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*Chapter Twenty-Five*

# RENEWABLE ELECTRIC GENERATION IN COMPETITIVE MARKETS

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## INTRODUCTION

California's electric generation system is one of the most diverse in the world. Its electricity is supplied by a blend of fuels and technologies that include fossil generation, nuclear generation, renewable' generation, large hydro, and imported electricity from both the Northwest and Southwest, made up of nuclear, large hydro, and fossil generation. California's electricity accounts for 10 percent of the energy consumed in the state and for nearly 50 cents out of every dollar spent on energy. The state's network for providing electricity is elaborate: 1,013 power - plants, 2,500 substations, and 40,000 miles of transmission lines. Power in the state is provided by five investor-owned utilities, 26 municipal utilities, four irrigation districts and five rural electric cooperatives.'

This chapter examines the regulatory and market factors that have helped California to become a world leader in the development and use of renewable electric generation. The period under review here begins in the 1970s and covers twenty-five years. In the late 1970s, fossil generation dominated the electricity system in California. Heavy dependence on fossil generation, up to 70 percent of total generation, coincided with a period in which oil and gas were perceived to be in short and unreliable supply, raising concern about the longterm security of fossil supplies and associated cost and price escalations. This concern about cost and security of supply of fossil fuels prompted policy responses to reduce these long-term risks. The search for alternative, less risky supplies intensified, and policy incentives and regulations prompted market participants to explore alternatives. Renewable electric technologies offered an attractive option because they were produced domestically and thus were not subject to the vagaries and risks of political and economic instability overseas. These technologies were relatively clean, with little or no emissions associated with their use. Their reliable operation had been proven through technological demonstration. On the down side, however, renewable technologies were perceived to have high costs relative to conventional alternatives.

Methodologically, this chapter applies quantitative and institutional analysis to characterize the respective role of market forces and policy regulation in the development of renewables in California. The quantitative analysis includes an empirical estimation of a cost function utilizing panel data techniques and the application of the Hodrick-Prescott method to differentiate between *actual* and *potential* renewable electricity generation in California. The quantification portion also includes the application of a simple logit model to gauge the relative contribution of economic forces to the survival of renewable facilities in California. In the institutional portion, this chapter offers an analytical and historical account of the policy environment, including both policy challenges and policy responses. which has been conducive to *the* evolution of renewable energy in California. The quantitative and institutional framework enables us to highlight lessons learned and to offer an assessment of the future of renewables in the generation of electricity in California.

The remainder of this chapter is organized as follows: section two surveys the historical development of renewables in California; section three empirically addresses the role of market forces in the development of renewable-based electricity generation in California, and also applies a simple logit model to estimate the chance of renewables surviving under a rapidly changing market structure; section four is a discussion of the policy measures that have nurtured the development of renewables in California; and finally, the chapter concludes with a summary of findings and policy lessons.

## 2. CHARACTERIZATION OF RENEWABLE ELECTRICITY IN CALIFORNIA

Several observations can be made regarding the time-series data on the historical profile of electricity generation that are shown in Table 1. First, growth rates of electricity generation varied during the 1980s and 1990s. High rates of growth were recorded in the early eighties relative to the rates in the nineties. The deceleration in growth rates resulted from the introduction of energy conservation, enhanced efficiency, and saturation of electricity use. In 1990, for instance, regulators in California allowed utilities to share the savings they helped customers to achieve'

Second, the share of renewables in electricity generation has greatly increased between 1983 and 1998. This remarkable growth is due to a variety of factors that include incentive regulation and education programs that expanded the demand for environmentally clean generation sources. On the supply side, technological progress caused the cost of generation by renewable sources to decline geometrically over time. For instance, the cost of generating electricity from wind has fallen dramatically since the mid-1970s, when the U.S. Department of Energy estimated that it cost $1 per kilowatt-hour to generate electricity from wind in the United States. By 1996, that cost had dropped dramatically to only 5 cents per kilowatt-hour.4.4

Third, despite the remarkable growth that renewable energy has achieved, areas of malaise remain. Specifically, there are marked time-dependent variations in the growth of renewables. In other words, California's progress toward a renewable electricity market has been volatile. The degree of volatility varies according to utility and independent suppliers. During the period under consideration, the logarithm of the variance of renewables' supply by utilities was 0. 053, while the corresponding statistic for independent suppliers was 0.59; that is, more than eleven times as large. The higher volatility of electricity generated by independent suppliers of renewables is indicative of the higher risks that circumscribe the supply of renewables through independent suppliers. Utilities have integrated facilities and access to financing at favorable credit terms.

