Renewables Work

Job Growth from Renewable Energy Development in California

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Table of Contents

Executive Summary

Generating electricity from renewable energy sources provides more jobs than traditional energy sources, according to both economic models and real-life experience. Much of the cost of electricity from natural gas power plants is from the ongoing purchase of fuel. A higher portion of the generating cost goes to labor for renewable energy than for traditional energy sources.

California could take advantage of the job benefits of renewable energy by initiating long-term contracts or requirements that utilities obtain electricity from renewable sources. With such market guarantees, renewable energy companies would build 5,900 MW of new facilities in California by 2010. Added to the current capacity of 3,163 MW of clean renewable energy, the state would then be able to generate at least 20% of its electricity from renewables.

Studies done by the utility industry's own research institute, the California Energy Commission, and independent researchers summarize energy industry experience to measure the employment intensity of different electricity generating technologies. The most conservative projections from these studies show significant employment benefits from new renewable energy development.

- Building 5,900 MW of renewable energy capacity would lead to the equivalent of 28,000 year-long construction jobs and 3,000 permanent operations and maintenance jobs.
- Over thirty years of operation, these new plants would create 120,000 person-years of employment.

Other studies and the experience of existing renewable energy operations support these projections as reasonable and conservative.

Although natural gas power plants can often produce power at a slightly lower cost per kilowatt-hour when measured in a short-term time frame, the generating cost does not benefit the regional economy through the creation of jobs as much as money spent on renewable energy. Building 5,900 MW of natural gas power plants would result in:

- $10.3 billion in gas purchases over thirty years to fuel the new plants.
- 29,000 person-years of employment, one-fourth as many jobs as the equivalent capacity of renewable energy would create.

Wind power typically provides 70% more jobs than gas, and solar technologies provide twice as many jobs. Job creation from geothermal energy is 11 times higher than from natural gas. Landfill gas plants employ 14.7 times as many workers.

The California renewable energy industry has reached a healthy level of maturity, involving companies of all shapes and sizes. At least 300 companies are directly involved in renewable energy development and production. This industry includes more small start-up companies than many other industries, but large and well-established companies are also involved in wind, solar, and geothermal energy production. California is home to 46 renewable energy companies

Impact Comparison of Developing 5,900 MW of Capacity

	Job Creation (person-years)	Gas Purchases
Renewables	120,766	0
Natural Gas	29,028	$10.3 billion

Employment Rates by Energy Technology (jobs/MW)

Technology	Construction Employment	Operating Employment
Wind	2.57	0.20
Geothermal	4.00	1.67
Solar PV	7.14	0.12
Solar Thermal	5.71	0.22
Landfill/Digester Gas	3.71	2.28
Natural Gas	1.02	0.13

larger than 100 employees. This diversity will provide both stability and agility in a rapidly evolving market.

Many renewable energy projects have already been proposed. The California Power Authority has signed letters of intent with private developers for 66 projects in 24 counties, including many rural areas where jobs are most needed. These plants would have a combined capacity of 2,255 MW, and are now in the due diligence process.

PREFACE

by Daniel Kammen
Professor of Public Policy
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Once again CALPIRG has developed a critically important and eye-opening report on our energy future. The report demonstrates what should be obvious to any labor economist, but is routinely neglected when evaluating the myriad benefits of clean, renewable energy systems: the job creation potential is enormous.

Each new solar, wind, biomass, or fuel cell-related job created is, in effect, a vote for energy security, price stability, and generally a vote to buy American. Renewable energy is a plentiful resource in the U.S., and therefore each new job in this field is another job, and another dollar of gross national product, that we choose to reinvest in the American economy as opposed to providing as a subsidy to OPEC and other nations.

This report documents a second critical feature of renewable energy investments – they are investments in innovation and new job creation. With most of the renewable energy industry in the early commercial phase, little sustained market growth has yet to take place for any of these technologies. Thus, each new solar system, windmill, or fuel cell sold represents new economic activity and growth. This has two effects: 1) investments in renewables are truly investments in job creation; and 2) with relatively few of these systems in the field, the cost declines through learning. This learning curve will result in dramatic decreases in per unit costs as sales ramp up. A double victory.

Thus, despite the cries of many old-style utilities, renewable energy investments provide a sure fire way to generate new, important, domestic jobs, push technology prices down, and safeguard the environment. CALPIRG has yet again identified and documented a compelling case for clean, sustainable energy investment. Bravo!

INTRODUCTION

The California Energy Crisis shook the state and the nation last year. Electricity prices skyrocketed for some consumers. Energy companies went bankrupt. Blackouts stunned the state six times. Weeks of rolling blackouts were narrowly averted.

The state's initial responses included historic efforts at energy conservation, which proved to be highly successful, and the construction of new natural gas power plants. Three large plants and several small plants were built, and dozens of other plants were proposed and approved.

This year, the state is facing a different crisis – a budget shortfall predicted to be as high as $23 billion.[1]

In the ongoing budget negotiations in Sacramento, the debate is about *which* programs need to be cut and *how much* to raise taxes. For years, California relied on a windfall from Silicon Valley to lift the whole state budget. In 2000, 23% of California's General Fund revenues came from taxes on stock options and capital gains. Then the tech bubble burst, and the state is now grasping for ways to balance the books.

We shouldn't let the downturn in computer manufacturing and Internet services cripple the state. California is home to a wealth of capital and expertise developed by Silicon Valley, the aerospace industry, and other high-tech industries. It is also home to rich resources for wind, solar, and geothermal energy. By providing market guarantees to renewable energy producers, the state can encourage investment in wind turbines, photovoltaic panels, geothermal plants, and all the planning, manufacturing, installation, and servicing that go along with them. With a stable market, the state will barely have to miss a beat cashing in on its core competencies by developing new energy technologies. And developing California's in-state resources will build the industry to help it capitalize on the growing worldwide renewable energy market thereafter.

This will also create greater energy stability. Once this phase of development is complete, California will have a strong base of generating capacity from in-state sources. We will not be as vulnerable to shortages in the natural gas supply or in Northwest hydropower. Developing in-state resources will also reduce the ability of out-of-state energy companies to manipulate the California market to their advantage.

Power plant developers have canceled plans for many of the newly approved natural gas power plants in recent months. We should take this as an opportunity to grow smarter by concentrating on renewables for our energy development.

Diversifying our energy mix would help reduce our over-dependence on fossil fuels and their inherent price and supply volatility. Choosing clean power sources would avoid new air pollution at a time when increasing road traffic is exacerbating the state's notorious air quality problems. Building our capacity of renewable energy would be a smart long-term investment for affordable power for California consumers. And, as important as any of this, renewable energy development will provide a boost to the state economy by creating jobs and strengthening tax revenues.

California should begin this period of increased renewable energy development now by creating a guaranteed market for electricity from renewable sources.

Employment Rate Projections

Several recent studies have measured the employment rates of different energy technologies. Each of these studies concluded that renewable energy provides more jobs than traditional energy technologies.

Projections from the research arm of the utilities provides a clear understanding of job creation from renewable energy. Other studies show these projections to be conservative.

California Energy Commission Projections

The California Energy Commission's Public Interest Energy Research program sponsored a study in 2001 from the Electric Power Research Institute (EPRI), a non-profit energy research consortium founded and supported by electric utilities. The report "characterizes the status and prospects of each renewable energy resource in the state and estimates the current and potential economic and environmental benefits they provide." The report concludes that renewable energy technologies "can make California's electricity more reliable, affordable, and cleaner."[2]

The EPRI report includes estimates of job creation from renewable energy development based on existing and planned projects in California and the market outlook of project developers and equipment manufacturers. The construction employment rate in the report ranges from 2.57 jobs/MW for wind to 7.14 jobs/MW for PV. EPRI's operating employment rate ranges from 0.12 jobs/MW for PV to 2.28 jobs/MW for landfill/digester gas. These figures include direct jobs at the generating facilities as well as indirect jobs from component manufacturing.

EPRI states in its report that these employment projections are "likely characteristics for the next 5-10 years." However, to be more conservative, one can assume a steadily decreasing employment rate over the next decade due to economies of scale and increasing experience of renewable energy companies. Although it is difficult to quantify this decrease based on historical precedent, it is likely that there would be much more efficient use of installers, service technicians, and manufacturing personnel at the end of a period of rapid renewable energy market growth. A decline of 10% per year in the construction employment rate and 5% per year in the operating and maintenance employment rate leads to very conservative job growth estimates. (See Table 1.)

