refinery operating costs and consumer prices.[21]

With the state's inherently greater exposure to transport fuel price volatility, there are no particularly promising solutions on the near-term horizon. Instead, declining in-state production of petroleum products coupled with growing reliance on foreign crude as input will only increase the state's price vulnerability. Growing shares of ethanol additives in California's restricted gasoline market also poses further concerns in the near-term unstable global market for grains and foodstuff.

Trends in Electricity Supply

As seen in the figure below, net electricity generation in California has increased in recent years, particularly by electric generators. This increase in electricity supply has been driven primarily by rapidly rising electricity demand over the past decade (see Figure 14 and 15).

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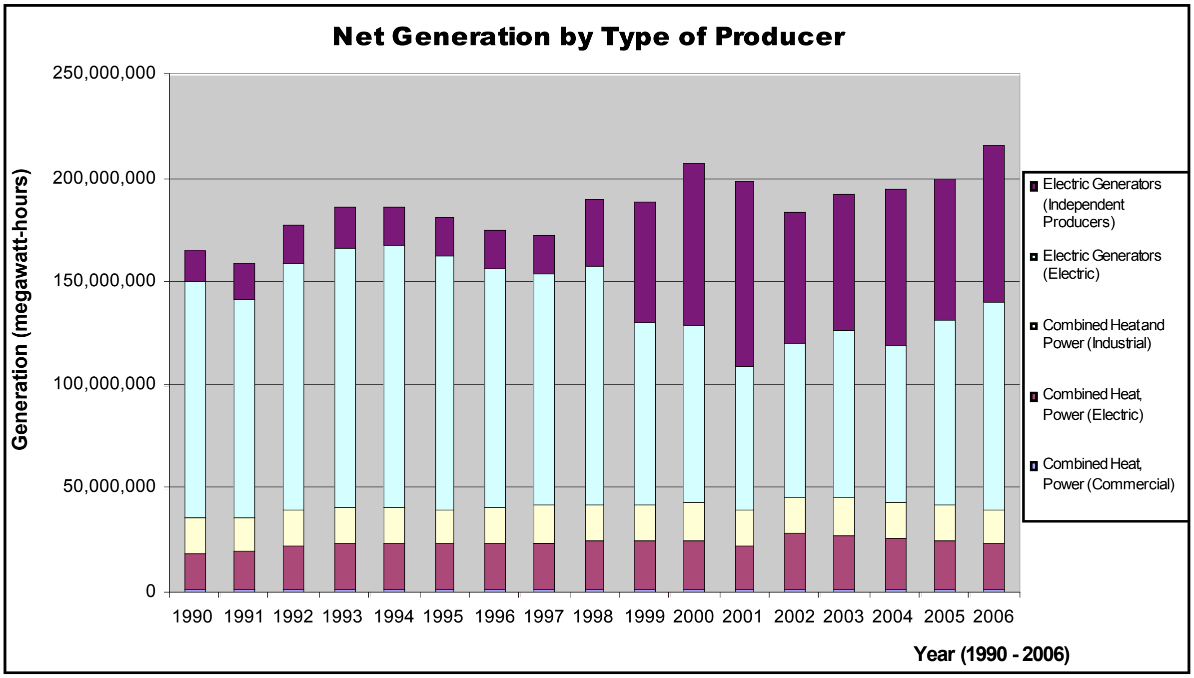
[20] EIA, State Profile of California

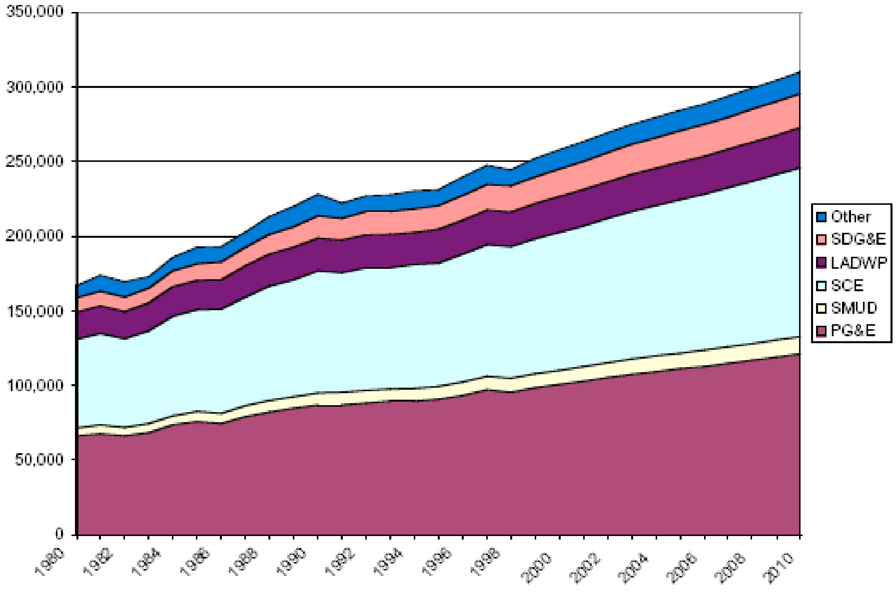
[21] http://futures.tradingcharts.com/chart/CN/M

Figure 14: Electricity Net Generation by Producer



Source: Graph generated from the DOE data
http://www.eia.doe.gov/cneaf/electricity/st_profiles/california.html

Figure 15: California Historic & Forecast Electricity Consumption by Utility Service Area (GWh)



Source: Energy Commission staff

Source: California Energy Commission, http://www.energy.ca.gov/reports/2000-07-14_200-00-002.PDF

While California leads the nation in hydroelectric power generation and other renewable power generation like solar and wind, the state still relies significantly on natural gas and imported electricity for its power supply (see Figures 16 and 17). In fact, California imports more electricity than any other state including hydroelectric-based power from Pacific Northwest and coal- and natural gas-fired power from the Southwest.

Figure 16: California Electricity Generation by Source, 2005

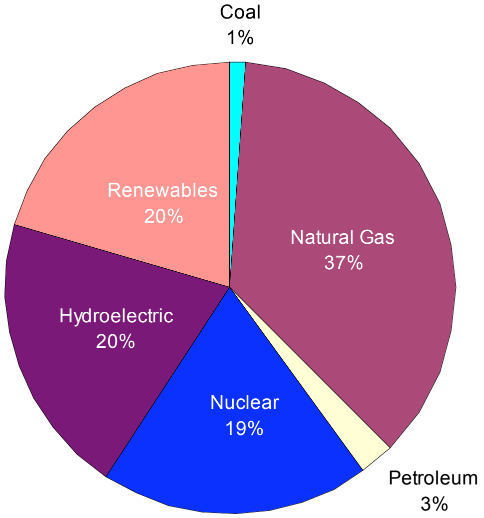
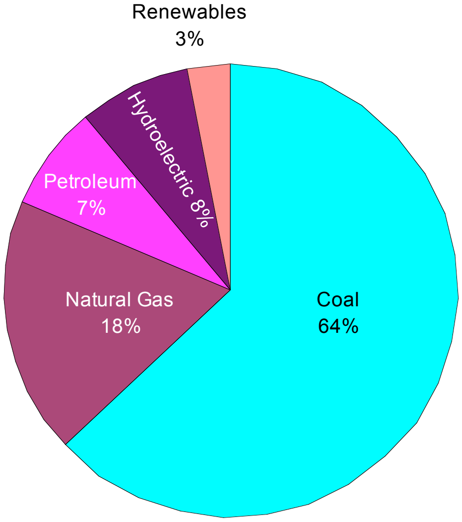


Figure 17: U.S. Electricity Generation by Source, 2005

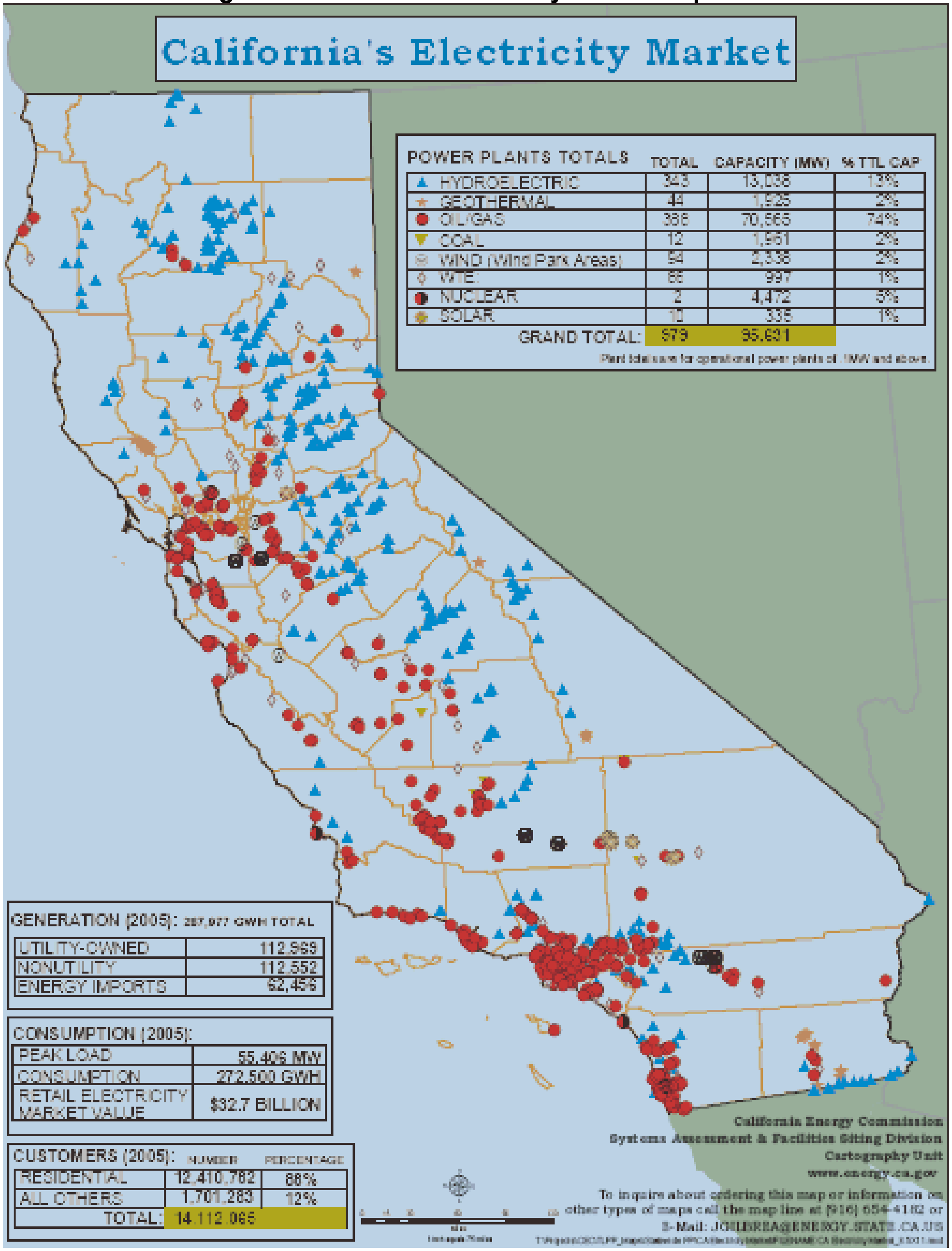


In 2000 and 2001, California's supply and demand imbalance and subsequent vulnerability to localized price instability was actualized in a catastrophic energy crisis characterized by extreme electricity price shocks and four major blackouts. Multiple factors contributed to this imbalance, including among others:

- Heavy dependence on out-of-state electricity providers
- Northwestern drought conditions that reduced hydroelectric power generation capacity
- Rupture on a major natural gas pipeline supplying California power plants
- Increased electricity demand from western states driven by strong economic growth
- Increase in unplanned power plant outages
- Increased electricity demand for air-conditioning and other cooling uses due to unusually high temperatures

Following the energy crisis, the state government created an Energy Action Plan to eliminate outages and excessive price spikes. To achieve these goals, the plan calls for optimizing energy conservation, building sufficient new generation facilities, upgrading and expanding the electricity transmission and distribution infrastructure, and ensuring that generation facilities can quickly come online when needed. Yet the state's power sector continues to face some vulnerability to price shocks, particularly in natural gas. The current situation of California's electricity market is depicted in Figure 18 below.

Figure 18: California Electricity Market Map



POWER PLANTS TOTALS

	TOTAL	CAPACITY (MW)	% TTL CAP
▲ HYDROELECTRIC	343	13,038	13%
★ GEOTHERMAL	44	1,925	2%
● OIL/GAS	388	70,565	74%
▼ COAL	12	1,951	2%
⊗ WIND (Wind Park Areas)	94	2,338	2%
◊ WTE:	66	997	1%
● NUCLEAR	2	4,472	5%
✹ SOLAR	10	335	1%
GRAND TOTAL:	979	95,631	

Plant totals are for operational power plants of 1MW and above.