## 3. MARKET FORCES: THE ROLE OF COSTS

In general, costs can be divided into three categories: fixed capital costs, fuel costs, and operating and maintenance costs. Renewables are characterized by high capital costs relative to nonrenewables. We attempt to explain the observed variations in generation according to source, renewable versus nonrenewable, by applying a simple regression model to California's electricity generation and cost data.' The data are panel covering the period 1990 to 1995 for nine technologies: five renewable (small hydro, solar, wind, organic waste, and geothermal), three fossil-fueled (coal, gas, oil), and nuclear. The model examines annual variations in electricity generated by each technology type during the six-year period and attempts to establish the relative contribution of its capital costs, fuel costs, and operating and maintenance costs. The analysis yields crude estimates of the elasticity of output - electricity generation - with respect to capital, fuel and operating and maintenance costs. Algebraically, the model is

$$F_{it} = \alpha_o + X_{it}\beta + a_i + \varepsilon_{it} \qquad i = 1,\ldots 9,\ t=1990,\ldots,\ 1995.$$

Where Fit connotes the annual generation by the ith technology, Xit contains

TABLE 1:
*California Electricity Generation 1983-1998*

| | **1983** | **1985** | **1989** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1998** |
|---|---|---|---|---|---|---|---|---|---|---|
| **TOTAL GENERATION** | 199,609 | 210,172 | 238,567 | 252,355 | 242,434 | 245,535 | 242,026 | 257,799 | 256,367 | 268,136 |
| **HYDRO-ELECTRIC** | 59,351 | 33,898 | 32,742 | 26,092 | 23,244 | 22,373 | 41,595 | 26,706 | 51,665 | 48,462 |
| **NUCLEAR** | 6,738 | 18,911 | 33,803 | 36,586 | 37,167 | 38,622 | 36,579 | 38,828 | 36,186 | 41,565 |
| **COAL** | 17,564 | 14,977 | 19,702 | 21,402 | 23,442 | 32,435 | 22,907 | 25,095 | 17,925 | 29,043 |
| **OIL** | 6,535 | 2,790 | 9,275 | 4,449 | 523 | 107 | 2,085 | 1,954 | 489 | 123 |
| **GAS** | 45,486 | 69,771 | 78,916 | 76,082 | 75,828 | 87,032 | 70,715 | 95,025 | 78,378 | 79,616 |
| **GEOTHERMAL** | 7,020 | 10,957 | 15,247 | 16,038 | 15,566 | 16,491 | 15,770 | 15,573 | 14,267 | 12,554 |
| **ORGANIC WASTE** | 731 | 1,171 | 5,204 | 6,644 | 7,312 | 7,362 | 5,760 | 7,173 | 5,969 | 5,368 |
| **WIND** | 52 | 655 | 2,139 | 2,418 | 2,669 | 2,707 | 2,867 | 3,293 | 3,182 | 2,776 |
| **SOLAR** | 2 | 33 | 471 | 681 | 719 | 700 | 857 | 798 | 793 | 839 |
| **OTHER** | 0 | 0 | 4 | 4 | 0 | 2 | 0 | 0 | 0 | 230 |
| **ENERGY IMPORTS** | 56,130 | 57,009 | 41,064 | 61,959 | 55,873 | 37,704 | 42,892 | 43,354 | 47,514 | 47,559 |

Source: California Energy Commission, 1999.

the observed explanatory variables of technology i in period, . The variables are capital, fuel and operating costs. All variables are transformed into logarithmic scale. The ai's are the fixed effects that may vary by technology and reflect unobserved technology-specific characteristics that may be correlated with Xit. The Eit are typical disturbance terms, assumed to be identically and independently distributed, with a zero mean and a constant variance.' Table 2 contains a summary of the empirical findings.