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

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

The Renewable Energy Office of the California Energy Commission uses an input/output model for calculating the economic development benefits of renewable energy. The model was created by Oak Ridge National Laboratory and is based on industry experience as compiled by Jack Faucett Associates in 1987.[3] CEC has gradually modified and updated this model over time to account for changing conditions. In 2000, at the request of Independent Energy Producers, the office published an estimate of the amount of renewable energy under construction since 1996 and likely to come online in the near future.[4]

This analysis found that 470 MW of clean renewable energy was in some stage of development or planning. The CEC estimated that these facilities would create the equivalent of 6,081 year-long construction jobs and 882 permanent jobs. This equates to an average employment rate of 12.9 jobs/MW for construction jobs and 1.87 jobs/MW for permanent jobs.

This is twice as high as the weighted average rate for construction jobs in the EPRI study for these three technologies and three times higher than EPRI's average rate for operation and maintenance jobs.

The employment rate is higher in the Renewable Energy Office's model than the EPRI model in every category of job except operating employment at wind plants. In order to use the most conservative assumptions, the analysis in this report uses the Renewable Energy Office's 0.20 jobs/MW rate for wind operating jobs and the EPRI rates for all other jobs.

With these employment rates, the 5,900 MW of capacity outlined in Appendix A would yield 28,000 construction jobs and 3,000 O&M jobs.[6] Including thirty years of

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.

Table 4. Weighted Average Employment Rate for New Renewable Energy Plants

Total Capacity Developed (MW)	5,900
Construction Jobs	28,437
Operating Jobs	3,078
Construction Employment Rate (jobs/MW)	4.82
Operating Employment Rate (jobs/MW)	0.52

operation, this would amount to 120,000 person-years of employment, as shown in Table 3.

Other models and information from existing manufacturing facilities described below show this to be a very conservative projection of likely job creation. A low-end estimate for the amount of solar PV in the energy mix also causes these job creation projections to be conservative, since PV has the highest construction job rate among renewable energy technologies.

Other Projections

Job creation studies independent of the California Energy Commission support the findings of the CEC projections. The number of jobs created by renewable energy development is higher in every category of jobs in these studies than the CEC projections, showing the CEC's assumptions to be conservative.

Renewable Energy Policy Project Model

The Renewable Energy Policy Project (REPP) analyzed employment from the renewable energy industry in a Winter 2002 report. In this study, REPP looked at two clean renewable energy technologies – solar PV and wind – as well as biomass co-firing. Rather than measuring employment per MW of capacity, this study measured job creation per dollar of investment. While other studies have shown that building 100 MW of renewable energy creates more jobs than 100 MW of fossil fuel-based generation, this study went one step further to include the higher startup cost of renewable energy technologies. The study concluded that wind and PV create 40% more jobs per dollar of investment than coal.

This study also calculated job creation in the different work activities involved. For solar, 30% of the jobs would be for module assembly, 42% for other manufacturing ac-

Note on Units

Megawatts (MW) is a unit of measurement indicating how fast a plant can put out electrons. This is the standard measure of the size of a power plant. It is also used to determine if the total generating capacity on the grid is enough to satisfy demand at any one time.

Megawatt-hours (MWh) is a unit measuring the total amount of electrons produced over some time frame. This is the measure of the output of a power plant. A 50 MW power plant operating at full capacity for one hour produces 50 MWh of electricity. This is the appropriate unit for talking about how much of the state's electricity was produced by various sources in a given time frame. 1,000 MWh equals one gigawatt-hour (GWh).

California is currently most focused on meeting demand during peak demand times. The state will meet off-peak demand as long as energy regulators plan for peak demand, at least until solar power becomes the dominant source of electricity. Hence, their focus is on peak capacity, and employment intensity in this report is measured in jobs/MW.

Wind power does not always run at peak capacity during peak demand times. Its capacity is therefore often expressed in terms of average capacity – 30% of peak capacity. Geothermal, solar, and biogas energy can be relied upon to operate at full output level when electricity is needed most. Capacity of those technologies is thus expressed in terms of full peak capacity. Hence, the 5,900 MW of energy growth analyzed in this report includes wind capacity in average megawatts and the capacities of other renewables in peak megawatts.

tivities, 21% for distribution and contracting, and 7% for servicing. For wind, 67% of the jobs would be for manufacturing components, 11% for installation, 20% for servicing, and 2% for transportation.[8]

Nevada AFL-CIO Use of REPP Model

The REPP model was used by the Nevada AFL-CIO for comments submitted to the Nevada Public Service Commission in January 2002 regarding pending policy decisions on the promotion of renewable energy. These comments included an analysis of the job impacts of a renewable portfolio standard (RPS) in Nevada. This analysis determined that an RPS of 5% in 2003 increasing to 15% in 2013 would create 27,000 new jobs. The analysis included the O&M jobs from geothermal energy development along with the total jobs from wind, solar, and biomass co-firing, although it did not include the construction jobs associated with geothermal energy.

Further, this study calculated the financial offset to the cost of implementing an RPS due to job creation. Assuming that jobs created would replace unemployment benefits paid, the Nevada RPS would create an economic benefit to the state of $469 million over ten years.[9]

Application of REPP Model to California

Because this model does not include electricity from solar thermal plants or landfill/ digester gas operations and does not include geothermal construction jobs, it cannot give an overall picture of job creation from an RPS in California. However, the results of the data compiled by REPP's interviews and market analysis for its national model can provide a check on the CEC projections and give a clear picture of employment within the wind and PV industries.

Inputs for California conditions:

- 52% of renewable energy capacity additions from wind, 31% from geothermal, 2% from PV, and 16% from other sources.
- An RPS of 10% in 2003 increasing to 20% in 2010.
- Total statewide electricity demand of 266,000 GWh in 2003, increasing to 327,000 in 2012.

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

Under these conditions, California would generate 223,000 GWh of electricity from renewable sources over a ten-year period. Wind energy development would create 32,000 manufacturing and installation jobs and 800 permanent maintenance jobs. This is 48% more construction jobs than the CEC projections and 8% more maintenance jobs. In the solar industry, 11,500 manufacturing and installation jobs and 90 permanent maintenance jobs would be created. This is far higher than the job creation for both construction and operating jobs in the solar industry in the CEC projections. The REPP model thus supports the CEC projections as conservative.

The REPP model's exhaustive breakdown of activities within renewable energy industries demonstrates the types of jobs that would be created by wind and solar power development. The distribution of 21,574 wind energy construction jobs and 972 solar PV construction jobs – the job creation determined by the CEC analysis – is shown in Tables 5 and 6.

Kennedy/Kerry Study

UC-Berkeley Professor Daniel Kammen produced an analysis of the economic benefits of clean energy development at the request of U.S. Senators Edward Kennedy and John Kerry. Dr. Kammen derived the analysis from a combination of historical experience related to him by renewable energy companies and median values of economic models produced by others.[12]

This analysis found that the initial stages of increased development of wind energy would create 2.64 jobs/MW in manufacturing jobs, declining to 0.87 jobs/MW ten years later. Installation and O&M jobs would be created at the rate of 5.07 jobs/MW initially, declining to 2.63 jobs/MW after ten years.

In the solar energy industry, Dr. Kammen's analysis found that increased production activity would initially result in 31.26 manufacturing jobs/MW and 6.52 installation and O&M jobs/MW, declining to 5.79 manufacturing jobs/MW and 4.09 installation and O&M jobs/MW ten years later.

The calculations in this analysis differ from other studies in that installation jobs are grouped with maintenance jobs rather than manufacturing jobs, in order to draw the distinction between jobs that are certain to be local and those that may be located at distant manufacturing plants. The CEC projections and other studies group installation jobs with manufacturing jobs in order to distinguish between temporary employment and permanent jobs. Even without the installation jobs, however, the manufacturing employment rates in the Kennedy/Kerry analysis are higher than those in the CEC projections for solar energy and very similar for wind energy. Since the operating job rate is grouped with the installation job rate, it is not comparable to the operating job rate in the CEC 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

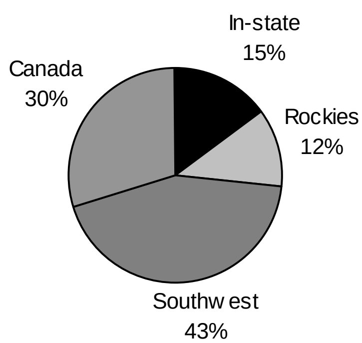
Real-Life Experience

Natural Gas

If California were to meet its electricity demand growth with natural gas power plants instead of renewable energy, fewer jobs would be created.