GENERATION (2005): 287,977 GWH TOTAL

UTILITY-OWNED	112,969
NONUTILITY	112,552
ENERGY IMPORTS	62,456

CONSUMPTION (2005):

PEAK LOAD	55,406 MW
CONSUMPTION	272,500 GWH
RETAIL ELECTRICITY MARKET VALUE	$32.7 BILLION

CUSTOMERS (2005):

	NUMBER	PERCENTAGE
RESIDENTIAL	12,410,782	88%
ALL OTHERS	1,701,283	12%
TOTAL:	14,112,065	

California Energy Commission
Systems Assessment & Facilities Siting Division
Cartography Unit
www.energy.ca.gov

To inquire about ordering this map or information on other types of maps call the map line at (916) 654-4182 or E-Mail: JCHILBREA@ENERGY.STATE.CA.US

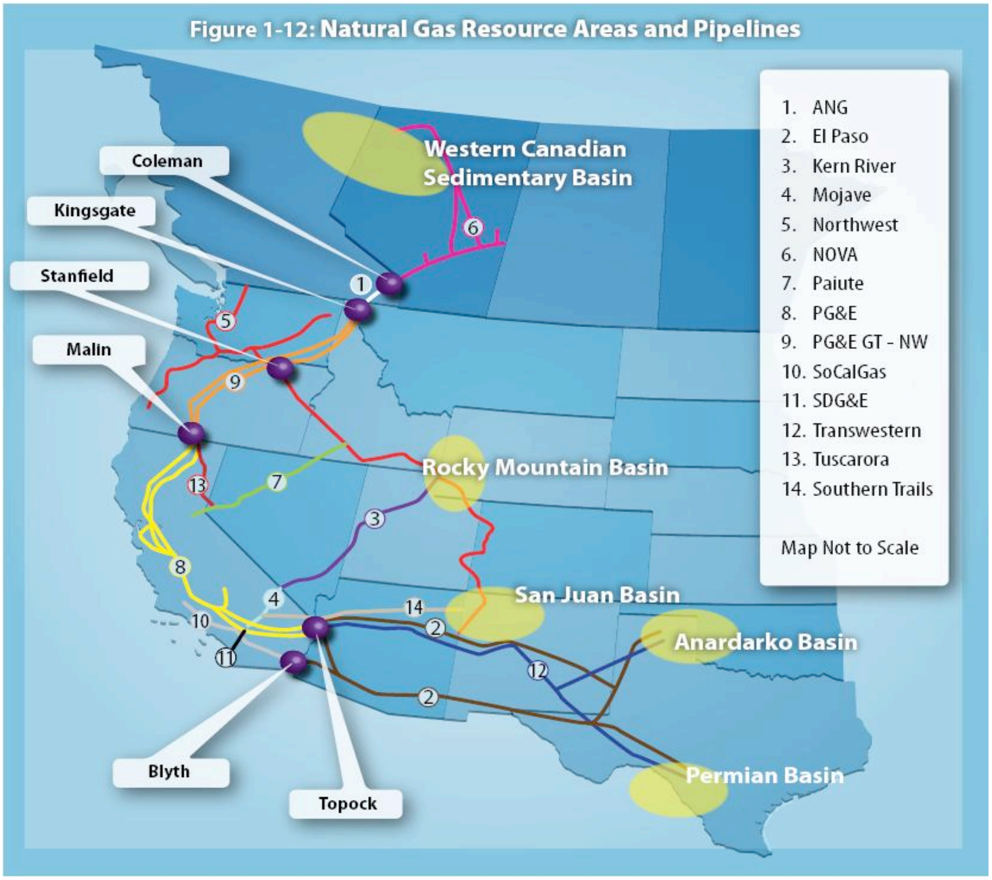
Source: California Energy Commission.

Natural Gas

In the late 1970's, concerns over air quality and rising petroleum costs prompted California utilities to switch a majority of their electricity generators from coal and petroleum to natural gas. As a result, 44% of California's electricity capacity is natural gas-fired, higher than the U.S. average. More recently, other states like Utah, Oregon and Washington have followed California's footsteps by increasing their natural gas fired generation capacities. This is due in part to rising concern over air quality and to recent decreases in hydroelectricity potential with drought conditions.

In light of these regional trends, California is increasingly competing for natural gas supplies available to the western United States delivered via pipeline particularly since it is the end destination of the pipeline network (as illustrated below).

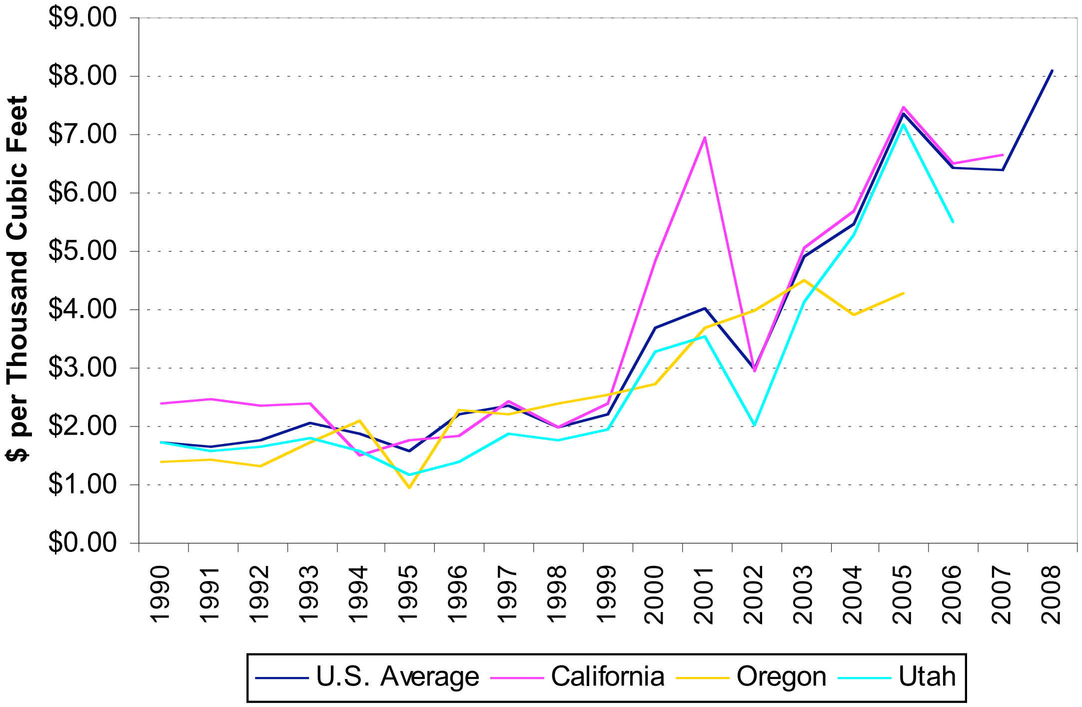
Figure 19: Natural Gas Resources and Pipelines in Western U.S.



Source: California Energy Commission.

With greater demand and limited domestic production, natural gas prices have been continuously rising with particularly fast increases since 2000. As seen in Figure 20 below, California's natural gas prices are higher than other states in the region and closely follow the growth of the U.S. average price. Following the historic price trends and with growing demand from the electricity sector, natural gas prices are forecasted to continue rising to new heights in upcoming years in base case scenarios.

Figure 20: Natural Gas Wellhead Prices, 1990 - 2008



Source: EIA, Natural Gas Navigator database.

While foreign LNG (liquefied natural gas) remains relatively cheap and is expected to become a greater share of U.S. natural gas supply (see Figure 21), it will not likely ease California's growing demand in the short run. Specifically, California currently lacks the equipment to import and store foreign LNG while harbor berth space shortage further complicates importing LNG.[22] Instead, California's efforts to minimize the impacts of volatile natural gas prices on ratepayers have focused on diversification, using renewable energy sources and promoting energy efficiency and demand-side management to reduce peak use and overages in electricity demand. The state is also considering new LNG

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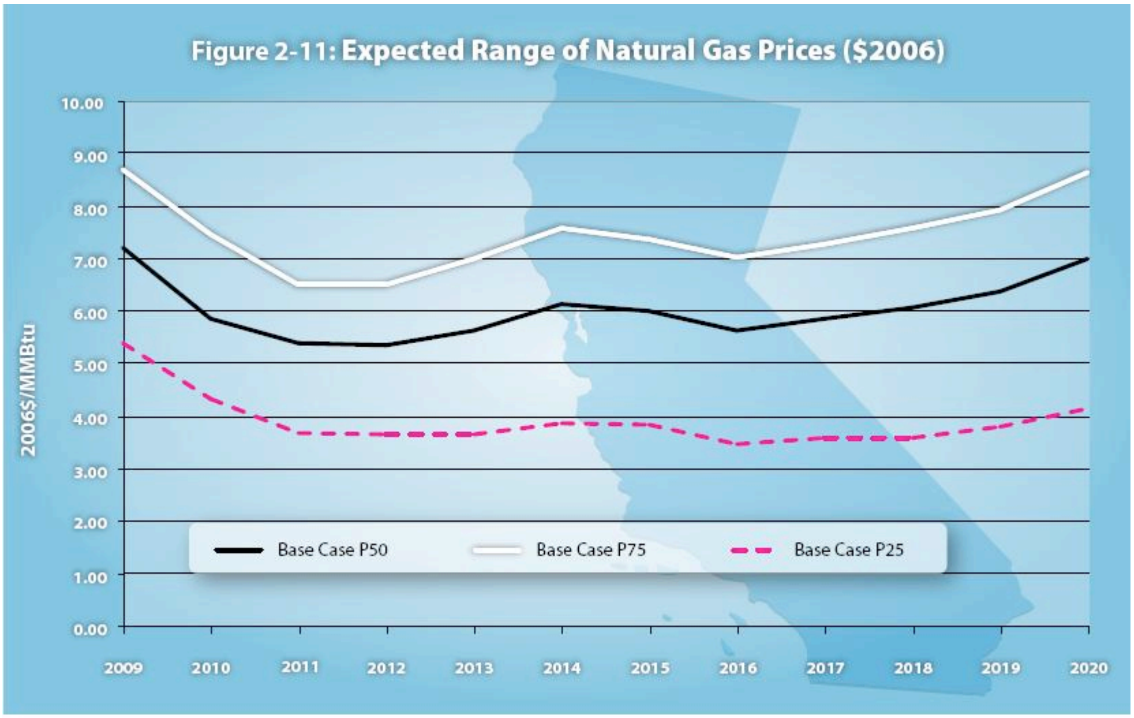
[22] California Energy Commission

infrastructure to stabilize domestic natural gas prices with more efficient capacity for imports.[23]

Figure 21: Natural Gas Price Forecasts, 2009 – 2020



Source: Global Energy Decisions, Inc.

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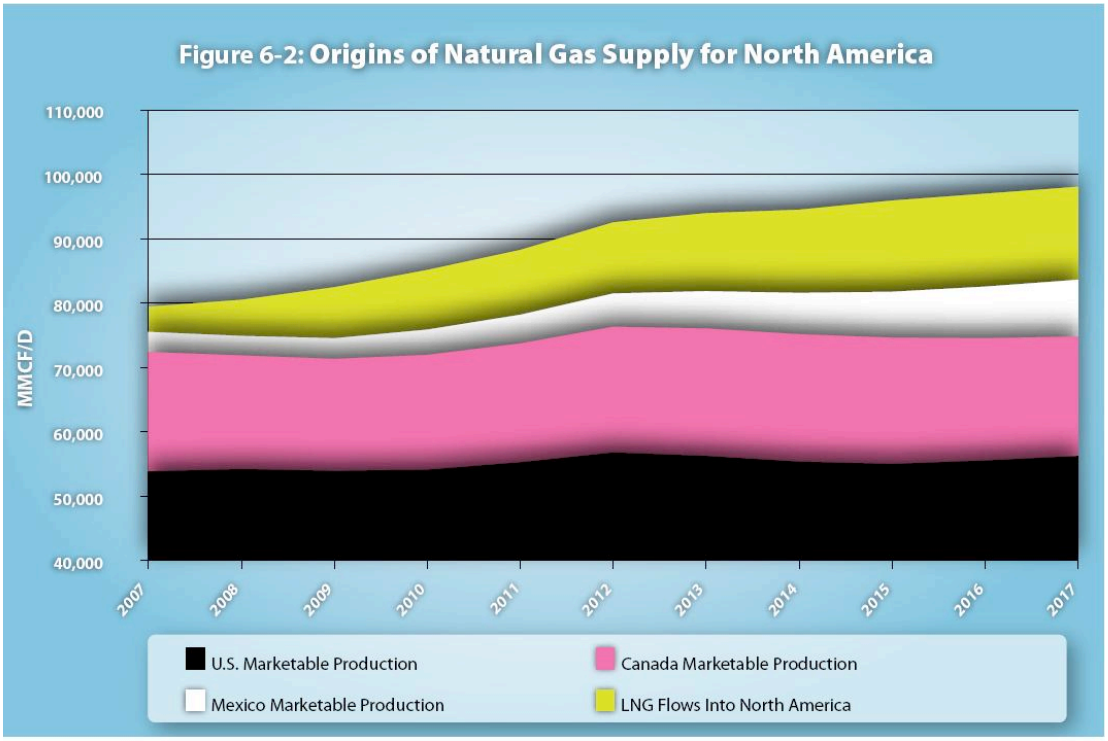
[23] California Energy Commission

Figure 22: North American Sources of Natural Gas Supply



Source: California Energy Commission.

Coal

In the past, California has limited its use of coal-fired power plants due to the massive amounts of carbon dioxide and other pollutants emitted in combustion. Although it has long been viewed as a virtually inexhaustible resource, recent estimates of real extraction cost, but both USGS and independent researchers, suggest that coal will become economically scarce in the relatively near future. What this means is that coal exploitation costs, inclusive of environmental damage aversion in extraction and use, will be rising sharply. For these reasons, it is unlikely to emerge as a significant component of California's fuel mix.

Renewable Energy Supply

Solar Background

Along with conventional energy sources, California is also endowed with a tremendous supply of solar energy as a result of environmental conditions and accumulated technological capacity. In recognizing the possibility of harnessing solar energy to provide clean and natural electricity, California has pledged to meet 33% of the state's electricity with renewable sources by 2020.[24] With its favorable geographic conditions, California has two main technological options for harnessing solar energy: photovoltaic (PV) technology and concentrated solar power (CSP) technology.

PV technology creates electricity by using PV cells to convert solar radiation directly into electricity. Besides zero emissions, solar PV technology is also advantageous in small-scale applications as PV panels require minimal space and can be installed on rooftops or other urban surfaces. California recognized this advantage when it laid out the foundation for the current California Solar Initiative in 2004 with the Million Solar Homes Plan (see Future of Solar Power section). Nevertheless, solar PV faces limitations in providing a constant power supply as it only functions with incident solar radiation and often lacks capacity to store excess energy. At the same time, because solar PV is the most effective during the afternoon hours with most direct solar radiation, it can play a critical role in displacing peak power needed for air conditioning and cooling in the summer.

CSP technology differs from PV technology both in terms of its function capabilities and technological scale. CSP generates power by first capturing intense solar radiation through reflective mirrors or lenses, often designed as parabolic troughs or dishes. The captured radiation is then used to heat water to drive steam turbines that can generate electricity. As a result, CSP applications tend to be larger-scale both in terms of its generation capacity and space requirements and thus located in more remote areas. A major benefit of CSP systems is that it can effectively store excess energy in the form of heat and produce electricity on overcast days and evenings. Therefore, CSP can be seen as more reliable with relatively cheaper and more efficient storage capabilities than PV.

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[24] CEC, http://www.energy.ca.gov/renewables/index.html

Given these two technology options' differing benefits and disadvantages, California's supply conditions and potential are reviewed to shed light on the viability of expanding the role of solar power in the state.