The results indicate that the single most important variable in explaining technology-specific generation variations is the cost of capital. On average, a ten percent change in capital costs is associated with an eight percent change in technology-specific generation. Since renewable technologies are highly capital intensive, this finding implies that market participants in general and policy makers in particular must find appropriate ways and means that can effectively contribute to lowering the capital costs, thereby enhancing the competitiveness of renewables in the electricity market.

Judged by the size of its coefficient, fuel cost is a strong determinant of the variations in technology-specific generation in California. The negative parameter estimate of the fuel costs variable, 0.59, suggests that lowering the fuel cost by 10 percent can increase the generation by about 6 percent. This result corroborates the powerful role that fuel prices have played and continue to play in the development of renewables. The low fossil fuel prices that prevailed during most of the 1990s constrained development of renewable electricity technology in California. Although the costs of installing and generating electricity with renewable resources continued to decline and technological advances continued to improve generating efficiencies, these factors historically have been unable to keep pace with the declining costs of energy from fossil fuels, making it difficult for the use of renewables to increase as a share of total electricity generation and use.

TABLE 2.
*Fixed-Effects Model: Generation and Costs by Technology*

| Variable | Coefficient | T -value | Mean*" |
|---|---|---|---|
| Logarithm of fuel cost cents/kWh | -0.59* | -3.53 | 0.39 |
| Logarithm capital cost cents/kWh | -.810* | -4.03 | 1.74 |
| Logarithm O&M cents/kWh | -.354* | -2.67 | -.103 |
| Constant | 10.17* | 26.63 | |
| R-squared within | 0.453* | | |
| Between | 0.97 | | |
| Overall | 0.33 | | |
| Sample size | 54.0 | | |

▪ Means the variable is significant at the 95 percent level.
' Logarithm of costs.

Operating and maintenance (O&M) costs are least important as determinants of the historical variations in electricity generation in California; the approximate measure of elasticity of negative 0.35 implies that reducing O&M costs by 10 percent can cause a generation increase of nearly 3.5 percent. It should be noted, however, that for most technologies the cost share of O&M is low and therefore the significance of this variable is in fact lower than what is implied by the parameter estimate. Finally, we note that the value of the Hausman test statistic leads us to accept the current specification of the model. The value of the x2 test statistic is 19.7. Therefore the hypothesis of systematic difference in coefficients is supported.

### *3.1 The Potential for Renewables*

To arrive at the potential of renewable electricity generation, we utilize the Hodrick-Prescott de-trending method. The historical fluctuations evident in the time series of electricity generation can result from seasonal, cyclical, and random or trend factors. For our purposes, it is desirable to separate the trend that underlies the renewable time series from its other components to arrive at the potential production of renewables. That is, we filter out undesirable elements ( noise) while extracting the trend. The Hodrick-Prescott (H-P) filter uses a method of constrained optimization to fit the trend path to the time series.

In the context of renewable electricity generation, the historical long-term pattern depicted by its time series can be viewed as the sum of cyclical (short term) and growth components. The cyclical components arise because of short-term irregularities due, for example, to spells of drought in the case of small hydro, periods of random low winds in the case of wind power, or otherwise when renewable facilities are not operational because of contractual or maintenance reasons. The conceptual framework is that the time series of renewable electricity generation, Ft is the sum of a growth component, gt, and a cyclical component, ct: Ft=g + c, for t=1983 to 1998. One measure of the smoothness of g, path is the sum of the square of its second difference. The c, are deviations from g, and the H-P method considers that over long time periods, their average is zero. Therefore, the H-P method boils down to minimizing the following relationship for determining the growth components:'

$$\textbf{Min}\ \{g_t\}^{T}{}_{t=-1}\ \{\Sigma^{T} c_t^{2} + \lambda\, \Sigma^{T}\ [\ (g_t - g_{t-1}) - (g_{t-1} - g_{t-2})\ ]^{2}$$

The parameter λ is a positive number that penalizes variability in the growth component series. The larger the value of A., the smoother is the solution series. Following H-P, the value of (symbol) that was selected for our annual series is 800.