Much of the cost of generating electricity from natural gas power plants is from the ongoing purchase of fuel. Although gas plants can often produce power at a slightly lower cost per kWh when measured in a short-term time frame, the generating cost does not benefit the regional economy through the creation of jobs as much as money spent on renewable energy.

Figure 1. 1999 Sources of Natural Gas for the California Market[14]



California already imports 85% of the natural gas used in the state. Since production from in-state reserves is expected to remain flat for the foreseeable future, the gas needed to fuel new power plants would come from Canada, the Southwest, the Rockies, and possibly farther. Meeting electricity demand growth with natural gas power plants would require the purchase of an additional $10.3 billion of gas from out-of-state providers over thirty years.[13]

Employment Rates

Fossil fuel-based power plant developers are required to estimate the number of jobs to be created by proposed power plants as part of the permit application process. A review of the applications for the 19 plants that have been built or approved since July 2001 reveals that these plants were projected to create a total of 6,337 person-years of work directly within the construction projects. New gas transmission lines needed for new plants are included within these direct employment estimates.[15]

The permit applications for five of the plants included estimates for indirect jobs created by the construction project.[16] This includes manufacturing jobs created by an increased need for materials and components to supply the construction project, as well as work resulting from the increased general business activity due to newly employed individuals living in the area. The estimates are based on data specific to power plants.

The number of secondary jobs ranged from 40% of the number of direct jobs for the Moss Landing plant to 170% of direct jobs for Sunrise. The average of the five plants was 1.1 indirect jobs for every direct construction job. (See Table 10.) Assuming the same rate for other plants, the nineteen recently proposed natural gas power plants would create 13,000 total person-years of employment, an average of 1.02 jobs/MW. (See Table 9.) This is much less than the 2.6-7.1

Table 8. Employment at Existing California Natural Gas Power Plants[17]

Plant	Capacity (MW)	Operating Staff	Employment Rate (jobs/MW)
Alamitos	2,121	84	0.04
Redondo	1,312	67	0.05
Huntington	573	34	0.06
Morro Bay	1,056	80	0.08
Moss Landing	1,404	80	0.06
South Bay	732	77	0.11
Grayson	283	52	0.18
Harnes	1,606	162	0.10
Scattergood	823	112	0.14
Pittsburg	2,022	215	0.11
El Segundo	997	63	0.06
Coolwater	658	58	0.09
Etiwanda	1,046	57	0.05
Ormand Beach	1,613	59	0.04
Mandalay	677	47	0.07
Total	16,923	1,247	0.07

jobs/MW employment rates of renewable energy technologies.

Building more natural gas power plants would also result in fewer permanent jobs than renewable energy. The 15 large California gas plants that were divested by utilities employ 1,247 people. These plants have a combined capacity of 16,923 MW – a rate of 0.07 direct jobs per MW.[18] (See Table 8.)

New combined cycle natural gas plants are expected to employ even fewer people, as they are more automated and easier to maintain than traditional steam turbine plants. Plans for 19 new plants include an average of only 25 jobs per plant. These 465 operating jobs yield a rate of 0.04 direct jobs/MW.[19]

Estimates for indirect operating jobs were included in the permit applications of three recently proposed natural gas power plants.[20] The number of secondary operating jobs for each of these plants was 170%-180% of direct operating jobs. Assuming the same rate for other plants, 1,332 total operating and maintenance jobs would be created by the nineteen recently proposed natural gas power plants, an average of 0.10 jobs/MW. (See Table 9.)

Natural gas electricity generation also involves employment in gas extraction and transportation. 326,000 people work in oil and gas extraction in the U.S. and 154,000 people work in oil and gas transportation.[21]

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

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

Plant	Number of Indirect Jobs for Every Direct Job: 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

Since many of these jobs involve both crude oil and natural gas, government and industry analysts measure employment for both resources combined. Allocating these jobs according to the economic value of oil and gas produced, an estimated 59% of this employment is associated with natural gas – a total of 281,000 jobs.[22] This yields an employment intensity of 0.012 jobs per million cubic feet (mcf) of gas produced.

At the 2000 gas consumption rate of California natural gas power plants of 7.94 mcf/GWh, the employment rate for natural gas extraction and transmission associated with California electricity generation is 0.09 jobs/GWh.[23] With the average capacity factor of 35% for California natural gas power plants, this equates to 0.03 jobs/MW.

Adding this to the operating employment rate for direct and indirect jobs at natural gas power plants, the operating employment rate for all jobs associated with natural gas electricity generation is 0.13 jobs/MW.

Table 11. Employment Rate from Natural Gas Electricity Generation (jobs/MW)

	Construction Jobs	Operating Jobs
Power Plant Direct Jobs	0.49	0.04
Power Plant Indirect Jobs	0.53	0.06
Gas Extraction and Transportation Jobs		0.03
Total	1.02	0.13

Renewable Energy

The employment rates at existing renewable energy facilities support the CEC job growth projections as reasonable and conservative.

These are real jobs at currently operating facilities. California is home to 46 renewable energy companies larger than 100 employees. At least 300 companies are directly involved in renewable energy development and production.[24] These companies provide a wide range of business and technical services for the renewable energy industry. Much of this business activity is directed to overseas markets, but the companies are here and are ready to capitalize on opportunities for expansion within the California market in addition to their global activities.

These companies range from major energy conglomerates with renewable energy divisions to small businesses catering to niche markets. This diversity will help the industry take advantage of opportunities as they arise. Large traditional companies provide stability, experience, and ready capital. Small newcomers can quickly adapt to changing conditions and new technologies. The geographic variety of both large and small companies will create jobs throughout California.

Employment Rates

The number of people employed to build or operate specific renewable energy facilities is competitive information. Most businesses involved in energy production are integrated companies that own, develop, and operate varying shares in different projects. The amount of labor involved in one part of a company's operations is thus difficult for an outside observer to determine. Energy companies are generally willing to release such information for aggregation into models such as those described in the last section, but are often not willing to go on record with specific employment details. However, information from the companies that have shared such information for this report supports the validity of the aggregated averages in the job creation models.

San Gorgonio Farms operates 34 MW of wind turbines in Riverside County with a staff of 25.[25] This O&M employment rate of 0.74 jobs/MW is much higher than the CEC's projections for wind energy of 0.20 jobs/MW.

The Coram Energy Group is a wind farm operator in the Tehachapi area. The company employs five people full-time for the operation and repair of turbines with a combined capacity of 25 MW. In addition, they contract out much of the work involved in keeping the turbines online.[26] This O&M employment rate of 0.20 jobs/MW without secondary jobs is equivalent to the CEC's projections for total wind energy operating employment.

The Sunray Energy solar thermal power plants have a combined capacity of 44 MW and employ 50 people, not including outside contract work.[27] This 1.14 jobs/MW rate is much higher than EPRI's projection of 0.22 jobs/MW for operating and maintenance jobs at solar thermal plants.

Shell Solar employs 1,100 people worldwide and has an output of 60 MW of PV panels per year.[28] This employment rate of 18.3 jobs/MW is more than twice as high as EPRI's estimate of 7.14 jobs/MW, although some of this staff is dedicated to developing new technologies.

PowerLight has 100 employees and an annual output of 20 MW/yr of PV panels. This employment rate of 5.0 jobs/MW for panel manufacturing and the installation of a portion of the panels supports the EPRI rate of 7.14 jobs/MW, which includes all installation and outside materials and component manufacturing.

Mammoth Pacific employs 23 people at geothermal plants with a combined capacity of 40 MW.29 Using the rate determined for natural gas plants of 1.9 secondary jobs for every direct job, this equates to total employment of 66 jobs – 1.65 jobs/MW. This is substantially equivalent to the geothermal operating employment rate of 1.67 in the EPRI model.

CalEnergy's ten geothermal plants in the Imperial Valley are maintained by a staff of 295.[30] The plants have a combined capacity of 330 MW. This yields an employment rate of 0.9 direct jobs/MW. Including direct and indirect jobs, the CalEnergy plants create 2.6 jobs/MW, more than 50% higher than the EPRI rate.

Wind

Large companies in the wind energy industry include:

- SeaWest WindPower – The largest independent developer of wind energy plants in the world. Headquartered in San Diego, SeaWest has three California offices, as well as an office in Wyoming and three offices in Europe. The company was founded in 1982, and has installed thousands of turbines around the world. SeaWest is involved in every aspect of wind power, including project planning, equipment manufacturing, financing, installation, and maintenance.[31]
- GE Wind – Formerly Enron Wind, founded in 1980. The world's fourth largest wind turbine manufacturer. Has 350 employees in California, with headquarters in Tehachapi and a sales office in Los Angeles.[32]
- EnXco – Founded in 1985 as a wind farm operations and maintenance company. Expanded into project development in 1996. U.S. headquarters in North Palm Springs, with additional offices in Mojave, Tracy, and Livermore. Has 155 employees in California.[33]

Wind turbines contain both highly specialized parts custom built for specific local conditions and standard motors and other components common to many industrial operations. Hence, the industry contracts many services from small parts manufacturers and buys products from traditional industrial suppliers.