Solar Power Supply and Potential

Solar Photovoltaic

As of 2007, California had approximately 279.5 MW of installed photovoltaic capacity, a mere fraction of the total potential capacity that PV systems could achieve given the state's abundant solar resources. The figure on the left below shows the gross potential energy that California can harness using PV technology or a minimum of 4.25 kwh/m^2/day of solar energy across the state.[25] Considering that California has a total area of 423,970 square kilometers or 163,695 square miles, the state's theoretical PV generation capacity lays on the scale of millions of MWh/day.[26]

Figure 23: CA Theoretical PV Potential

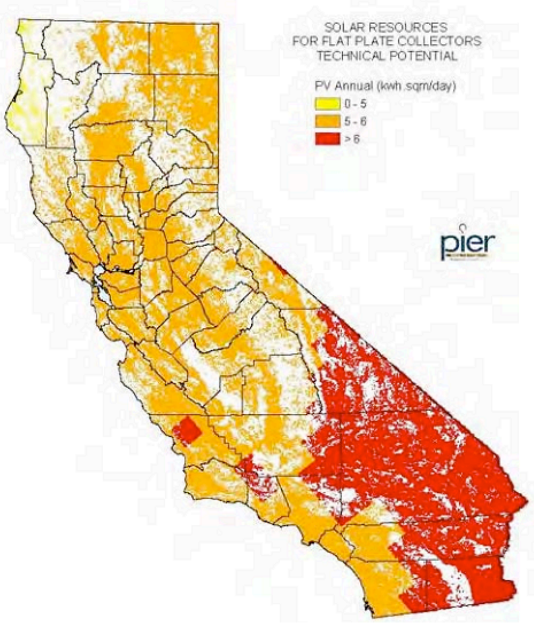
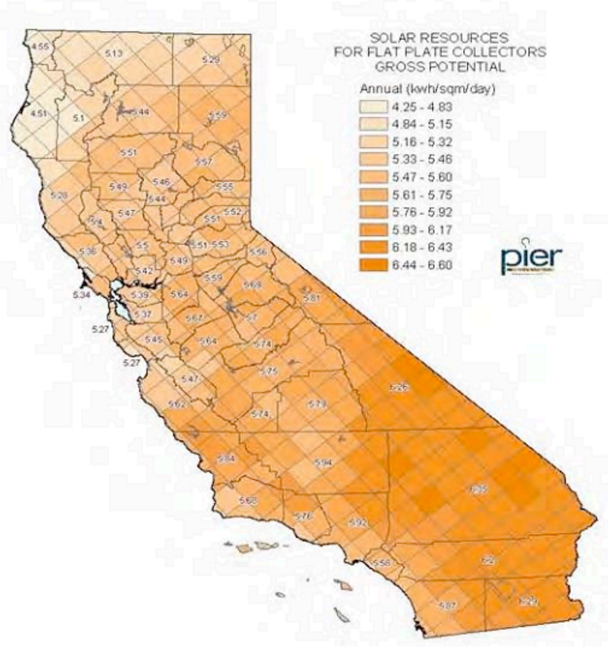


Figure 24: CA Gross PV Potential



In realistic terms, estimating California's PV generation capacity potential must also consider PV system's relatively low conversion efficiency of ten percent. By further taking into account the applicable built areas for PV installations, the

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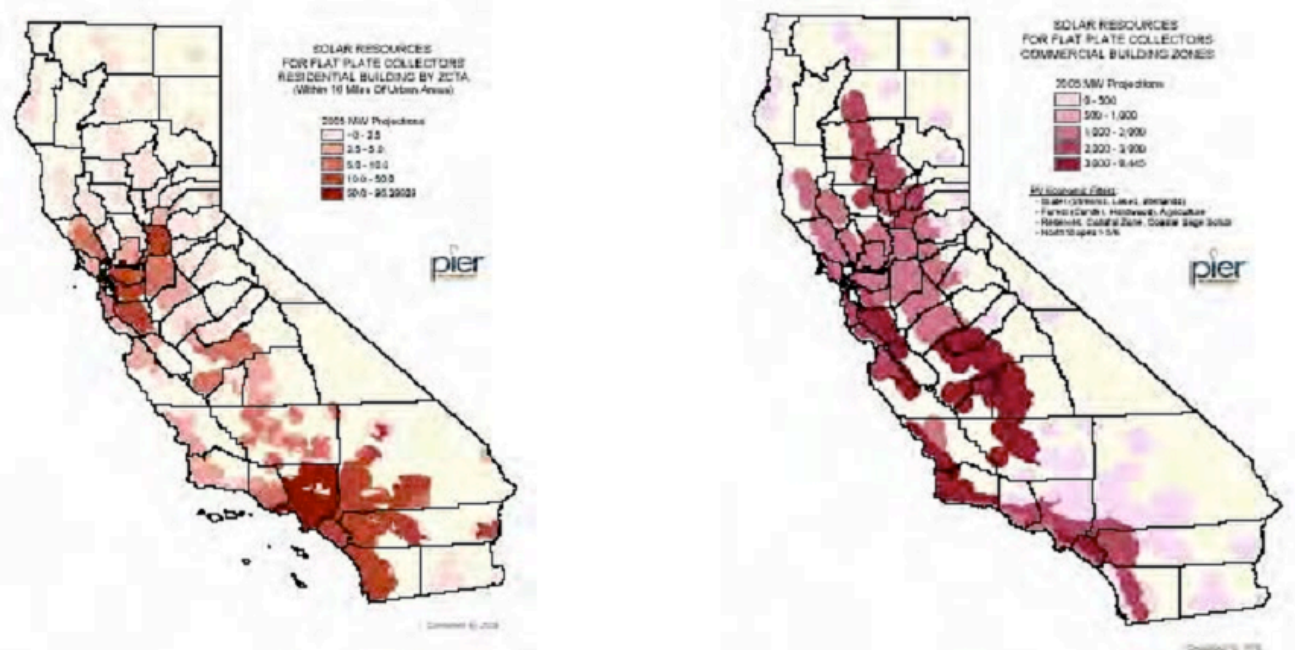
[25] California Solar Resources
[26] http://www.dof.ca.gov/HTML/FS_DATA/stat-abs/sec_A.htm

actual gross potential for California is depicted in the figure on the right.[27] Based on these additional factors, California's gross potential for PV is estimated to be 16, 822,184 MW or 100,139,176 MWh/day state-wide.

Another way of estimating California's technical potential of PV capacity is to look at specific technology options, namely solar PV rooftop systems. First, installing PV systems on California's 15 million existing homes would generate more than 38,000 MW of electricity, with concentrated potential from denser residential areas in the Bay Area, Los Angeles, and San Diego (see leftmost figure below).[28] Second, additional rooftop PV potential could be captured by installing systems on new homes in California. Assuming the typical size of a residential rooftop PV system is 2.5 kW, 430 MW of electricity could be captured from just the new homes in 2005.[29] Finally, additional technical potential of PV systems is available on the rooftops of commercial buildings. For example, the PV potential of the state from 2005 commercial building stock is a little over 37,000 MW, with greater potential concentrated near the coastal areas as seen in the rightmost figure below.[30]

Figure 25: Solar PV Potential in Residential and Commercial Buildings



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[27] California Solar Resources

[28] California Solar Resources pg. 10

[29] California Solar Resources pg. 10 (number based on 2005 new housing stock)

[30] California Solar Resources pg. 10 (2005 estimates)

In sum, California has enormous potential for generating much more power from solar PV technology. The state's installed PV capacity of 279.5 MW in 2007 clearly pales in comparison to the 75,000 MW capacity potential just from residential and commercial building rooftops. With an ambitious RPS goal of 33% by 2020 and significant untapped applicability, particularly in dense urban areas like San Francisco and Los Angeles, solar PV systems will likely play an increasing important role in supplying California's future electricity supply.

Concentrated Solar Power

To better understand California's CSP potential, it is important to differentiate between the different types of existing technology including parabolic troughs, power towers, and parabolic dish/heat engines. As previously mentioned, parabolic trough and power tower systems both use solar radiation to produce steam and drive turbines to generate electricity. Parabolic dish/heat engines, in contrast, use high temperature solar thermal energy to drive small engines located in the focal point of the dish.[31]

Parabolic Trough

As the only CSP technology utilized by California, a total of nine parabolic trough systems are in operation. Five of these parabolic trough systems are located at Kramer Junction in the Mojave Desert, with each having a capacity of 30 MW. The other four plants are also located in the Mojave Desert, with two additional plants with combined capacity of 40.8 MW in Daggett and another two with greater combined capacity of 160 MW in Harper Dry Lake. Altogether, these nine plants bring a total of 354 MW in parabolic trough generation capacity to California.[32]

Power Tower Facilities

This system uses a circular array of mirrors to focus sunlight onto a central power tower, which produces and supplies steam to a steam turbine power plant. This technology is currently in the experimental stage but commercial plants are expected to have capacities ranging from 30 to 200 MW. Like parabolic troughs, solar power towers also provide cost-effective thermal energy storage and thus can operate in the absence of solar radiation.

Parabolic Dish Engines

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[31] California Solar Resource pg. 13

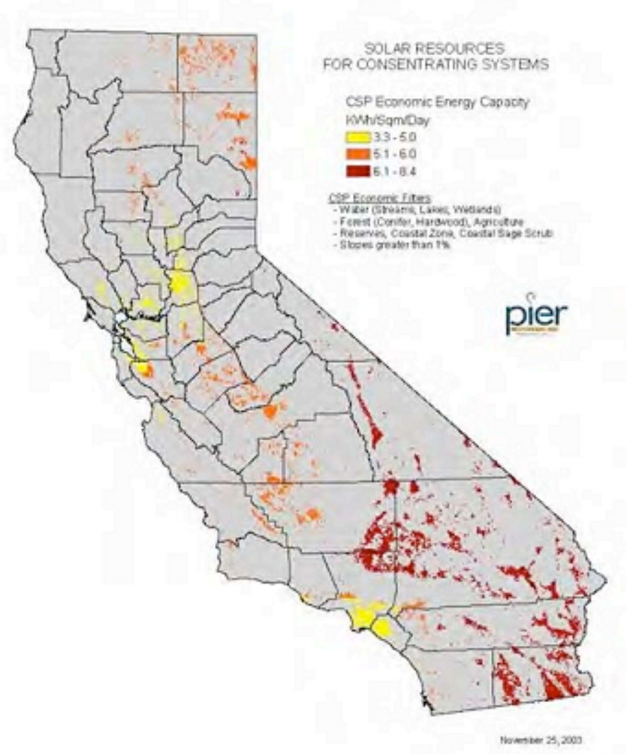
[32] Energyalmanac.ca.gov/electricity/solar_generation.html

Similar to power tower facilities, parabolic dishes also concentrate the sun's radiation on a small steam powered engine located above the dish. California currently has two parabolic dish units in Huntington Beach, but only in the developmental stage. Once in operation, these two units are expected to have a generation capacity of 5 kW to 25 kW.

CSP potential

Because CSP requires high concentrations of direct solar radiation and are most effective in desert-like conditions, California's southeastern portion of the state is an ideal location. However, more specific assumptions are needed to estimate areas in California feasible for future CSP development, including appropriate solar incidence and space limitations. For instance, since CSP systems require a certain amount of sunlight to operate, only areas with solar radiation greater than 6 kWh/day/m^2 can be considered feasible. Areas that include bodies of water, national parks and other ecologically sensitive areas must also be excluded. The figure below shows the areas that satisfy these conditions, with dark red areas confirming that most of the technical potential of CSP energy capacity is located in southeastern California deserts. Based on these factors, it is estimated that California has a technical potential CSP capacity of 1,061,361 MW.

Figure 26: CSP Potential in CA



Like PV systems, CSP systems also have a large untapped potential in California with only 354 MW of currently installed capacity. This suggests that large expansion of CSP is possible before approaching the state's technical potential. In fact, Southern California Edison utility recognized CSP's potential in the region in 2008 by signing a power purchase agreement with eSolar™ to build 245 MW CSP plants in the Antelope Valley region for operation by 2011.[33] Furthermore, advanced technology like thermal energy storage systems that increase power plant productivity can further expand the state's technical potential.

CSP has an additional benefit in its possible impact on employment generation, particularly in the context of the current economy. For example, a 2006 National Renewable Energy Laboratory (NREL) study in collaboration with Black & Veatch modeled positive economic effects of CSPs for California. The study used two possible deployment scenarios: a low scenario of 2,100 MW and a high scenario of 4,000 MW of cumulative CSP by 2020. The low deployment scenario represents about ten percent of the California's RPS requirement for IOUs while the high deployment scenario represents about 20 percent of the RPS requirement. Their findings, as summarized below, indicate gains in earnings and employment in both CSP facility construction and operation.

Table 7: CSP Expansion's Potential Economic Impacts on CA

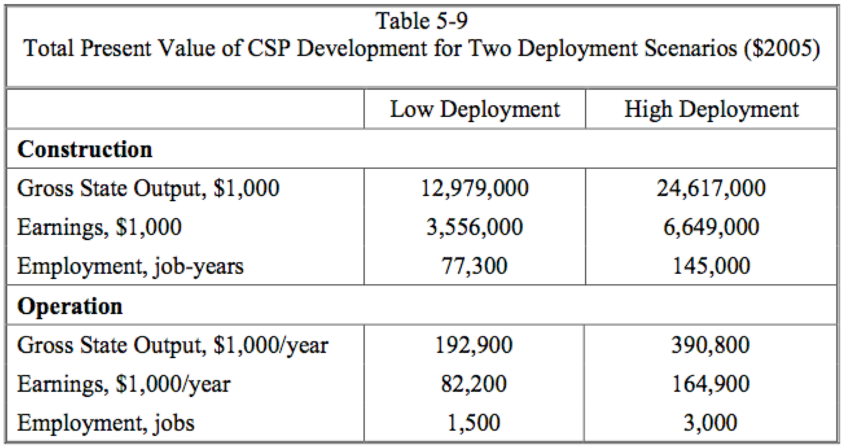


Table 5-9
Total Present Value of CSP Development for Two Deployment Scenarios ($2005)

	Low Deployment	High Deployment
Construction		
Gross State Output, $1,000	12,979,000	24,617,000
Earnings, $1,000	3,556,000	6,649,000
Employment, job-years	77,300	145,000
Operation		
Gross State Output, $1,000/year	192,900	390,800
Earnings, $1,000/year	82,200	164,900
Employment, jobs	1,500	3,000

Source: Stoddard et. al., NREL report.

For the low deployment scenario, the study showed $3.556 billion would be generated through construction earnings with an additional $82.2 million in operation earnings. This translates into 77,300 job-years for the construction sector and 1,500 new jobs in CSP facility operations. The high deployment scenario, with nearly doubled CSP installed capacity brings doubled output, earnings and employment for both construction and operational sectors.

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[33] http://www.esolar.com/news/press/2008_06_03

Therefore, with ideal conditions in the Mojave Desert and existing plans for expansion, CSP systems will undoubtedly remain a viable candidate for providing clean and renewable power for California.