Applying the H-P method, we arrive at estimates of the potential generation of electricity using renewables. The time series data cover the period 1983 to utilities is much higher than that of independent suppliers, the time-path of its growth varies from that of independents. More noteworthy, there is a clear tendency for the potential of utility-generated renewables to taper off dramatically more than renewables generated by independents, as Figures 1 and 2 suggest.

### *3.2 Survival of Renewable Projects*

This section applies a two-step model: first, a dichotomous model, and second, a Weibull survival model. Formally, the two-step model consists of two equations. The first is a binary equation that shows the supplier is either operating (Y= 1) or is not (Y= 0). A set of factors, such as nameplate capacity, quarter of the year, contract type and type of and so on, are gathered in a vector x and explain the decision to operate the specific independent supplier facility, so that8

$$\text{Prob}\ (Y=1) = F\ (\beta x)$$

$$\text{Prob}\ (Y=0) = 1 - F(\beta x)$$

The set of parameters B, reflect the impact of changes 'in x on the probability that the project will be operating. For example, among the factors that might interest us is the marginal effect of nameplate capacity on the probability of operating status.

The second equation is a Weibull equation that describes the duration or survival of independent renewable projects. Duration is represented by the random variable T. The Weibull distribution has a nonnegative random variable ( in our case the positive survival of renewable projects); that is, it is monotonically increasing. In the Weibull equation, each individual renewable project is assumed to be at risk at every instant, and that risk is summarized in the instantaneous failure or hazard rate function,

$$h(t) = h_o(t)e^{Bo+B_1 I_1+\ldots+B_k I_k}$$

For exponential regression, $h_0(t) = 1$. For Weibull regression, h0(t) pt^(p-1) where p is the shape parameter to be estimated from the data.

Two data sets are deployed in order to assess the chances of survival of renewable projects. The first set is a cross-section survey that contained information on the hurdle rate and prospective future operating plans of projects.' The second is cross-section time series panel data that were collected by the utilities on independent renewable projects in California on a quarterly basis from 1988-1996. The two surveys collected information on location (city, code), contractual agreement (SO1, SO4,* etc.), technology type, fuel type, project capacity, the year the project was commissioned, and the current operating status. Table 3 shows our empirical findings.

The results of the first equation indicate that projects with large nameplate capacity have higher prospects of remaining operational than projects with small nameplate capacity. The first derivative of the function with respect to capacity is positive, but the coefficient of the variable gauging capacity squared is negative, suggesting that capacity positively influences the operating status of projects. Second, the findings support the hypothesis that the contractual arrangement aided the survival of projects. That is, some contracts reduced uncertainty about revenue streams since the revenue per unit of energy per kWh was to be known in advance for extended periods, up to 10 years. Third, capacity utilization is positively associated with the operating status of projects. That is, projects that have a high capacity utilization are more likely to be operating during the sample period than projects with-small average capacity utilization. This result is in agreement with the conventional wisdom that low capacity factors, and low dependable on-peak capacity factors, are sources of renewable power cost disadvantage. California's wind capacity, which represents about 90 percent of the U.S. *wind capacity*. operated at only 23 percent realized average capacity factor in 1994," and thus is a prime illustration of this relationship.

Table 3.
Regression Results of the Two-Step Model:
Operation and Survival

| Equation/Variable | Marginal effect | Z-value |
|---|---|---|
| **Operating Status Equation** | | |
| Nameplate capacity | .0101572* | -2.12 |
| Capacity squared | .000107** | -1.78 |
| SO No. 1 | .194906 | 3.08* |
| SO No. 2 | .024350 | 0.30 |
| SO No. **4** | .088349 | 1.45 |
| Capacity utilization | .002739 | 2.18* |
| Change in utilization | .042630 | -2.57* |
| Log likelihood-83.6066 | | |
| **Survival Equation** | | |
| Nameplate capacity | .004302* | 1.901 |
| SO No. 1 | .268330* | 2.339 |
| SO No. 2 | -.21242* | -1.803 |
| SO No. 3 | -.86762* | -2.902 |
| SO No.4 | -.34323* | -2.864 |
| O&M costs | -.0040 | -1.238 |
| Predicted operation status | - I3825 | -1.238 |
| Constant3.3577* | 10.983 | |
| Log likelihood-103.254 | | |
| No. of observations | 163. | |

* Indicates the variable is significant at the 5 percent level.
** Indicates the variable is significant at the 10 percent level.