The largest wind farms currently in operation are in the Tehachapi area in Kern County, San Gorgonio Pass in Riverside County, and the Altamont Pass region of Alameda, Contra Costa, and San Joaquin counties. Future development will include replacing old turbines in these locations with larger, more efficient ones, as well as developing new sites. Most California counties have areas with wind resources strong enough to support electricity production.

Table 12. Geographic Distribution of Wind Energy Facilities[34]

County	Online Capacity (MW)
Kern	701
Riverside	368
Alameda	333
San Joaquin	265
Solano	67
Contra Costa	66
Merced	16

Table 13. Types of Companies in the Wind Energy Industry[35]

Type of Business Activity	Number of Companies
Battery Storage Systems	57
Business/Technical Consulting	76
Complete Wind Turbines	58
Electrical Components	46
Feasibility Studies / Site Analysis	55
Legal Assistance	10
Mechanical Components	31
Meteorological Consulting	23
Microprocessor Controls	16
Operation & Maintenance	32
Project Development/Installation	52
Project Financing	31
Turbine Monitoring Devices	27
Wind Measurement Devices	41
Total	136

The California Energy Commission compiled a directory of energy companies in California in 2001 for the purpose of promoting their services in expanding overseas markets. The survey reveals a remarkable breadth and depth of services already being offered.

Geothermal

Since electricity generation from geothermal energy consists of drilling wells and operating large steam turbines, the geothermal energy industry is dominated by large companies also involved in traditional energy production. Small consulting firms also play a significant role in helping these companies adopt to the unique characteristics of geothermal energy.

Major companies in the geothermal energy industry include:

- Calpine – Operator of the nation's oldest geothermal plants at the Geysers and developer of natural gas power plants. Headquartered in San Jose. Calpine also owns the license to develop power plants at geothermal fields in Shasta and Siskiyou counties. Calpine is currently upgrading its plants at the Geysers to increase output by 140 MW.[36]
- Caithness – The nation's largest producer of renewable energy, operating 420 MW of geothermal projects nationwide as well as solar and wind projects. Operates three 90 MW geothermal plants in the Coso region of the Mojave Desert, first developed in 1987.[37]
- CalEnergy – Operates ten geothermal power plants in the Salton Sea area of the Imperial Valley with a combined capacity of 330 MW. Seven of the plants went online from 1982-1990. One was added in 1996 and two more in 2000. The company is currently preparing a permit application for a new plant – at 200 MW the biggest by far – and intends to continue expanding on the Imperial Valley geothermal field after that plant is complete.[38]

Table 14. Types of Companies in the Geothermal Energy Industry[40]

Type of Business Activity	Number of Companies
Business/Technical Consultant	48
Civil & Geological Engineering	15
Developer/Builder	12
Drilling Equipment Supplies	17
Environmental Permitting, Monitoring & Control	38
Explor/Geology/Geochem/ Geophysics/Grad. Drill	31
Gathering Equipment	13
Legal Assistance	10
Plant Services - Pipelines	12
Power Plant Design Construction & Software	20
Project Financing	19
Pumps	26
Turbines/Condensers/ Heat Exchange Generators	29
Turnkey Projects	20
Well Completion	13
Well Logging	15
Total	145

- GeothermEx – A geoscience engineering firm based in Richmond. Provides technical evaluation of new projects, directs exploration activities, analyzes changing conditions, and performs financial projections for all types of geothermal energy projects.

Table 15. Geographic Distribution of Geothermal Plants[39]

County	Online Capacity (MW)
Sonoma	1,122
Lake	686
Imperial	475
Inyo	240
Mono	37
Lassen	2

California has fourteen geothermal fields of high enough temperature to support electricity production. The largest of these are the Imperial Valley area, the Coso Hot Springs region near Bakersfield, the Geysers region in Lake and Sonoma Counties, and the Medicine Lake area near the Oregon border. The Medicine Lake field is mostly undeveloped. The other fields have substantial generating capacity currently in operation, but still have untapped potential. All geothermal power plant development in the next decade will likely be in these four areas.

Solar Thermal

Three companies operate the solar thermal power plants in the Mojave Desert.

- The Kramer Junction Company (KJC) operates five 30 MW plants in Kramer Junction.
- Sunray Energy operates a 14 MW and a 30 MW plant near Daggett.
- Caithness Energy operates two 80 MW plants near Harper Dry Lake.

Science Applications International Corporation (SAIC), a Fortune 500 research and engineering firm, has their global headquarters in San Diego. SAIC has developed a 25 kW solar thermal electric system of the dish Stirling design.

New solar thermal power plants of large capacities will likely be in eastern San Bernardino County near the existing plants. SAIC's smaller solar thermal generators can be located across a more geographically diverse region. The company plans to market their system to utilities and businesses throughout California.

Solar PV

Market leaders in the solar photovoltaic industry include:

- PowerLight –The largest designer, manufacturer, and installer of grid-connected solar photovoltaic systems in the country, with operations in Berkeley and Oakland. Has its own line of patented PV products. *Inc* magazine has called PowerLight "one of the fastest growing privately-held busi-

Table 16. Types of Companies in the Photovoltaic Industry[43]

Type of Business Activity	Number of Companies
Arrays/Structures/Trackers	79
Battery Storage Systems	82
Business/Technical Consulting	99
Cells/Modules	72
Complete Systems	93
Concentrating Optics	11
Control Conversion	37
Legal Assistance	7
Project Financing	31
System Design/Engr	24
System Installation	77
Total	169

nesses." The company was founded in 1991, and annual revenues have doubled each year since 1997.[41]

- Shell Solar – Founded as ARCO Solar in 1977. Sold to Siemens in 1990 and recently acquired by Royal Dutch Shell. The world's fourth largest manufacturer of PV modules and systems. Shell Solar's main PV manufacturing plant is in Camarillo, in Ventura County.[42]

Because PV is marketed to individual residential and business consumers in addition to utilities and large industrial customers, the PV industry involves many distribution, consulting, and installation companies. The largest distributors include Real Goods, a marketer of many environment-friendly products based in Ukiah, and Solar Depot, a PV supplier based in San Rafael with a sales and design staff covering the whole state.

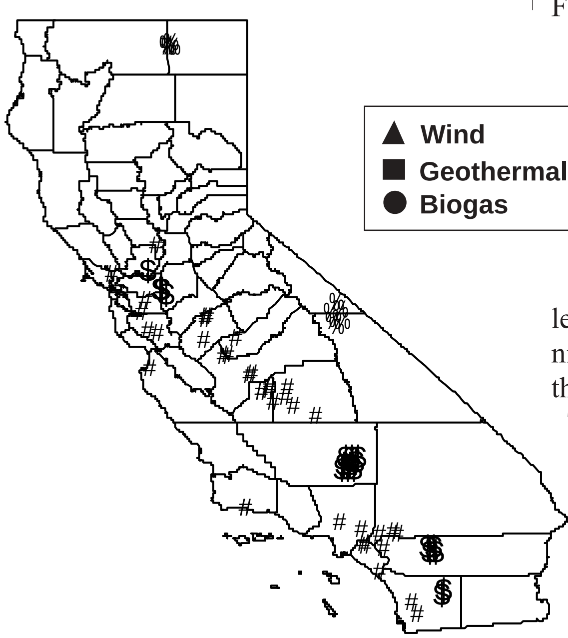
Location of Pending Projects

The mix of renewable energy projects currently negotiating for state financing indicate that these facilities will be geographically dispersed, creating jobs throughout California.

The California Consumer Power and Conservation Financing Authority (aka. California Power Authority, CPA) was created in May 2001 to provide stability in the California electricity market, ensure sufficient power reserves, and encourage the development of energy efficiency and renewable energy. In its first report to the Governor in February 2002, CPA concluded that the best way to guarantee reliable and affordable electrical power was to put nearly all of its financial backing behind energy efficiency and renewable energy.[44]

CPA put out a request for proposals for new energy projects in August 2001. Six months later, it had signed letters of intent (LOIs) with energy companies for 66 clean renewable energy projects that are now in the due diligence process.[45] These LOIs give a clear picture of where the next round of renewable energy projects will be located. (See Appendix B and Figure 2.)