Future of Solar Power in California

Based on the overview of solar technology utilized in California and estimates of the state's vast technical and gross potential capacity, it is clear that the state has the potential to harness and expand solar power to meet the population's growing energy needs. In particular, California produced 295,268 GWh in 2006 with only 616 GWh from solar (Simons and McCabe:2005). In comparison, over 100,000 GWh of energy was produced from fossil fuel resources such as coal, oil, and gas. Therefore, California stands to benefit from increasing its solar capacity and concurrently lowering its reliance on unclean and non-renewable sources of energy. While the extent to which California will use its solar resources ultimately depends on economic conditions and policies, several solar programs and initiatives are already in place for expanding the state's solar power generation capacity.

In particular, the statewide Go Solar California campaign launched by Governor Schwarzenegger in 2006 aims to install 3,000 MW of new solar electricity capacity by 2016. Using its $3.3 billion budget, the program is focused on developing the market for solar power by providing incentive schemes to reduce the cost of solar. For customers serviced by California's major investor owned electric utilities (IOUs) Pacific Gas and Electric Company (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDGE), the two major programs are the California Solar Initiative (CSI) and the New Solar Homes Partnership (NSHP). The goals and progress of these two programs are presented below. There is also a separate Publicly Owned Utilities (POU) program, which requires each municipal utility to offer a solar incentive program. This program has a budget of $784 million for 2007 through 2016 and a goal of adding 700 MW installed solar capacity by 2016.[34]

California Solar Initiative

The California Solar Initiative (CSI) was initiated in January 2007 and provides financial incentives to solar PV customers in the IOU service territories. Specifically, the CSI offers rebates for solar installations based on their expected performance in residential, commercial, industrial, government, nonprofit, and

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[34] Final CSI Jul 08 Progress

agricultural properties. The program has a total budget of $2.167 billion for 2007 through 2016 with a goal of reaching 1,940 MW of solar capacity by 2016.[35]

The implementation of this program has dramatically increased the installed on-grid photovoltaic capacity statewide, as shown in the figure below. In 2007 alone, California increased PV capacity by 81 MW. The growth was even more dramatic in the first six months of 2008 as PV capacity increased by 59.4 MW. As a result, this program has increased California's PV capacity by 138 MW from January 2007 to July 2008. If this trend continues, the CSI program is expected to add an additional 100 MW of installed PV capacity in 2008, putting California on track to meeting its 2016 goal.

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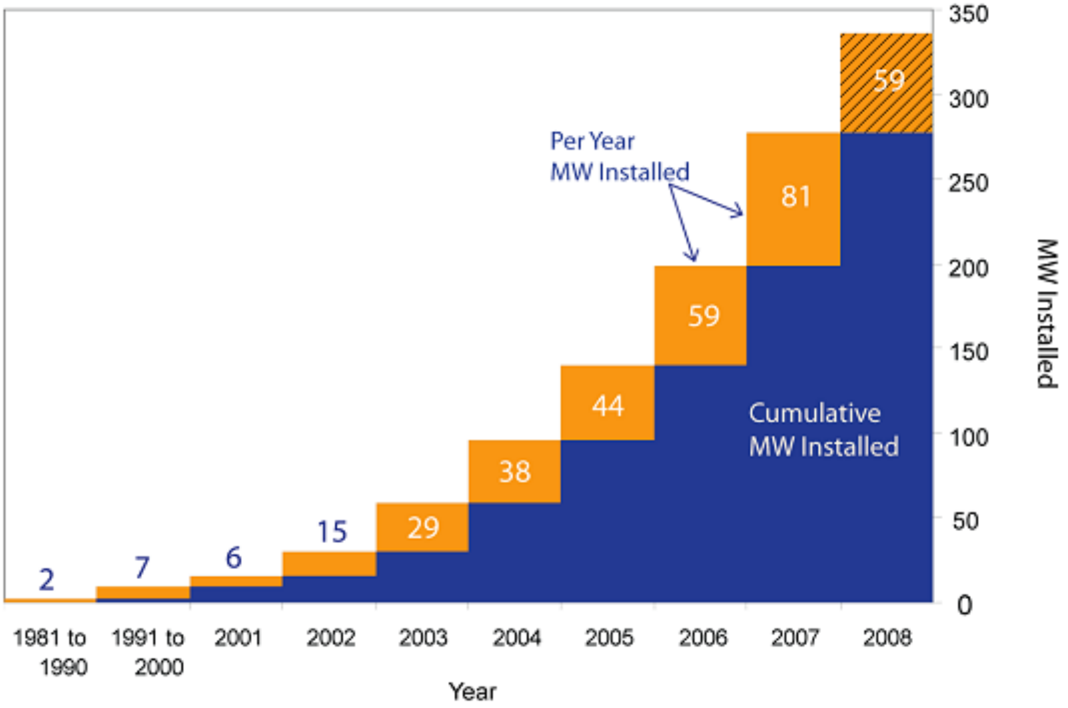
[35] Ibid.

Figure 27: Trends in Installed Solar Capacity in California



Source: Final CSI July 2008 Progress. The orange box represents marginal increases in MW of installed solar capacity for a given year. The shaded orange box over 2008 consists of only the data from the first half of 2008.

New Solar Homes Partnership

This program is designed to promote solar energy in new home construction within the PG&E, SCE, and SDGE service territories. It has a ten year budget of up to $400 million and a goal of 360 MW by 2016.[36] The NSHP program provides financial incentives and other support to home builders to encourage the construction of new, energy-efficient solar homes. In 2007, there was an increase of 8 MW of installed solar under the NSHP. The NSHP program currently serves 23 new construction communities in the state, primarily in Northern and Southern California with five communities in the Central Valley region.

Progress towards 2016 Goal

In spite of the success of the CSI and NSHP programs, it is still unclear whether California will be able to meet its ambitious goal of adding 700 MW of installed solar capacity by 2016. In a recent report prepared for the California Energy Commission, analysis by Navigant Consulting showed that California would

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[36] Ibid.

unlikely meet its 2016 goal without additional programs, policies and more aggressive incentives and business models. Even with current initiatives like NHSP and CSI, PV systems are still too expensive relative to conventional electricity and not economically competitive enough to stimulate significant market penetration. More specifically, Navigant models forecast that only 518 MW of additional installed solar capacity would be reached by 2016 under Business-as-usual scenarios. With new business models and existing incentives, the goal would remain unmet as only 1,752 MW would be reached by 2016 (Figure 27).

In contrast, the 2016 goal could be met with 4,384 MW of additional installed capacity if new programs and policies establish a two-tier approach that aggressively expand market adoption (see Figure 27). Specifically, this approach would need to make solar PV more competitive by dramatically reducing the cost of PV systems while streamlining the deployment and packaging of these systems with new business models. As highlighted in this scenario example, California needs to not only continue expanding its current programs and incentives but also pursue more aggressive policies and programs if the state is to meet its ambitious renewable goals by expanding its installed solar capacity.

Wind Background

As California's growing need for sustainable, clean, and efficient energy is mirrored in the launch of a new comprehensive state-wide solar initiative, wind power has remained the fastest growing energy source both within the U.S. and California. While wind-powered energy has been predominantly used in Europe, the U.S. has increased its wind energy grid more than any other country in recent years (see Figure 28). From 2000 to 2005, the U.S. wind industry grew 29 percent and jumped from being third to first in total national wind energy output from 2005 to 2008.[37] With the retail price of wind power already comparable to conventional electricity at between 4.5 to 7.5 cents per kWh, a survey by the American Wind Energy Association will highlight the U.S. as the world's largest market for wind.

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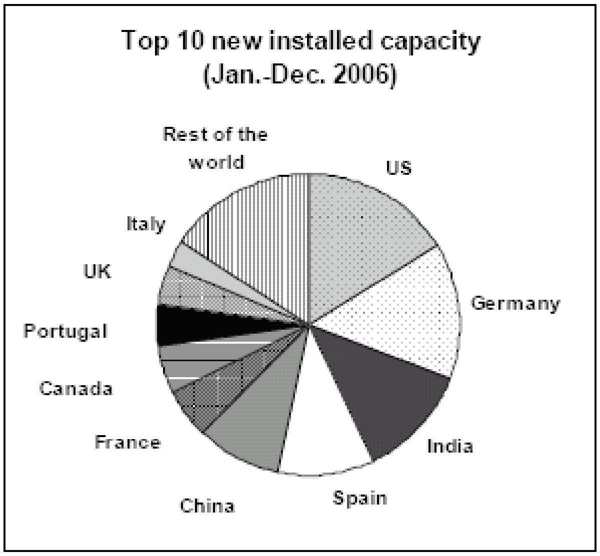
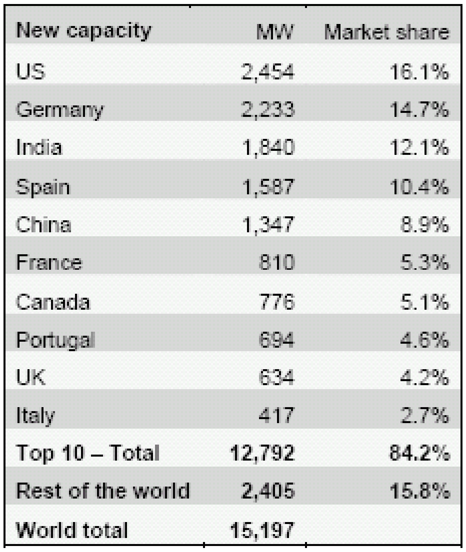
[37] Moskowitz, Clara. "U.S. Takes Global Lead in Wind Energy Production." LiveScience. URL: http://www.livescience.com/environment/080723-us-wind-energy.html

Figure 28: U.S. Installed Wind Capacity in International Context





New capacity	MW	Market share
US	2,454	16.1%
Germany	2,233	14.7%
India	1,840	12.1%
Spain	1,587	10.4%
China	1,347	8.9%
France	810	5.3%
Canada	776	5.1%
Portugal	694	4.6%
UK	634	4.2%
Italy	417	2.7%
Top 10 – Total	12,792	84.2%
Rest of the world	2,405	15.8%
World total	15,197	

Source: GWEC, 2006

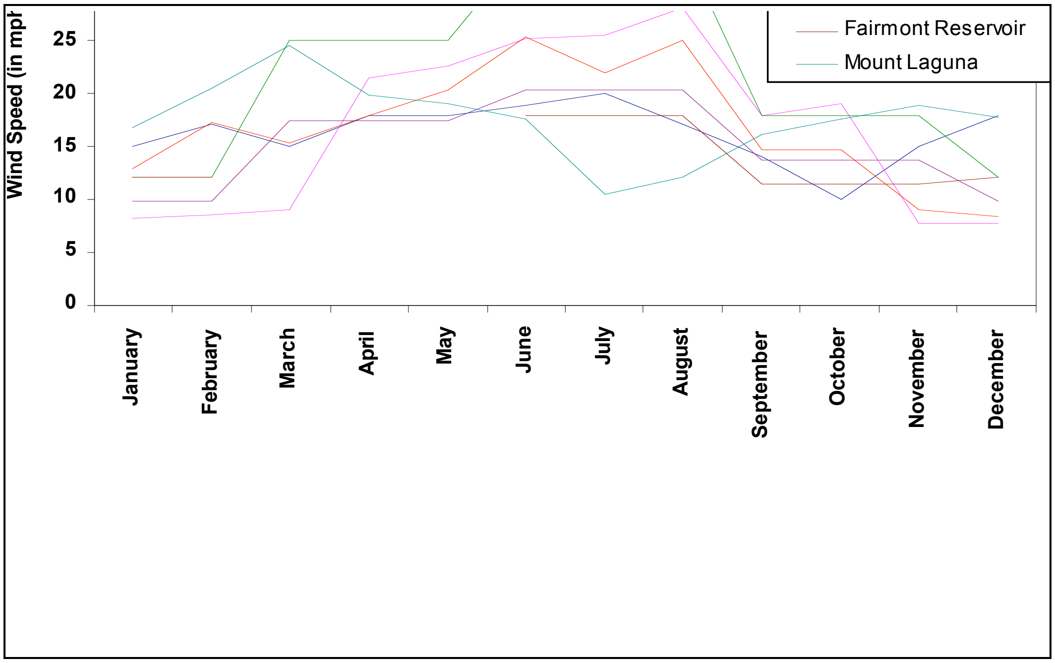
The growth of wind power can largely be attributed to its advantages as a renewable resource with clean power generation and its relatively lower cost compared to other renewable energy sources. On the other hand, wind power faces similar shortcomings to solar as an intermittent resource with limited capacity, predictability and reliability in the absence of energy storage. These concerns have been made the subject of recent studies that map out wind patterns, forecasts, and scheduling in attempts to hone in wind's viability as a growing energy source.

Mechanical energy from wind motion is converted to electrical energy through two basic types of applications, utility-scale wind farms including offshore wind farms and small-scale distributed wind generators.

Utility-scale Wind Farms

Utility-scale wind farms consist of wind turbines, an underground power transmission system, control and maintenance facilities and a substation with a connection to the power grid. These wind farms are generally located in areas with average annual wind speeds of at least 13 miles per hour, though California's spring and summer seasons tend to produce greater output with higher winds (see Figure 29). Although there are currently few in operation, wind farms can also be located offshore in water, with shallow water being the most economically favorable.

Figure 29: Monthly California Wind Speeds



Source: www.repp.org, www.crest.org

Distributed Wind Systems

Small-scale distributed wind systems refer to systems that range from 1 to 25 kW of installed capacity. These systems can provide on-site power using stand-alone or grid-connected configurations. In 2001, the number of small-scale wind farms in California already reached 3,958 turbines.

From a technical standpoint, there is also concern about wind energy's reliability and predictability in terms of constant power supply. For instance, in order to deliver constant and reliable energy to the state, all wind generators must be backed with fossil fuel burning generation. Unlike solar, wind power generation also faces an additional challenge of not coinciding with peak hours of electricity consumption in the afternoon. However, some scholars believe that this can be resolved with multiple, interconnected wind farms to reduce the delivery distance of electricity and smooth out delivery.[38]

Wind Power Supply and Potential

Within the U.S., California has remained a leader not only in working towards its ambitious RPS goal with expansion of solar generation capacity, but also in its rapid deployment of wind power. The U.S. installed 5,216 MW of new wind capacity in 2007, while California alone installed 108 MW of new capacity in

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[38] http://www.sciencedaily.com/releases/2007/11/071121144907.htm

2008. Despite ranking 17 among states for wind potential capacity, California is second only to Texas in total existing wind power capacity. Currently, wind power generation utilities are found in five major areas of California: Altamont Pass, Solano, Pacheco Pass, Tehachapi Ranges, and San Gorgonio Pass. Altogether, the top six California wind plant operators supply about 80% of the state's 1,609 MW of total installed capacity. In recent years, virtually all major wind operators in California have increased their specific yield with each converging around 800 kWh/m2/yr since 1999. The similar performances amongst Cannon, Kenetech, SeaWest, and Zond operators are particularly interesting given inherent differences in company equipment, management styles, wind resources, and terrain.

As wind operators increase their yield, the major IOUs in California such as PG&E, SCE, and SDGE are correspondingly increasing the use of wind power in their electricity supply mix (see Figure 29 and Figure 30). In 2008, the anticipated share of wind-generated power in each company's total power supply stood at 2%, 3%, and 3% respectively. In July of 2008, PG&E also signed a long-term purchase agreement with Rattlesnake Road Wind Power, a subsidiary of Horizon Wind Energy, for an additional 130 MW of installed wind capacity.[39] The growing shares of wind power is beginning to help California shift away from traditional fuels, with wind power reducing natural gas use for power generation by about 5% in 2007.

In terms of potential, most of the wind resource potential in California is located along the coasts, which is a geographic advantage over solar resources since higher and denser population is also concentrated along the coasts. The CEC estimates that wind generated electricity can supply 3.5 billion kWh, or enough to power over 530,000 homes with average annual household electricity consumption of 6,500 kWh.

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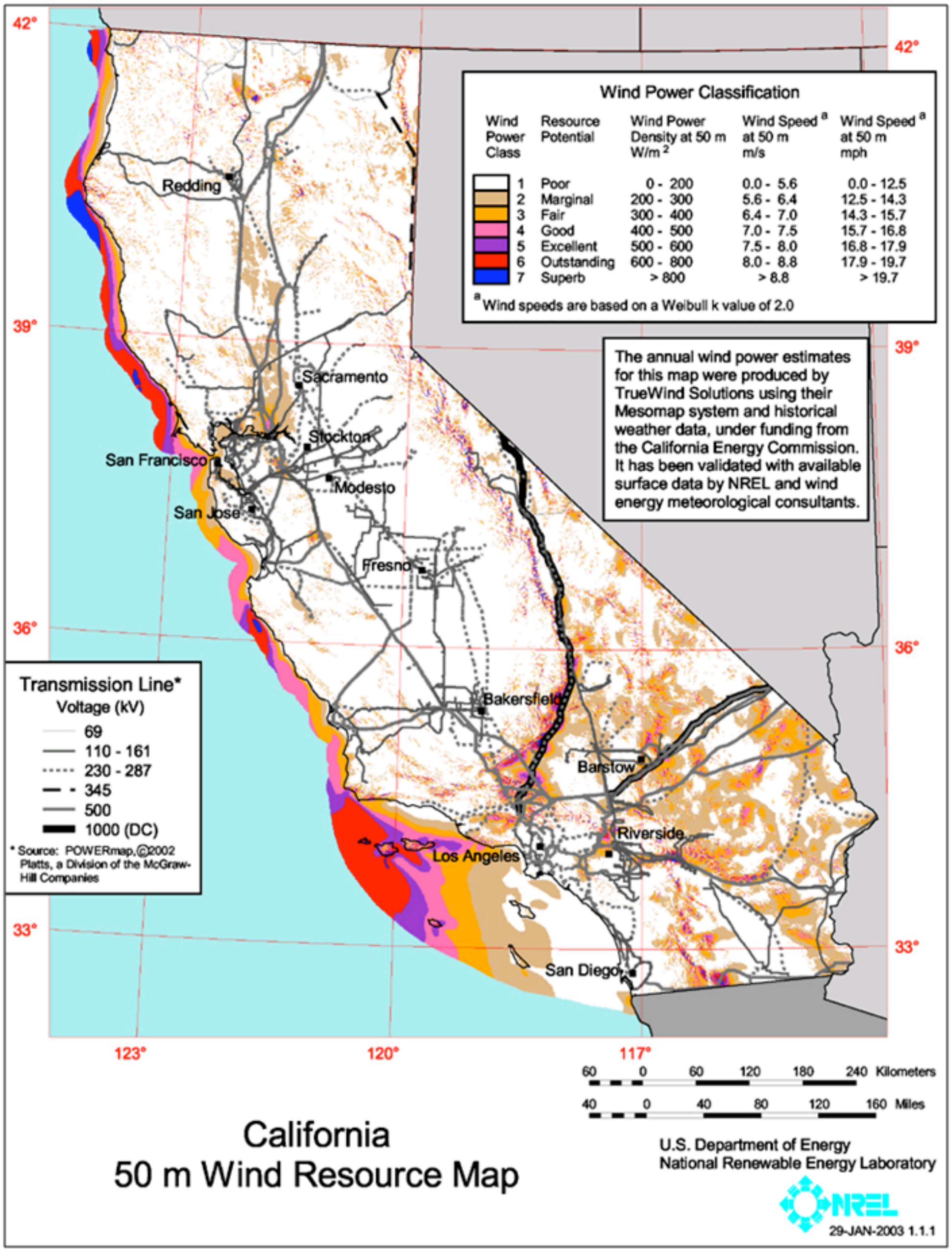
[39] http://www.reuters.com/article/pressRelease/idUS154165+01-Jul-2008+PRN20080701

Figure 30: California Wind Resource Map (at 50 meters)



Another source of wind power that could play a significant role in meeting California's electricity demands is offshore wind power. To evaluate this potential, Stanford researchers recently examined the potential in three key offshore wind resource areas, Northern California, San Francisco Bay Area, and Southern California. Based on wind farm operation tests at different water depths in each of the three locations, researchers found that Northern California could provide 11 TWh of wind energy per year. On the other hand, the Bay Area and Southern

California were “less than ideal” for harvesting wind energy due to existing marine life at shallow depths and greater wind intermittency, respectively. These impediments would require the Bay Area region to develop floating turbine support structures, while the Southern California region would require more validation of wind scheduling.[40] Nevertheless, with the development of transmission capacity, off-shore wind harvests can replace as much as 6.3 percent of carbon-emitting electricity sources. As a result, PG&E has started looking into ocean wave-energy projects in Northern California.

Future of Wind Power in California

With the growing role of wind power and the state’s goal of increasing renewable generation, California has taken different steps to ensure wind’s continued role in the state’s electricity supply. California’s RPS, for instance, serves as a major impetus for utilities to increase their share of wind power in the power mix by requiring retailers to use renewables like wind to meet a minimum percentage of their electricity. Although the cost of building wind facilities is currently still higher than fossil-fuel plants, there have also been major federal and state subsidies and tax credit incentives for wind farms.

Beginning in 2004, the California Independent System Operator (CAISO) released the Participating Intermittent Resources Program (PIRP) to better integrate intermittent resources of wind farms and generators. By empowering all market wind power suppliers and integrating and standardizing their operational abilities, this program helped increase their competitiveness in the energy market. Furthermore, by collecting data and resources, PIRP can remediate wind’s intermittency by forecasting production needs based on hourly data.[41] In essence, wind speed, direction, air temperature, barometric pressure, and aggregate generation data gathered from across meters can help “schedule” production of electricity and to route this energy where needed. As of 2005, CAISO had incorporated eight different wind power projects in San Gorgonio and Solano counties, with over 345 MW of energy in capacity.

On the small-scale, the supply of wind-powered electricity generation is also highly encouraged through tax credits, subsidies for installment, and net metering

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[40] Dvorak, Michael J. and Jacobson, Mark Z. and Archer, Cristina L. “California Offshore Wind Energy Potential.” Stanford University. URL: http://www.stanford.edu/~dvorak/papers/offshore-wind-ca-analysis-awea-2007.pdf

[41] CAISO. “Incorporation of Wind Power Resources into the California Energy Market.” URL: http://www.caiso.com/docs/2005/04/05/2005040508370111356.pdf [See Appendix H.]

laws. First, state law AB 1207 ensures that homeowners, farms, and small businesses cannot be "unreasonably" restricted from their ability to use small wind energy. Second, California's net metering law requires IOUs and rural cooperatives to allow up to 1 MW of unused energy in customer reserve. This is important because net metering allows customers to receive value for the electricity produced by intermittent wind and to "store" this energy on the power grid without battery storage systems or other energy meters.

The California Wind Energy System Credit was also approved in 2001 to incite further wind power facilities and to regulate facilities' standards. This law grants credits for up to 7.5 percent of net installed system cost after deducting the value of any municipal, state, or federal financial incentives, or about $4.50 per watt of peak generating capacity. With this credit, small businesses will more likely find it in their interest to generate their own electricity. Finally, logistical support for property owners to install small-scale windmills and turbines to harness wind energy is also provided through by local workshops, courses, and websites. A list of existing wind projects in California is included in Table 17.

Despite all the recent efforts, California still may not be able meet its RPS goal of 20 percent renewable power by 2010. This has not only been reported in the media, but the CPUC's second quarterly report in 2008 has also suggested that the achievement of this goal may need to extend to 2012 or 2013.[42] In recognizing the challenges to maximizing California's potential for wind power supply while meeting the approaching RPS goals, the CEC has identified these different focus areas for restructuring and improving wind facilities:

- Allow operation at a minimum net load of between 18,000 to 20,000 MW in combined in-state generating resources and power exchange agreements,
- Optimize the use of pumped storage hydro to integrate variable renewable energy generation,
- Target in-state generating resources for providing scheduling flexibility hourly,
- Maximize the California power grid for load increase of 12,000 MW over three hours and a maximum evening load decrease of 14,000 MW over three hours,
- Consider allowing import and export scheduling to occur more frequently and at times other than simply on the hour,
- Maintain and consider other means of regulation capability,

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[42] "State utilities to miss energy deadline." URL: http://www.sfgate.com/cgi-bin/article.cgi?file=/c/a/2008/08/02/MN281240PJ.DTL

- Expand ancillary service markets, incentives, and requirements to resolve operational flexibility and to reduce costs and revenue reductions on generation providers,
- Renew or renegotiate long-term contracts for increased grid flexibility and adequacy,
- Project, monitor, and evaluate the production life of plants in the face of competition from new resources, renewables or other means, and
- Measure, verify, and catalogue the flexibility characteristics of individual generating resources.

As California continues to develop its wind resources, some have criticized the ambiguity of publicized data on wind capacity in California. These critics are concerned that state data seems to rely heavily on reported data from wind companies, which may face consistency issues due to staff turnover, lack of cooperation, and blatant non-reporting.[43] However, even critics have acknowledged that underreporting of wind farms in California may simply be the result of the rapid growth of small turbines across the state. Furthermore, a 2006 California State University telephone survey commissioned by FPL Energy found that Californians "overwhelmingly" favor wind energy with 83 percent favoring expansion of production throughout the state, and 96 percent supporting wind power in the renewable energy mix.[44]

With general public support and concentrated resources in Northern and Southern California coasts, wind power will thus likely continue to be a major player in the state's renewable power mix. Wind power generation could also serve as an important complement to solar power generation with differences in the location of greatest potential, geographic requirements, storage capabilities and cost.

Economic Benefits of Expanding Renewable Energy Supply

Besides their environmental benefits, renewable energy as a more labor-intensive industry has often been praised for generating new employment opportunities. As a result, many studies have been conducted in the past few years to explore the employment implications of renewable energy, on both technology-specific and industry-wide levels. In general, these studies have found that solar and wind energy generation both have higher employment

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[43] Gipe, Paul. "California Updates Wind Stats—Finally." WindStats, 2002. URL: http://www.wind-works.org/articles/lg_ws0202.html

[44] "Californians overwhelmingly support wind power." URL: http://www.fplenergy.com/news/contents/2006/091906.shtml

generation rates than conventional fossil fuel energy generation but that the rates will decrease over time.

Employment Generation Rates

As early as 2000, the Renewable Energy Office of the CEC published an estimate of the amount of renewable energy under construction since 1996 and likely to come online in the near future. The CEC found that 470 MW of clean renewable energy was in some stage of development or planning. Their estimates of employment gains and changes in employment rates for wind, geothermal and landfill/digester gas are summarized below:

Table 8:

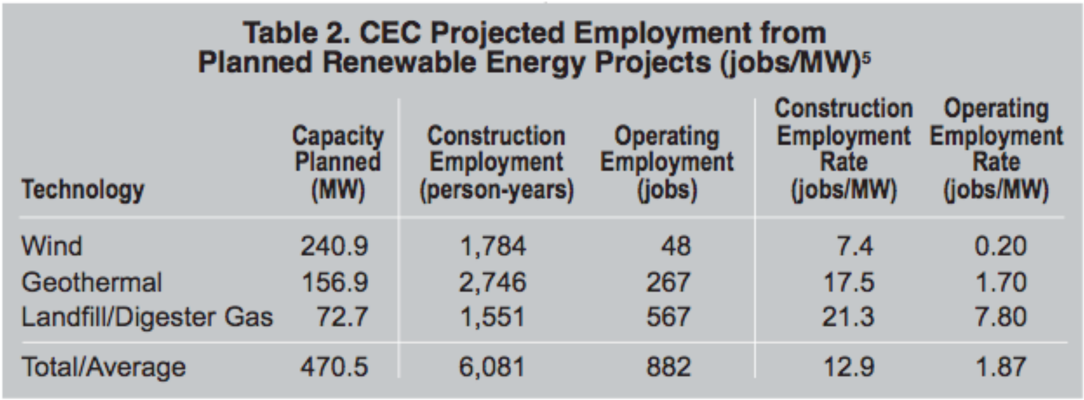


Table 2. CEC Projected Employment from Planned Renewable Energy Projects (jobs/MW)[5]

Technology	Capacity Planned (MW)	Construction Employment (person-years)	Operating Employment (jobs)	Construction Employment Rate (jobs/MW)	Operating Employment Rate (jobs/MW)
Wind	240.9	1,784	48	7.4	0.20
Geothermal	156.9	2,746	267	17.5	1.70
Landfill/Digester Gas	72.7	1,551	567	21.3	7.80
Total/Average	470.5	6,081	882	12.9	1.87

In 2002, the Electric Power Research Institute (EPRI) expanded on this work in a comprehensive study commissioned by the CEC's Public Interest Energy Research Program (CalPIRG). Because employment data for many renewable energy facilities are proprietary and confidential, it is often difficult to estimate the real-life employment creation potential of renewable energy. However, this study was able to collect and use data from a sample of six companies to estimate actual employment implications and compare future projections (see Table 9).