Figure 2. New Renewable Energy Projects Pending with the California Power Authority[46]



Company Diversity

Companies large and small, old and new, are involved in renewable energy industries. Whereas fossil fuel-based energy production is dominated by a handful of giant energy conglomerates, renewable energy companies come in all shapes and sizes. These industries involve more small start-up companies than many other industries, but large and well-established companies are also involved in wind, solar, and geothermal energy production. This diversity will provide both stability and agility in a rapidly evolving market.

According to a CEC survey of California energy companies, a majority of renewable energy companies are 11-30 years old. More than a quarter of them were formed in the past ten years. 15% are more than 30 years old.

Nearly half of the companies involved in renewable energy industries have less than 10 employees. 29% employ 10-50 people. 4% are larger than 1,000 employees.

Companies with annual revenues of $1 million or less make up 44% of California's renewable energy industries. 20% of companies have revenues greater than $10 million.[47]

Renewable energy industries are a mix of union and non-union workplaces. To help ensure that jobs created by renewable energy growth are good jobs for California workers, renewable energy companies should be encouraged to uphold neutrality and card check agreements, thereby pledging not to engage in activities that prohibit efforts to unionize and to honor a non-confrontational process for union recognition if workers vote for representation.

Figure 3. Size of Renewable Energy Companies

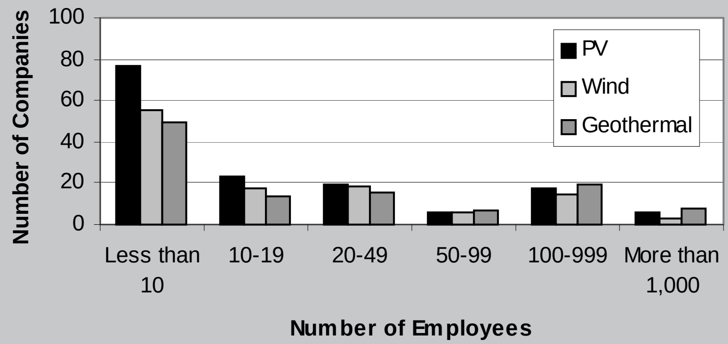


Figure 4. Age of Renewable Energy Companies

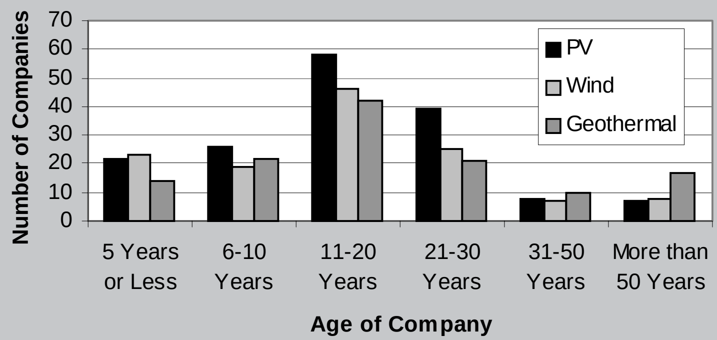
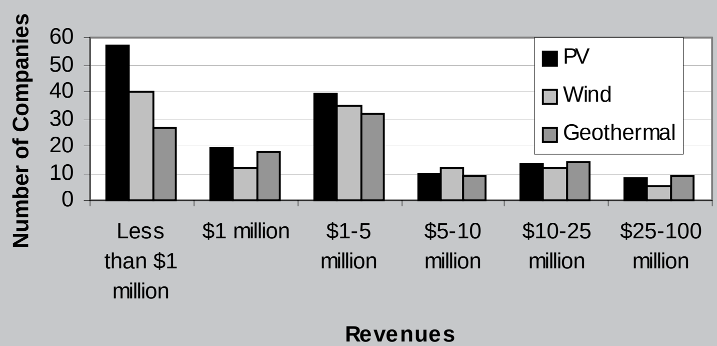


Figure 5. Revenues of Renewable Energy Companies



Comparison of Technologies

The California Energy Commission employment projections offer the clearest picture of job growth from renewable energy technologies. Comparing these projections with data from existing natural gas power plants and the permit applications of gas plant developers, it is clear that renewable energy provides more jobs than traditional energy sources.

Building an average 500 MW natural gas power plant results in 2,460 person-years of employment, including thirty years of operation. Building the equivalent capacity of renewable energy can create 4,000-36,000 person-years of employment, depending on the technology. Wind power typically provides 70% more jobs than gas, and solar technologies provide twice as many jobs. Job creation from geothermal energy is 11 times higher than from natural gas. Landfill gas plants employ 14.7 times as many workers. (See Table 17.)

Table 17. Employment Rates by Energy Technology

Technology	Construction Employment (jobs/MW)	Operating Employment (jobs/MW)	Total Employment for 500 MW of Capacity (person-years)	Factor Increase over Natural Gas
Wind	2.57	0.20	4,285	1.7
Geothermal	4.00	1.67	27,050	11.0
Solar PV	7.14	0.12	5,370	2.2
Solar Thermal	5.71	0.22	6,155	2.5
Landfill/Digester Gas	3.71	2.28	36,055	14.7
Natural Gas	1.02	0.13	2,460	1.0

Table 18. Impact Comparison of Developing 5,900 MW of Capacity

	Job Creation (person-years)	Gas Purchases
Renewables	120,766	0
Natural Gas	29,028	$10.3 billion

The mix of renewables likely to come in the next decade would yield four times as many jobs as natural gas power plants if renewable energy development proceeds rapidly. Building 5,900 MW of new natural gas power plants would create only 29,000 person-years of employment. Developing the equivalent amount of renewable energy would create an estimated 120,000 person-years of employment.

Choosing the natural gas path would also result in the departure of $10.3 billion from the state economy over thirty years from out-of-state fuel purchases.[48]

Policy Recommendations

Renewable portfolio standard

A requirement that at least 20% of California's electricity comes from wind, solar, and geothermal energy by 2010 is reasonable and achievable. This would create economies of scale, spur innovation, and establish markets and technologies. Renewable energy industries would be able to springboard off this boost to achieve higher levels of market penetration with less assistance. Fifty percent of electricity demand met by renewable energy by 2030 should be the goal. The best policy instrument to move the state toward this goal is a requirement that all electricity retailers acquire 20% of their electricity from renewable energy producers by 2010.

Long-term state contracts

The biggest barrier to developing renewable energy resources is that nearly all of the costs are upfront. To ease this hurdle, the state can enter into long-term contracts with renewable energy producers, guaranteeing a set price for most of the lifetime of the renewable plant.

In May 2001, California created the Consumer Power and Conservation Financing Authority (CPA). Part of the stated purpose of this new agency is to "create financial incentives for ... use of renewable energy resources."[49] The most effective incentive to ensure that new renewable energy facilities actually get built is a guaranteed stable wholesale price for the electricity from these facilities. Administering long-term contracts in conjunction with private utilities would achieve this guarantee. CPA should be encouraged to continue and strengthen its efforts to finance renewable energy projects. CPA should also be authorized to negotiate long-term contracts that are assignable to the utilities when they regain financial stability.

Tax equity

Tax equity needs to be established between renewable energy producers and traditional energy suppliers. Since the assets of renewable energy producers are worth more in terms of replacement value, they currently pay higher taxes. Several policy options exist to level the playing field:

- Energy producers could be taxed on output rather than assets.
- Tax rates could be adjusted for renewable energy producers to make taxes on their facilities roughly equivalent to traditional power plants per unit of output.
- The state could tax traditional fuels to compensate for the negative environmental and public health effects of fossil fuel combustion and nuclear fission.

Given the positive effects a healthy renewable energy industry will have on the state economy, reducing the industry's debilitating tax burden would be a wise financial move for long-term economic strength.

Incentives for development and production

New energy technologies need assistance in order to compete with mature technologies, as well as to ensure the state does not miss out on opportunities that need a development boost but will be beneficial in the long run. Historically, there has never been a new energy technology commercialized without government financial help. If a new technology proves to indeed provide a valuable benefit to and gain acceptance from the public, assistance will gradually become unnecessary and can be terminated. Since subsidies to a few manufacturers are easier to administer than subsidies to consumers, they can be even more effective at pushing the commercialization of new energy technologies.

Incentives for consumers

As long as consumers are expected to shoulder the burden of the investment costs of solar panels and small wind systems, the government must provide financial incentives to install this equipment. Even though wind and solar power generation is cost-effective for consumers over the lifetime of the equipment, the high initial investment precludes most consumers from taking advantage of good opportunities they may have. A well-funded buy-down program results in considerable load reductions on the grid. Since many residential solar arrays produce more power than a household uses during peak demand times, this will reduce the need to build power plants throughout the state which only serve peak need. The state should continue its programs in this area.