More importantly, the CalPIRG study included more granularities by estimating job creation from both existing and planned California projects while taking into account the market outlook of developers and equipment manufacturers. The study also took into account economies of scale and companies' ability to climb the learning curve by including annual declines of 10 percent in construction employment rate and 5 percent in operating and maintenance employment rate. As a result, the study's estimates of job growth are much more conservative than the CEC study, with lower employment rates in every category except operating employment at wind farms.

Table 9: CalPIRG Findings on Employment Rates

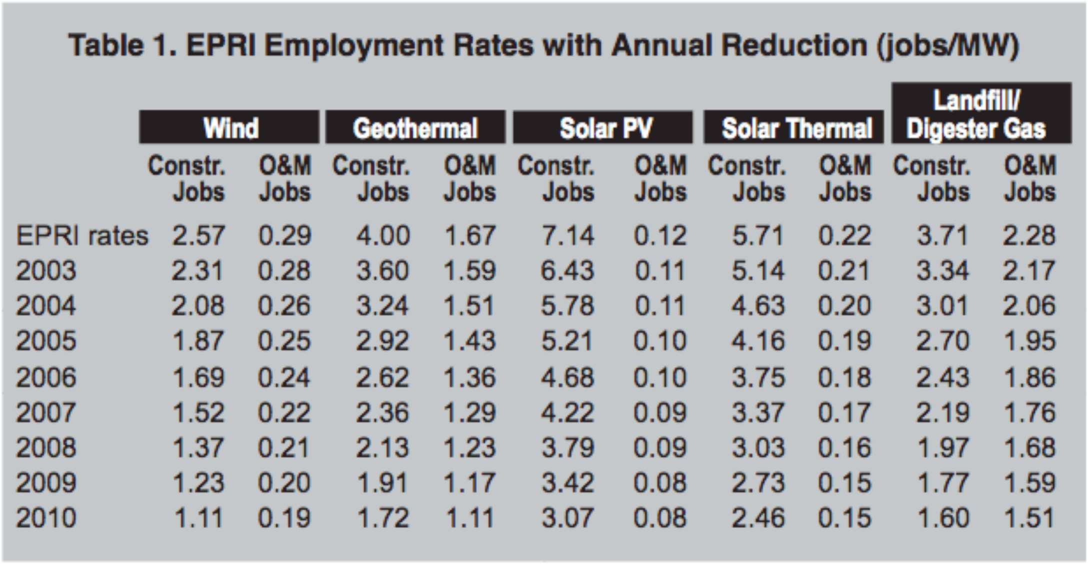


Table 1. EPRI Employment Rates with Annual Reduction (jobs/MW)

	Wind		Geothermal		Solar PV		Solar Thermal		Landfill/ Digester Gas	
	Constr. Jobs	O&M Jobs	Constr. Jobs	O&M Jobs	Constr. Jobs	O&M Jobs	Constr. Jobs	O&M Jobs	Constr. Jobs	O&M Jobs
EPRI rates	2.57	0.29	4.00	1.67	7.14	0.12	5.71	0.22	3.71	2.28
2003	2.31	0.28	3.60	1.59	6.43	0.11	5.14	0.21	3.34	2.17
2004	2.08	0.26	3.24	1.51	5.78	0.11	4.63	0.20	3.01	2.06
2005	1.87	0.25	2.92	1.43	5.21	0.10	4.16	0.19	2.70	1.95
2006	1.69	0.24	2.62	1.36	4.68	0.10	3.75	0.18	2.43	1.86
2007	1.52	0.22	2.36	1.29	4.22	0.09	3.37	0.17	2.19	1.76
2008	1.37	0.21	2.13	1.23	3.79	0.09	3.03	0.16	1.97	1.68
2009	1.23	0.20	1.91	1.17	3.42	0.08	2.73	0.15	1.77	1.59
2010	1.11	0.19	1.72	1.11	3.07	0.08	2.46	0.15	1.60	1.51

Also in 2002, a study by UC Berkeley Professor Kammen found equally high employment rates in the construction and manufacturing sector of clean energy through 2010. Although some results of this study are not directly comparable because installation jobs are grouped with maintenance rather than manufacturing jobs, its employment rates for manufacturing is nevertheless higher than the CEC solar projections and similar for wind projections.

Table 10: UC Berkeley Employment Generation Rate Projections

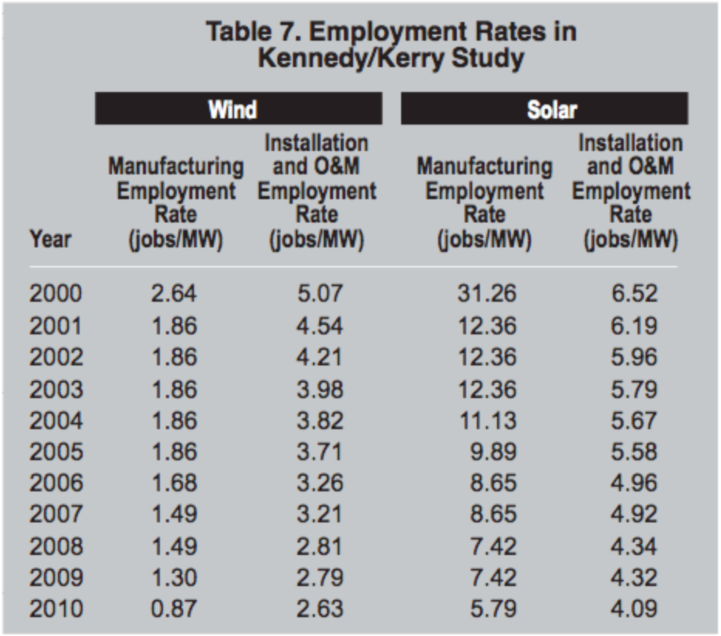


Table 7. Employment Rates in Kennedy/Kerry Study

	Wind		Solar	
Year	Manufacturing Employment Rate (jobs/MW)	Installation and O&M Employment Rate (jobs/MW)	Manufacturing Employment Rate (jobs/MW)	Installation and O&M Employment Rate (jobs/MW)
2000	2.64	5.07	31.26	6.52
2001	1.86	4.54	12.36	6.19
2002	1.86	4.21	12.36	5.96
2003	1.86	3.98	12.36	5.79
2004	1.86	3.82	11.13	5.67
2005	1.86	3.71	9.89	5.58
2006	1.68	3.26	8.65	4.96
2007	1.49	3.21	8.65	4.92
2008	1.49	2.81	7.42	4.34
2009	1.30	2.79	7.42	4.32
2010	0.87	2.63	5.79	4.09

Using data from conventional natural gas power plant permit applications, the CalPIRG study also estimated the employment generation rate for natural gas plants. In reviewing 19 plants built or approved since July 2001, the study found 6,337 person-years of employment were created directly through construction. From the five plants that reported indirect job creation through manufacturing and increased business activity from employees, the study estimated an additional 1.1 indirect construction and 1.9 indirect operation jobs for every direct or indirect job generated by the power plants. In sum, a total employment rate of 1.12 jobs/MW was estimated with 13,000 total person-years of employment for the 19 plants (see Table 18). This rate is notably lower than the two to seven jobs/MW generated by wind power and much lower than the six to 37 jobs/MW generated for solar power.

Employment Generation by Sub-sector

On the aggregate level, the CalPIRG study projected that 5900 MW of increased renewable capacity will be built between 2001 and 2010. This translates into 28,000 additional person-years of construction jobs and 3,000 additional person-years of O&M jobs. With a thirty year operational lifetime, total generated employment would be 120,766 person-years (see Table 20). For the solar and wind industries, construction jobs are primarily from manufacturing of various components of the technology. For the wind industry, most of the jobs will come from manufacturing and installation of blades and wind towers. Similarly, most of the generated solar industry construction jobs will be in assembling the PV modules, system integration and installation.

Table 11: Breakdown of Construction Jobs by Industry

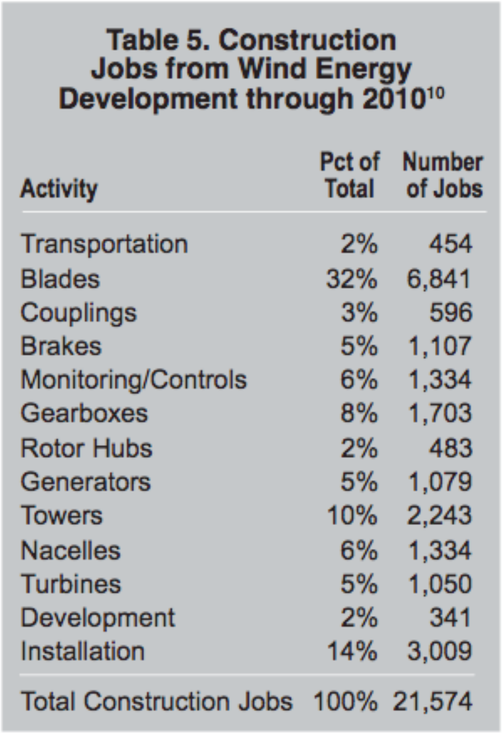


Table 5. Construction Jobs from Wind Energy Development through 2010[10]

Activity	Pct of Total	Number of Jobs
Transportation	2%	454
Blades	32%	6,841
Couplings	3%	596
Brakes	5%	1,107
Monitoring/Controls	6%	1,334
Gearboxes	8%	1,703
Rotor Hubs	2%	483
Generators	5%	1,079
Towers	10%	2,243
Nacelles	6%	1,334
Turbines	5%	1,050
Development	2%	341
Installation	14%	3,009
Total Construction Jobs	100%	21,574

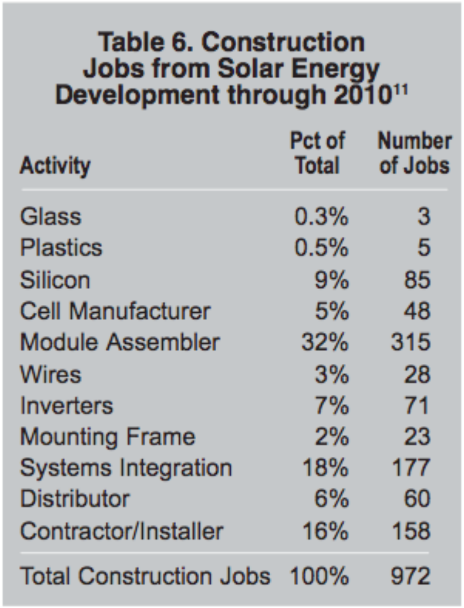


Table 6. Construction Jobs from Solar Energy Development through 2010[11]

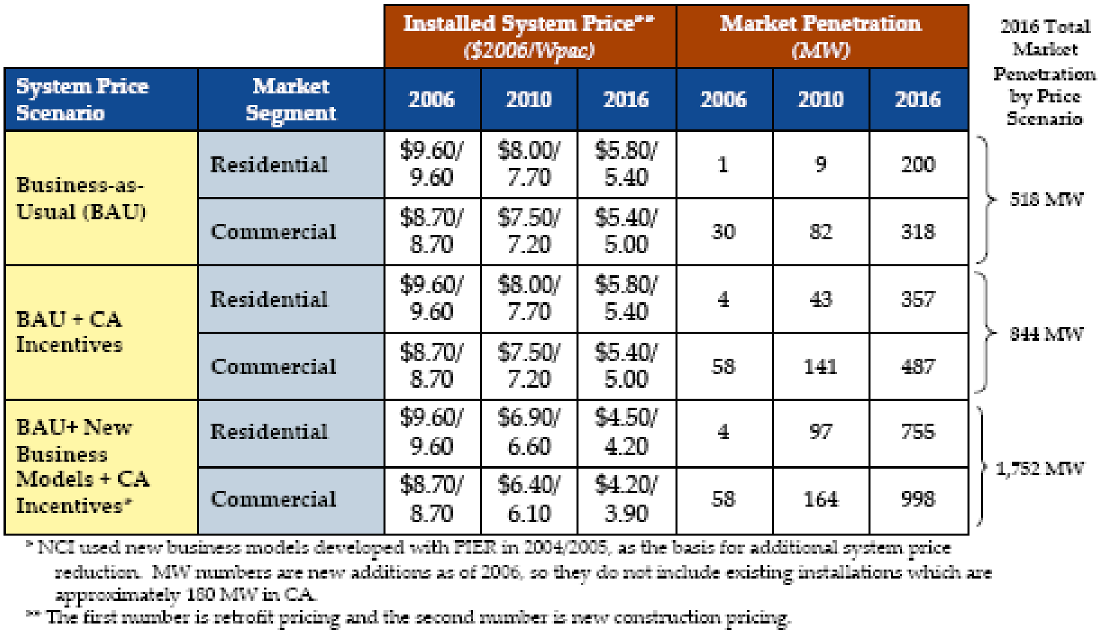
Activity	Pct of Total	Number of Jobs
Glass	0.3%	3
Plastics	0.5%	5
Silicon	9%	85
Cell Manufacturer	5%	48
Module Assembler	32%	315
Wires	3%	28
Inverters	7%	71
Mounting Frame	2%	23
Systems Integration	18%	177
Distributor	6%	60
Contractor/Installer	16%	158
Total Construction Jobs	100%	972

Interestingly, the CalPIRG study's employment breakdown by sub-industry is comparable to another study conducted in 2002, the Renewable Energy Policy Project Model study. Besides finding that wind and solar PV create 40% more jobs per dollar of investment than coal, this study found similar composition of manufacturing and installation jobs in solar and wind industries. Specifically, the study concluded that for solar, 30% of jobs would be in module assembly, 42% in other manufacturing activities, 21% in distribution and contracting, and 7% in servicing. For wind, 67% of the jobs would be in manufacturing components, 11% in installation, 20% in servicing, and 2% in transportation.

In sum, various existing studies on the economic and employment implications of renewable energy expansion have shown that solar (PV in particular) will have relatively higher employment generation rates per MW of installed capacity than wind in both manufacturing and O&M sectors. As expected, the employment generation rates for wind and solar are both significantly higher than that of coal and natural gas.

Table 12

Table 12: Business-as-Usual Scenario Results (assuming 3% real electricity price escalation.)



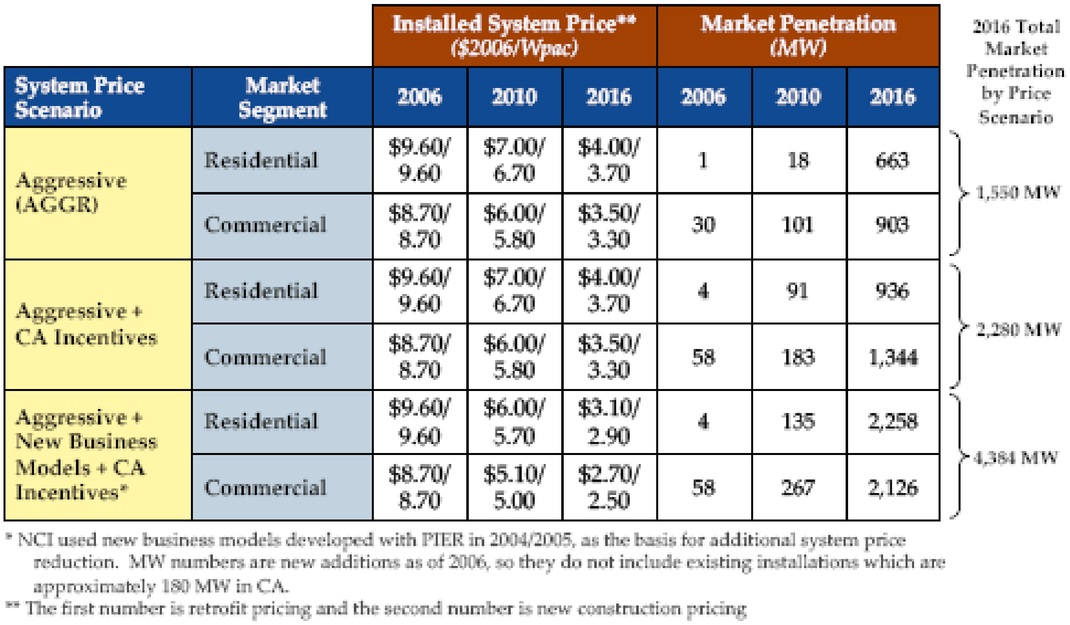
		Installed System Price** ($2006/Wpac)			Market Penetration (MW)			2016 Total Market Penetration by Price Scenario
System Price Scenario	**Market Segment**	**2006**	**2010**	**2016**	**2006**	**2010**	**2016**	
Business-as-Usual (BAU)	Residential	$9.60/ 9.60	$8.00/ 7.70	$5.80/ 5.40	1	9	200	518 MW
	Commercial	$8.70/ 8.70	$7.50/ 7.20	$5.40/ 5.00	30	82	318	
BAU + CA Incentives	Residential	$9.60/ 9.60	$8.00/ 7.70	$5.80/ 5.40	4	43	357	844 MW
	Commercial	$8.70/ 8.70	$7.50/ 7.20	$5.40/ 5.00	58	141	487	
BAU+ New Business Models + CA Incentives*	Residential	$9.60/ 9.60	$6.90/ 6.60	$4.50/ 4.20	4	97	755	1,752 MW
	Commercial	$8.70/ 8.70	$6.40/ 6.10	$4.20/ 3.90	58	164	998	

* NCI used new business models developed with PIER in 2004/2005, as the basis for additional system price reduction. MW numbers are new additions as of 2006, so they do not include existing installations which are approximately 180 MW in CA.

** The first number is retrofit pricing and the second number is new construction pricing.

Table 13

Table 13: Aggressive Scenario Results (assuming 3% real electricity price escalation).



		Installed System Price** ($2006/Wpac)			Market Penetration (MW)			2016 Total Market Penetration by Price Scenario
System Price Scenario	**Market Segment**	**2006**	**2010**	**2016**	**2006**	**2010**	**2016**	
Aggressive (AGGR)	Residential	$9.60/ 9.60	$7.00/ 6.70	$4.00/ 3.70	1	18	663	1,550 MW
	Commercial	$8.70/ 8.70	$6.00/ 5.80	$3.50/ 3.30	30	101	903	
Aggressive + CA Incentives	Residential	$9.60/ 9.60	$7.00/ 6.70	$4.00/ 3.70	4	91	936	2,280 MW
	Commercial	$8.70/ 8.70	$6.00/ 5.80	$3.50/ 3.30	58	183	1,344	
Aggressive + New Business Models + CA Incentives*	Residential	$9.60/ 9.60	$6.00/ 5.70	$3.10/ 2.90	4	135	2,258	4,384 MW
	Commercial	$8.70/ 8.70	$5.10/ 5.00	$2.70/ 2.50	58	267	2,126	

* NCI used new business models developed with PIER in 2004/2005, as the basis for additional system price reduction. MW numbers are new additions as of 2006, so they do not include existing installations which are approximately 180 MW in CA.

** The first number is retrofit pricing and the second number is new construction pricing

Table 14: California IOU's 2006 Power Purchase Agreements

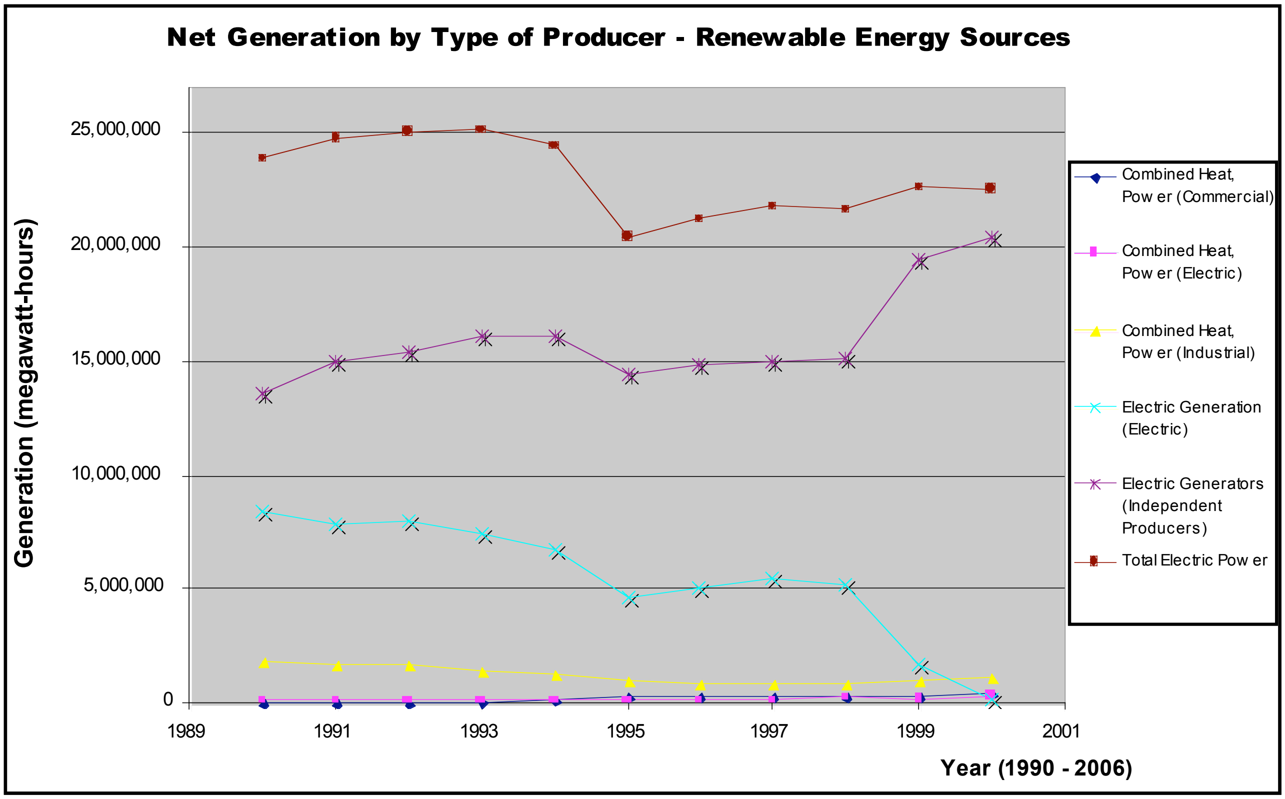
AWEA Wind Power Projects Database

Utility/Power Companies Purchasing Wind Through Long-Term Contract (at least 100 MW) through end 2006

Power Company	PPA for Customers	Owned & used for customers	Total for customers	Owned, selling power to 3rd party	PPA, selling to third party
Xcel Energy	1,296.61	26.00	1,322.61		
SCE	**1,026.00**	**-**	**1,026.00**		
MidAmerican	268.00	592.60	860.60		
PGE	**793.00**	**-**	**793.00**		
TXU Energy	705.00		705.00		
Puget Sound Energy	-	378.00	378.00		
AEP	373.20	-	373.20	310.00	
Alliant	338.20	-	338.20		
City Public Services San Antonio	260.00		260.00		
Exelon	259.00		259.00		
Austin Energy	215.00		215.00		
Public Service New Mexico	204.00		204.00		
Reliant	198.00		198.00		
Seattle City Light	175.00		175.00		
L.A. Department of Water & Power	169.00		169.00		
Northwestern Energy	135.00		135.00		
Basin Electric	131.00	3.00	134.00		
San Diego Gas & Electric	**132.00**		**132.00**		
Lower Colorado Municipal Authority	116.00		116.00		
Aquila	112.00		112.00		
Oklahoma Gas & Electric	111.00		111.00		
Great River Energy	106.00		106.00		
Kansas City Power & Light		100.50	100.50		
Portland General Electric	100.00		100.00		
PPM Energy			-		606.00
TOTALS	**7,615.01**	**1,331.02**	**8,946.03**	**310.00**	**606.00**

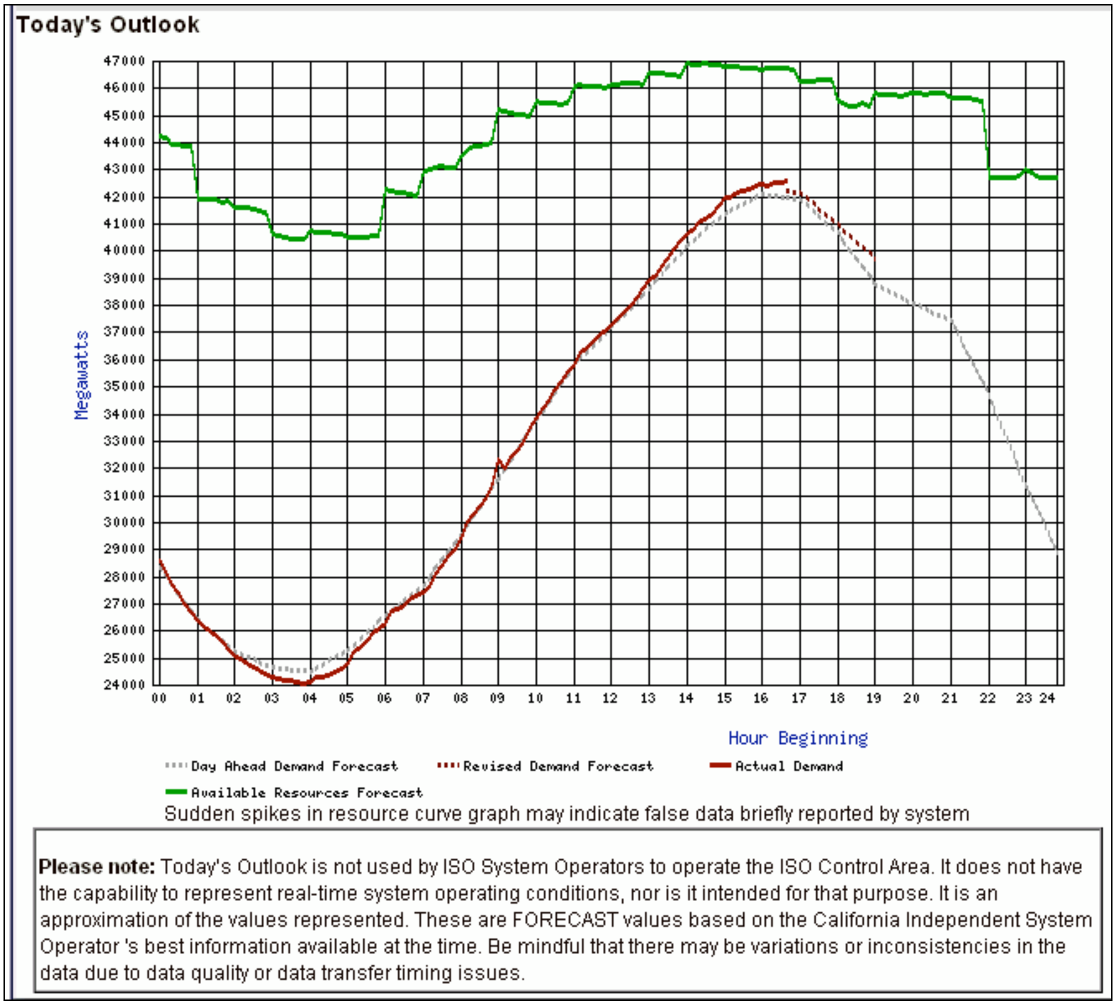
Source: AWEA, http://www.awea.org/projects/2006_Projects_Details.xls

Table 15: Renewable Electricity Generation by Type of Producer



Graph constructed from the following table: "Electric Power Industry generation by Primary Energy Source, 1990 – 2006." Source: http://www.eia.doe.gov/cneaf/electricity/st_profiles/california.html

Table 16: California Installed Wind Capacity and Potential for Electric Generation



Sudden spikes in resource curve graph may indicate false data briefly reported by system

Please note: Today's Outlook is not used by ISO System Operators to operate the ISO Control Area. It does not have the capability to represent real-time system operating conditions, nor is it intended for that purpose. It is an approximation of the values represented. These are FORECAST values based on the California Independent System Operator 's best information available at the time. Be mindful that there may be variations or inconsistencies in the data due to data quality or data transfer timing issues.