Appendix A. Renewable Energy Market Growth

California's renewable energy capacity is greater than that of any other state, but growth has stalled in the past ten years. Eight percent of California's electricity now comes from clean renewable sources. With market guarantees provided by public policy, California could generate 20% of its electricity from clean renewables by 2010. This would meet the goal for renewable energy growth established by Governor Gray Davis.[50]

Historical Growth

Renewable energy in California grew steadily in the 1980s, then stalled in the uncertain market leading up to deregulation. Much of this growth has come from independent generators that sold their output to the utilities.

Wind energy in California grew from 52 GWh in 1983 to 655 GWh two years later, then rose to 2,418 GWh in 1990. For the next decade, annual wind energy production inched up at an average growth rate of 118 GWh per year.

Solar power production jumped from 33 GWh in 1985 to 679 GWh in 1990 due mainly to the solar thermal power plants in San Bernardino County that came online during that time. Since 1993, solar power output has been hovering around 800 GWh/yr.

Geothermal energy in California dates back to the 1950s. Since 1986, geothermal energy production has fluctuated between 12,000 and 16,000 GWh/yr. Throughout the 1990s, the utilities gradually sold their geothermal facilities to independent producers.

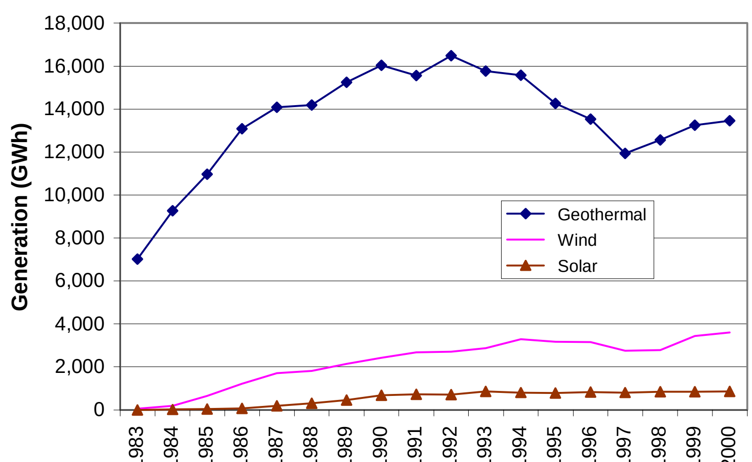
Future Growth

California has only begun to realize its vast potential for electricity generation from renewable sources. The state could generate 63,000 GWh/yr of electricity from renewables by 2010. This is more than three times as much renewable energy production as in 2000, when the state produced 19,000 GWh from clean renewable sources. Most of this would come from wind and geothermal energy. Solar resources could also provide significant growth in the next decade as the first step toward even more substan-

Table 19. California Renewable Energy Growth[51]

	Generation (GWh/yr)			
Source	1985	1990	1995	2000
Utility				
Geothermal	10,122	9,684	5,855	1,252
Wind	0	0	13	7
Solar	2	2	3	3
Non-Utility				
Geothermal	835	6,354	8,412	12,204
Wind	655	2,418	3,169	3,597
Solar	31	679	790	857
Total				
Geothermal	10,957	16,038	14,267	13,456
Wind	655	2,418	3,182	3,604
Solar	33	681	793	860

Figure 6. California Renewable Energy Growth



tial capacity thereafter. Electricity generation from landfill gas will gradually increase as well. (See Table 19.)

The California Energy Commission estimated in February 2002 that California will need 316,655 GWh of electricity in 2010 under the most likely demand growth scenario.[52] A renewable energy capacity of 63,000 GWh/yr in 2010 would thus constitute 20% of the state's electricity supply.

Wind Energy

Current capacity

Wind power is the fastest growing energy source worldwide. New wind power capacity grew by 24% annually throughout the 1990s,[54] with a growth rate of 37% in 1999 and 28% in 2000.[55]

California now has more than 16,000 wind turbines that generate an average of 400 MW of electricity.[56] This provides for about 1.5% of California's electricity needs.

Future growth

In 1998, scientists at the Lawrence Berkeley National Laboratory analyzed all previous California wind resource studies. They found that the state's 36 best sites could generate an average of 10,000 MW, 32% of current electricity needs. Their economic analysis showed that most of this development could occur sooner rather than later. By the year 2010, 3,000 MW could be operational at less cost than other energy resources. At an added cost of just 2 ¢/kWh over conventional power, an additional 1,600 MW of wind power could be developed by 2010, for a total of 4,600 MW of average capacity, including the current capacity of 400 MW.[57]

Since this analysis, the outlook for natural gas prices has changed dramatically. Market analysts predict a steady increase in the average price of gas, and wide price fluctuations around that average are all but certain. For this reason, these predictions should be taken as very conservative estimates. Continued high gas prices would result in no price premium for this amount of wind power development in the next decade.

The Lawrence Berkeley analysis documents California's potential to add 4,200 average MW of new wind power capacity. To be conservative, this report assumes that only 3,700 MW of wind will be developed by 2010 under favorable market conditions.

Beyond the potential for developing wind farms to produce bulk electricity, single home-sized wind turbines in the 10-50 kW range are becoming popular in California. Since they don't need as much wind as the larger turbines, they can be effective in more areas. The American Wind Energy Association (AWEA) estimates that 60% of the U.S. can effectively utilize small wind systems for a combined peak capacity of 40,000 to

Table 20. Future Renewable Energy Growth with Market Guarantees[53]

	Capacity (MW)*			Generation (GWh/yr)			
Source	2000	2001-2010 Growth	2010	2000	2001-2010 Growth	2010	2010 Pct of Total Energy Mix
Wind	420	3,700	4,120	3,604	32,412	36,016	11%
Geothermal	2,200	1,500	3,700	13,456	9,198	22,654	7%
Solar PV	15	200	215	33	491	523	0.2%
Solar Thermal	354	400	754	860	981	1,841	1%
Landfill Gas	174	100	274	1,362	830	2,192	1%
Total	3,163	5,900	9,063	19,315	43,912	63,227	20%

* Wind in average MW. All others in peak MW.

80,000 MW. With the California Energy Commission's rebate program of up to 50% on the purchase price of a home wind turbine system, the initial investment can be recovered in just six to ten years, while small wind systems are designed to operate for at least 30 years.[58] However, this dispersed generation is not included in this report's projections for renewable energy growth.

Geothermal Energy

Current capacity

California currently has 2,200 MW of geothermal electricity generating capacity, producing nearly 6% of the state's electricity.[59] The geothermal industry includes fifteen companies and associations with operations in California, six of which own more than 100 MW of generating capacity.[60]

Future growth

The total potential of geothermal energy is almost limitless. The thermal energy in the uppermost six miles of the earth's crust amounts to 50,000 times the energy of all oil and gas resources in the world.[61] This is a renewable resource that maintains its thermal energy over time.

Energy analysts estimate that the state has the potential for an additional 4,000 MW of geothermal electricity generating capacity at a small average price premium using current technology.[62] The rate of development of this resource will increase as the technology advances. Already the best resource areas can be developed at a cost lower than the cost of natural gas power plants.[63]

According to the Geothermal Energy Association, California has the potential to boost output from existing plants in the near term by 300-600 MW and can develop up to 1,000 MW at known but undeveloped reserves at each of three locations – the Salton Sea, northern California, and the Geysers area north of San Francisco – for a total of 3,600 MW that can be practically developed with today's technology.[64]

Given these predictions and the low cost of geothermal energy production under favorable conditions, it is reasonable to expect at least 1,500 MW to come online by 2010.

Photovoltaics

Current capacity

Due to PV's dispersed nature, it is difficult to estimate total current generating capacity. Based on solar panel sales information, the U.S. Department of Energy estimates that 194 MW of PV capacity is installed nationwide.[65] In California, there is probably no more than 15 MW of electricity generation capacity, including 7 MW installed by the Sacramento Municipal Utility District and another 8 MW scattered throughout the state.[66]

Future growth

There is tremendous potential for rooftop applications of PV in California. The California Solar Energy Industries Association estimates that there are enough suitably oriented rooftops in the state to host more than 20,000 MW of PV panels in the long term.[67] This is more than one-third of total peak demand.