Table 17: Wind projects in California

Project Name	Gross Capacity	% of Ownership	Net Capacity
Cabazon	39.8	100%	39.8
Diablo Wind	20.5	100%	20.5
Green Power	16.5	100%	16.5
Green Ridge Power	159	50%	79.5
High Winds	162	100%	162.0
Mojave 16/17/18	85	50%	42.5
Mojave 3/5	46	48%	22.1
Sky River	77	100%	77.0
TPC Windfarms	29	50%	14.5
Victory Garden IV	22	100%	22.0
Wind Power Partners '90	15	50%	7.5
Wind Power Partners '91	23.9	50%	11.9
Wind Power Partners '91-92	27.9	50%	13.9
Wind Power Partners '92	30	50%	15.0
Wind Power Partners '93	41.2	100%	41.2
Wind Power Partners '93	26.3	99%	26.2
Wind Power Partners '94	40.2	100%	40.2

Table 18: Employment Implications of Natural Gas Power Plants

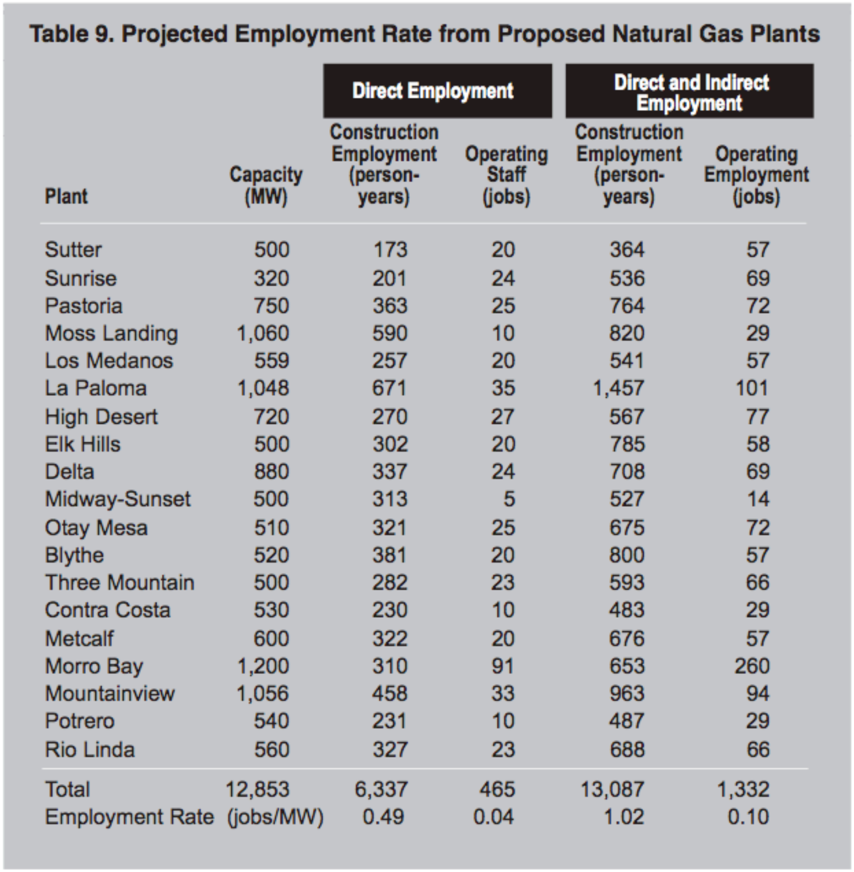


Table 9. Projected Employment Rate from Proposed Natural Gas Plants

		Direct Employment		Direct and Indirect Employment	
Plant	Capacity (MW)	Construction Employment (person-years)	Operating Staff (jobs)	Construction Employment (person-years)	Operating Employment (jobs)
Sutter	500	173	20	364	57
Sunrise	320	201	24	536	69
Pastoria	750	363	25	764	72
Moss Landing	1,060	590	10	820	29
Los Medanos	559	257	20	541	57
La Paloma	1,048	671	35	1,457	101
High Desert	720	270	27	567	77
Elk Hills	500	302	20	785	58
Delta	880	337	24	708	69
Midway-Sunset	500	313	5	527	14
Otay Mesa	510	321	25	675	72
Blythe	520	381	20	800	57
Three Mountain	500	282	23	593	66
Contra Costa	530	230	10	483	29
Metcalf	600	322	20	676	57
Morro Bay	1,200	310	91	653	260
Mountainview	1,056	458	33	963	94
Potrero	540	231	10	487	29
Rio Linda	560	327	23	688	66
Total	12,853	6,337	465	13,087	1,332
Employment Rate	(jobs/MW)	0.49	0.04	1.02	0.10

Source: CalPIRG (2002)

Table 19

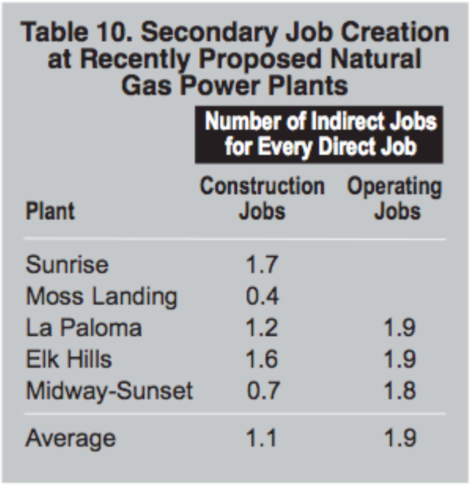


Table 10. Secondary Job Creation at Recently Proposed Natural Gas Power Plants

	Number of Indirect Jobs for Every Direct Job	
Plant	Construction Jobs	Operating Jobs
Sunrise	1.7	
Moss Landing	0.4	
La Paloma	1.2	1.9
Elk Hills	1.6	1.9
Midway-Sunset	0.7	1.8
Average	1.1	1.9

Source: CalPIRG (2002)

Table 20: Employment Implications of Renewable Energy Development, 2001 – 2010

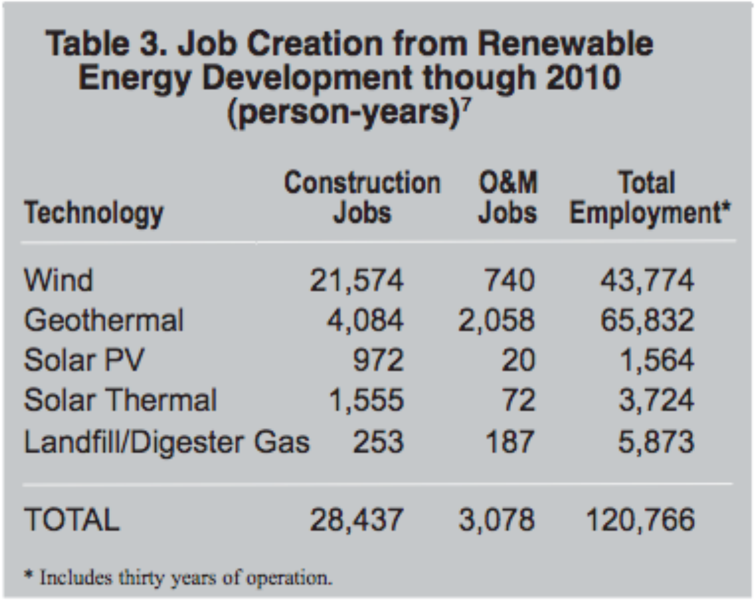


Table 3. Job Creation from Renewable Energy Development though 2010 (person-years)[7]

Technology	Construction Jobs	O&M Jobs	Total Employment*
Wind	21,574	740	43,774
Geothermal	4,084	2,058	65,832
Solar PV	972	20	1,564
Solar Thermal	1,555	72	3,724
Landfill/Digester Gas	253	187	5,873
TOTAL	28,437	3,078	120,766

* Includes thirty years of operation.

5. Technical Annex A – 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 A.1 and A.2 (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.[45] 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: 2005), 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

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

changes are not only substantial, but may in some cases even outweigh direct effects. Only a model that consistently specifies economywide interactions can fully assess the implications of economic policies or business strategies. In a multi-country model like the one used in this study, indirect effects include the trade linkages between countries and regions which themselves can have policy implications.

The model we use for this work has been constructed according to generally accepted specification standards, implemented in the GAMS programming language, and calibrated to the new California SAM estimated for the year 2003.[46] The result is a single economy model calibrated over the fifteen-year time path from 2005 to 2020.[47] 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.

In each period, the supply of primary factors — capital, land, and labor — is usually predetermined.[48] 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.[49]

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

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

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

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

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

[49] 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.

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

The government collects income taxes, indirect taxes on intermediate inputs, outputs and consumer expenditures. The default closure of the model assumes that the government deficit/saving is exogenously specified.[50] The indirect tax schedule will shift to accommodate any changes in the balance between government revenues and government expenditures.

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

Trade

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

Dynamic Features and Calibration

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

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

Figure A.1: 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. Emissions Policy Analysis
4. Transportation services/demand

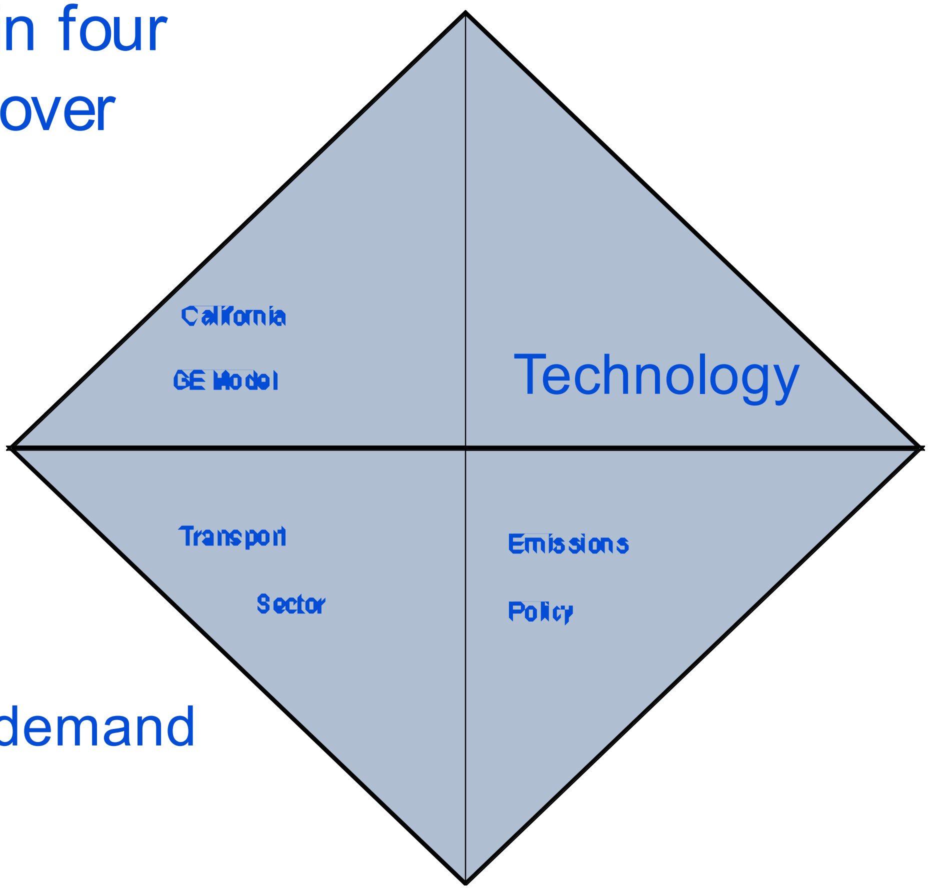
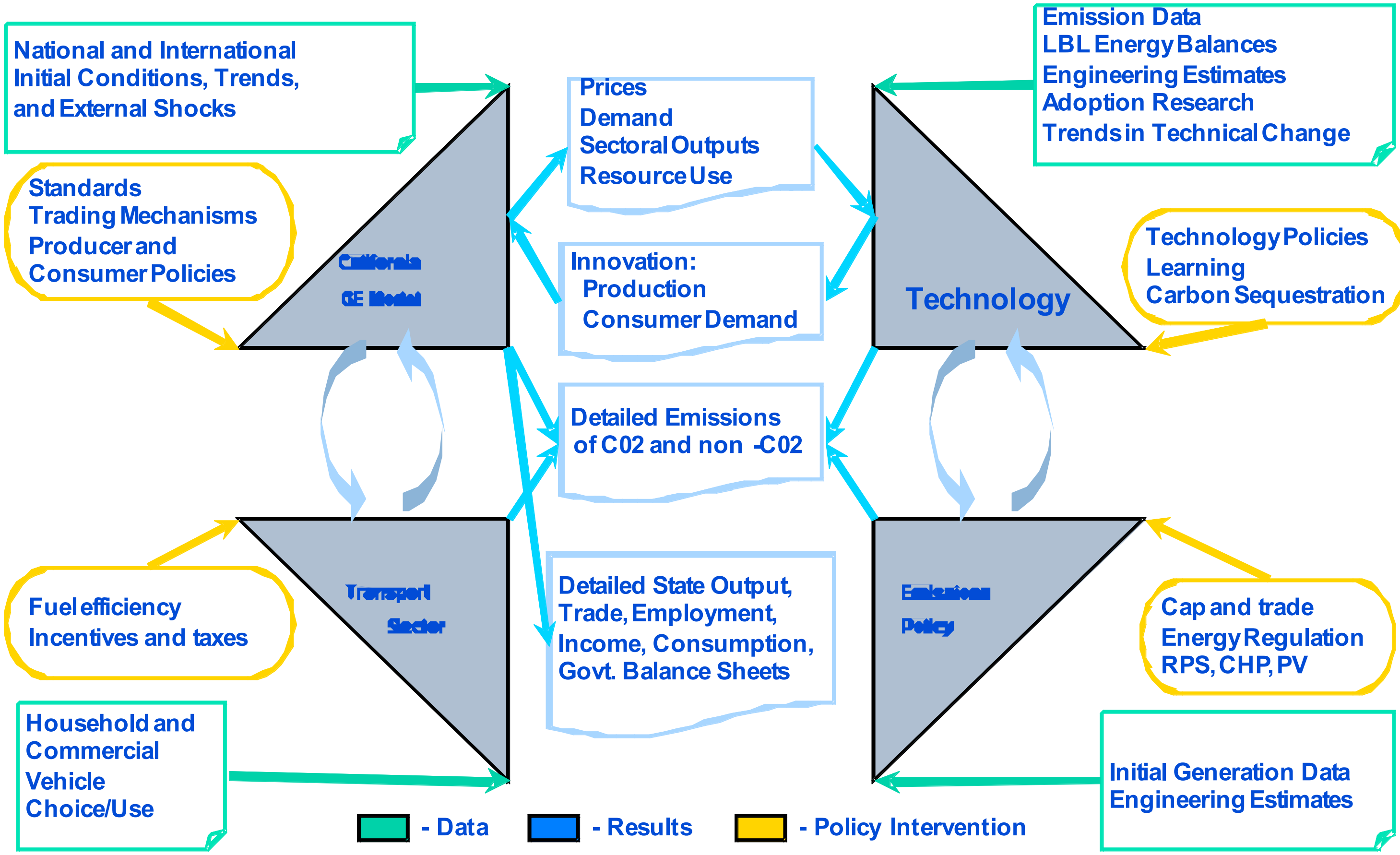


Figure A.2: Schematic Linkage between Model Components



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 availa=ble 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 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.[51] 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.

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,

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[51] 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.

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.[52] 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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[52] See e.g. Babiker et al (2001) for details on a standard implementation of this approach.

Table A.2: 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 2.1. 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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