Because PV involves installations at many dispersed locations, with each installed unit

Table 21. California PV Additions with 35% Annual Growth

Year	New Additions (MW)	Total Capacity (MW)
2001		15
2002	5	20
2003	7	27
2004	10	37
2005	13	50
2006	17	67
2007	24	91
2008	32	123
2009	43	165
2010	58	223

adding a small increment of energy, PV will not add power to the California grid as quickly as other resources. However, due to its long-term value as a reliable, low-maintenance source of electricity that reaches peak capacity at peak demand times and reduces the need for costly transmission line upgrades, it should be encouraged as a fundamental component of California energy development in the next decade. Costs will continue to drop as manufacturers reach economies of scale and new technologies become commercialized. Communities throughout California should be encouraged to follow Sacramento's lead and use bulk purchasing power and central coordination to add significant amounts of PV power to the grid.

From 1989-99, the growth rate of worldwide PV module shipments averaged 18%. For the same time period, the U.S. growth rate was 21%. Recently the growth rate has been much higher. The average growth rate in 1997-99 in the U.S. and worldwide was 31%. In 1999, the U.S. growth rate of PV module shipments was 52%, the highest ever, while the worldwide growth rate of shipments remained at a healthy 30%.[68] With a conservative assumption of 35% annual growth over the next decade, California will have 223 MW of photovoltaic capacity by 2010.

A more likely progression under favorable policies would see capacity added even faster. Capacity has already begun to accumulate in larger increments. Alameda County's Santa Rita Jail recently installed a 500 kW PV system, and San Francisco is now planning to add 10-12 MW within three years.[69] A concerted push in Los Angeles will encourage the installation of 100,000 rooftop PV systems – approximately 200 MW – by 2010 in that area alone, according to the California Department of Water Resources.[70] If all of these efforts are sustained and are replicated in other regions, PV capacity in 2010 will be far higher than 200 MW.

Solar Thermal Energy

Current capacity

California currently has nine parabolic trough solar thermal power plants, all in San Bernardino County, operated by three separate companies. The plants range in size from 4 to 80 MW, with a combined capacity of 354 MW. This constitutes over 90% of the solar thermal electricity generation in the world.[71]

Future growth

Experience with prototype designs has shown that a workable size for solar thermal power towers by 2010 will be 200 MW per plant. Solar experts believe that developers will take advantage of opportunities to build these plants if the state offers long-term contracts for the electricity produced.[72] Just two plants in the Mojave by 2010 would boost California capacity by 400 MW.

Appendix B. Location of Renewable Energy Projects Seeking Financing from the California Power Authority

Project	Capacity (MW)	Location
WIND		
PacifiCorp Power Marketing	100	Solano/Alameda Co.
Clipper Windpower, LLC	53	Cape Blanco, Oregon
Clipper Windpower, LLC	100	Altamont Pass
enXco	30	Altamont Pass, Contra Costa Co.
enXco	18	Altamont Pass, Contra Costa Co.
Cannon Energy Corporation	100	Morongo Indian Reservation, Riverside Co.
Cannon Energy Corporation	200	Cuyapaipe Indian Reservation, San Diego Co.
Cannon Energy Corporation	200	Cuyapaipe Indian Reservation, San Diego Co.
Windridge, LLC (FP&L)	60	Mojave, CA
Clipper Windpower, LLC	38	Riverside Co.
CVT Marketing Group, LTD	50	Tehachapi Pass area, Kern Co.
High Winds LLC (FP&L)	150	Birds Landing, CA (Montezuma Hills)
Southern Sierra Power (FP&L)	200	Kern Co.
Enron Wind Development	33	Riverside Co.
SeaWest Windpower, Inc.	35	San Gorgonio Pass, near Palm Springs, CA
Enron Wind Development	300	Tehachapi Pass area, Kern Co.
enXco	60	Tehachapi Pass area, Kern Co.
Oak Creek Energy Systems	5.4	Tehachapi Pass area, Kern Co.
Oak Creek Energy Systems	41.8	Tehachapi Pass area, Kern Co.
Oak Creek Energy Systems	52.5	Tehachapi Pass area, Kern Co.
Oak Creek Energy Systems	18	Tehachapi Pass area, Kern Co.
Wind Total	1845	
GEOTHERMAL		
Cal Geo Co.	15	Modoc Co.
Cal Geo Co.	15	Modoc Co.
Cal Geo Co.	30	Siskiyou Co.
Cal Geo Co.	30	Siskiyou Co.
Cal Geo Co.	30	Siskiyou Co.
Mammoth-Pacific	15	Mammoth area
Heber Geothermal Co.	28	Mammoth area
Mammoth-Pacific	60	Mammoth area
Second Imperial Geothermal Co.	32	Mammoth area
Cal Geo Co.	15	Mammoth area
Cal Geo Co.	45	Mammoth area
Geothermal Total	315	

Project	Capacity (MW)	Location
LANDFILL GAS / BIOGAS		
Monterey RWMD	1.0	Marina, Monterey Co.
Microgy	1.4	Lemoore
Microgy	1.2	Hanford
Microgy	1.8	Lemoore
Microgy	1.5	Corcoran
Microgy	1.0	Hanford
Microgy	1.6	Firebaugh
Microgy	2.2	Burrel
Microgy	1.8	Burrel
Microgy	1.4	Hilmar
Microgy	2.2	Hilmar
Microgy	5.3	Chowchilla
Microgy	1.0	Hilmar
Microgy	1.2	Los Banos
Microgy	2.4	Tulare
MM Yolo Power	2.5	Davis
USA Waste of CA (Tri-Cities)	2.56	Fremont
USA Waste of CA (Redwood)	2.56	Novato
USA Waste of CA (Kirby Canyon)	1.28	Morgan Hill
USA Waste of CA (Altamont)	1.28	Livermore
Ridgewood Olinda I	2.0	Brea, Orange Co.
Ridgewood Olinda II	7.2	Brea, Orange Co.
MM Tulare Energy	1.8	Visalia, CA
MM West Covina	11.7	West Covina, CA
MM Lopez Energy	6.1	Lake View Terrace, CA
MM San Diego (Miramar)	6.5	San Diego, CA
MM San Diego (North City)	3.8	San Diego, CA
USA Waste of CA (El Sobrante)	2.56	Corona, CA
MM Prima Deshecha Energy	6.1	San Juan Capistrano, CA
MM Tajiguas Energy	3.1	Santa Barbara, CA
MM Woodville Energy	0.6	Woodville, CA
MM San Bernardino Energy (Colton)	1.2	Colton, CA
MM San Bernardino Energy (Mid Valley)	2.5	Rialto, CA
MM San Bernardino Energy (Milliken)	2.5	Ontario, CA
Biogas Total	94.8	

Appendix C. Description of Generating Process and Labor Requirements by Technology

Electricity generation from renewable energy sources requires a wide variety of activities, many of which are highly specialized and labor intensive.

Wind Power

The power of wind is captured and converted to electricity by wind turbines. Wind turns the rotor blades of the turbine, which turns a shaft that spins a generator to produce electricity.

Key components of wind turbines include:

Rotor blades – Modern rotor blades are manufactured from light composite materials (such as wood or fiberglass composites) that are strong enough to sustain gusty winds. The shape of the blades is dictated by aerodynamic principles. As a result, blades must be manufactured according to exacting standards.

Hubs – Hubs transfer the rotation of the blades to the generator. Hubs are typically made of steel. Many are connected to a gearbox that transfers the low-speed rotation of the rotor into a higher-speed rotation needed to power the generator.

Generators – Generators convert the rotational energy of the hub into electricity. Conventional, high-speed generators are common and can be obtained "off the shelf," but the high rotational speeds required necessitate the use of a costly gearbox.[73] Innovative low-speed generators are now in development that could potentially eliminate the need for a gearbox.

Towers – Towers are important to the operation of wind turbines because wind tends to be more powerful and less turbulent at higher elevations. Towers come in one of two configurations – conical tubular steel (the most common) or latticed steel. Conical steel towers are made in sections then bolted together with hot rolled steel flanges. The process for manufacturing towers is similar to that of manufacturing oil tanks and pressure vessels.

Controllers – Electronic controls are essential to the effective use of modern wind turbines. Control mechanisms communicate data from the turbine (including calls for maintenance) via telephone or radio, alter the direction of the rotors to take best advantage of wind conditions, and manage the quality of power generated.[74]

Another important element of wind turbine construction is the cost of infrastructure to provide physical and communications access to the turbines (roads and telecommunication equipment) and to carry electricity from the turbines to the power grid. In cases where electrical transmission lines must be run for long distances to gain access to a power grid, the cost can increase the effective installed cost of the wind farm by up to 50 percent.[75] As a result, wind resources located closer to existing infrastructure are more preferable than those located in distant locations.

Land also plays a key role in wind power generating facilities. While wind farms tend to cover large surface areas in relatively undeveloped locations, the footprint of the turbines within that area tends to be rather small. As a result, wind power generation can coexist with other land uses, such as farming and ranching. Land for wind farms is typically leased, either from public entities (providing a financial windfall to taxpayers) or from rural landowners, who are able to augment their earnings from agriculture.[76]

The operations and maintenance needs of wind turbines tend to be low when the turbine is relatively new, but increase as the equipment ages.

Geothermal Power

Geothermal systems use the earth's heat to generate electricity. The most common geothermal systems tap underground reservoirs of hot water, which, upon being brought to the surface, becomes steam that turns a turbine, creating electricity.

Exploration and exploitation of geothermal resources is similar to that of fossil fuels. Reservoirs of hot water must be identified under the earth's surface using geologic, geophysical, and geochemical data.[77] Drilling equipment similar to that used by the oil and gas industry is then used to tap the resources.

Drilling geothermal wells poses technical challenges due to high temperatures and hard rock formations. To drill a well, a drill bit is mounted on the end of a metal tube called a drill string, which is rotated to turn the bit. As the drill bit goes deeper into the ground, new lengths of pipe are inserted on top of the string. A liquid called drilling mud is pumped down the tube to cool and lubricate the drill bit.[78] After the well is drilled, typically to depths of between 200 and 3,500 meters, steel pipe is cemented into the hole to carry hot water (and/or steam) to the surface.

Some wells that produce high-quality steam feed the steam directly into a turbine that generates electricity. Other wells feed high-temperature water into a low-pressure tank where it "flashes" into steam to power a generator. Plants using lower-temperature sources often feed the liquid into a heat exchanger, where it heats another liquid with a lower boiling point, which then vaporizes to drive the turbine. These plants are known as "binary" geothermal plants. In all cases, the cooled liquid is reinjected into the reservoir through an injection well.

Geothermal energy production shares many technologies with fossil fuel extraction and conventional power plants. There are differences, however. First, because geothermal power plants tend to be located on or near the geothermal resource, there is no need to transport fuel over long distances. Second, hot geothermal brine can be very corrosive, leading to the need for more resistant pipes, heat exchangers, and other parts.

The bulk of the cost of a geothermal project – as much as 60 percent – is incurred at the very first stage, exploration. Operations and maintenance also require a significant amount of labor.

Photovoltaics

Photovoltaics in electric generating applications can either obtain access to sunlight directly (flat-plate photovoltaics) or have highly concentrated sunlight focused on them by a lens. The choice between flat plate systems and photovoltaic concentrators depends largely on the quality of the sunlight available in a particular location – locations that receive large amounts of direct sunlight can benefit from use of a concentrator, while those locations with more diffuse light are more appropriate for flat plate systems.[79]

PV is most commonly manufactured from wafers of crystalline silicon, which are then put through a semiconductor processing sequence to become working solar cells. The silicon used in PV manufacturing must be relatively pure, but not as pure as that used by the electronics industry. For many years, PV manufacturers have used silicon rejected by electronics firms, but the growing demand for PV could soon force manufacturers to turn to other sources of feedstock. The wafers are then chemically treated, soldered together, and hermetically sealed under glass to form solar modules. The modules are then typically attached to frames for installation.[80]

An alternative to traditional PV has arisen in recent years in the form of "thin film" PV. Thin film PV is lighter and has the potential to be more flexible than traditional PV. Because it uses less semiconductor material, thin film PV could also eventually become cheaper than crystalline silicon devices. At present, however, manufacturing costs for thin film PV remain high.

Thin film PV uses amorphous silicon or other light-absorbing substances that can be spread thinly over a large surface, typically specially treated glass or metal. Like crystalline silicon PV, thin film PV is then packaged into modules for installation.

Both crystalline silicon and thin-film PV must be attached to other electrical systems in order to convert the electricity generated by the PV into useful power. DC-AC inverters, wiring, batteries, and other electrical equipment is typically needed.

The process of manufacturing PV is highly specialized. Solar cell plants are complex and large and tend to be centralized to maximize economies of scale and opportunities for automation. Still, PV manufacturing and installation tends to be labor-intensive.

Photovoltaic concentrator systems add an extra piece of equipment – an optical concentrator that tracks the sun – to a modified conventional PV system. Because they can be used to focus sunlight onto a small area, concentrator systems have the benefit of reducing the number of solar cells needed to produce electricity. The materials to construct concentrators are readily available glass, plastic, metal, and electrical components.

Because of the sophisticated technology needed to manufacture PV systems, the types of jobs created tend to be similar in quality to those in other high-tech fields. The PV industry currently employs about 15,000 people in the U.S., with most in jobs such as manufacturing, engineering, sales, servicing, and maintenance.[81]

Solar Thermal

Solar thermal collectors differ from photovoltaics in that they use the sun's heat, rather than its light, to generate electricity. Mirrors focus sunlight on a receiver liquid, which collects the heat and uses it to generate electricity.

There are three main solar thermal technologies: parabolic trough systems, which use parabolic mirrors to focus sunlight on a receiver, consisting of a tube containing heat-transfer fluid; power towers, which use an array of ground-level mirrors to focus light on an elevated receiver; and dish-engine systems, which use mirrors similar to a satellite dish to focus light on a receiver. In trough and power tower systems, the receiver liquid goes through a heat exchanger to create steam, which is then used to power a conventional turbine. In dish-engine systems, the receiver becomes the working fluid in a Stirling engine, which produces electricity.[82]

Currently, parabolic trough systems are the most widely used solar thermal systems. Nine such systems were built in California by Luz International, which estimated that each of the 80MW plants required about 500 job-years to construct.[83] Power tower systems have been demonstrated in California, while dish-engine systems are in earlier stages of development.

Unlike PV, which requires access to significant amounts of pure silicon and other advanced materials, thermal collectors rely on more commonly available materials. Parabolic troughs, for instance, involve the following key components:[84]

Reflectors (mirrors) – Manufactured of silver-coated aluminum or glass, mirrors are specially coated to protect them from the elements and to maximize the amount of light reflected onto the receiver.

Receiver tubes – Either vacuum or non-vacuum tubes, these are manufactured of glass and stainless steel and hold the heat-transfer fluid.

Heat-transfer fluid – This is typically oil in trough systems, but other substances are used in dish-engine systems.

Heat exchangers, turbines – In trough systems, heat exchangers and conventional steam turbines are used to generate electricity from the heat contained in the heat-transfer fluid.

Control systems are also important parts of solar thermal systems, mechanically angling mirrors to best take advantage of available sunlight and providing data on operational status. Solar thermal systems also require regular maintenance, such as mirror cleaning. The Solar Two demonstration power tower project in California, for example, employed nine full-time staff, including three people to run the plant's control system, a maintenance crew, an instrument technician, an electrician, and a mechanic.[85]

Natural Gas

Combined-cycle natural gas power plants capture waste heat from a conventional gas turbine and use it to create steam that powers a second turbine. More efficient than traditional natural gas power plants, combined-cycle plants have become the standard for new plants in California and elsewhere.

Unlike solar, wind, and geothermal power, in which electricity is generated at the same location as the resource that is being used, natural gas is typically extracted at one site, then shipped to the power plant via pipeline. In essence, this breaks the natural gas electricity generation process into three stages: extraction and processing, transportation, and electricity generation.

Extraction and processing – Natural gas is produced from gas or oil wells drilled either on land or offshore. Exploration for natural gas deposits is similar to that for oil and geothermal reservoirs, involving scientific measurements to locate potential deposits and test drilling to confirm their presence.

Once natural gas is extracted, it often requires additional processing – "drying" and "sweetening" – to remove moisture, poisonous sulfur dioxide gas, and other contaminants.

Unlike solar, wind, and geothermal resources – which California possesses in abundance – the state imports about 85% of the natural gas it uses from other states and Canada. As a result, employment from the extraction and processing sector of the industry largely takes place out-of-state.

Transportation – Most natural gas is compressed and shipped via pipeline. Pipelines are typically made of steel and buried underground. Compressor stations and storage fields are sometimes required for long interstate pipelines. Transportation via pipeline requires large amounts of steel, as well as significant amounts of excavation activity. Pipelines also require continual monitoring and maintenance to ensure their safety.

Electricity generation – In combined cycle natural gas power plants, electricity is derived from two sources: a conventional gas turbine and a steam turbine powered by waste heat from the gas turbine. Compressors, boilers, piping, and emission controls are integrated at various points in the system.

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