In the second equation dealing with survival of renewable projects over time, it is noteworthy that the operational status of renewable projects is time-dependent. This time-dependency is due to variations in the seasons and weather conditions ( sun intensity, wind speed, availability of water or wood). We also found that the expected probability of survival declines slightly over time. The supplier's fuel type also affects the probability of survival. For instance, geothermal projects have an expected probability of survival of 0.93, and hydro-electric achieves an expected probability of 0.91. The expected probability of renewable facilities' survival also varies among the three investor-owner utilities. Renewable projects selling to Pacific Gas & Electric encounter an expected probability of 0.81. The corresponding probability for renewable projects selling to San Diego Gas & Electric is 0.87 and for Southern California Edison, it is 0.92. These variations are partly a reflection of composition (differences among utilities with respect to technology and contractual mix) and partly a reflection of differential utility load requirements.

## 4. THE STATE'S POLICY ROLE

While market forces influenced the relative cost-effectiveness of renewable electricity in California, the favorable regulatory environment greatly accelerated their penetration by reducing risk as well as by offering Monetary incentives to develop and use electricity generated by renewable sources. Specifically, over the past 25 years California has employed a large number of policy measures aimed at pursuing the public policy goal of advancing the development and use of renewable electricity generation. California's stakeholders realize that to be effective, renewable public policy must be consistent with the market environment in which it operates. Until 1996, the California electricity system was characterized by vertically integrated utility monopolies, controlling the production, transmission, and distribution of electricity. The state regulated these monopolies. In California, these are the California Public Utilities Commission ( CPUC), and the California Energy Commission (CEC), each with a different set of responsibilities relating to various aspects of the electricity market and its players.

The implementation of renewable public policy formulated in the environment of a regulated monopoly consisted of using a public process to issue a directive to utilities to carry out the elements of public policy. For example, utilities were directed to spend certain levels of funds on research and development to improve the efficiency and cost of renewables and other technologies, with regulators giving the criteria by which these funds are to be used and the projects on which they are to be expended.

The regulated market for electric generation saw the beginning .of the end in 1978, with the passage of the federal law known as the Public Utilities Regulatory Policies Act (PURPA). That landmark law opened the generation market to non-utility entities, by requiring utilities to purchase power from generating facilities that meet certain qualifying criteria. These facilities later came to be known as qualifying facilities, or QFs. The other provision of PURPA that led to the development of non-utility generation in California was the requirement that utilities pay for the power generated by these non-utility projects and delivered to the utility system the so-called "avoided cost," which in theory was to leave the ratepayer indifferent.

The avoided cost was to be equal to the cost of the power that the utility would have had to generate itself, or purchase from other sources, but for the production of the QF power. To the extent that this condition is met, the ratepayer should see no difference in cost of power whether-the utility generated it or the QF. Thus, the criteria of ratepayer indifference would be preserved.

In practice, however, the development of methodologies for estimating avoided cost were not so straightforward and often conflicted with each other. In fact, the principle of avoided cost was used to guide policy development that led to policy goals that encouraged renewable power generation.

The federal law left it up to the states to implement the details of the power purchase arrangements between utilities and independent power projects. In California, the development of contracts that governed the purchase of power by utilities from independent power projects was completed in 1983 and 1984. Some of these contracts have proven to be very lucrative, and within a year or two after the contracts were made available, led to the announcement of plans to develop almost 15,000 MW of independent power capacity.

This huge market response to the development and availability of power purchase contracts from the utilities was the result of a provision in the contracts that made the revenue stream that would result from the sale of power known to the project once the amount of energy production was known. That is, the electricity production from the project was the variable that projects needed to control in order to have certain revenue. The revenue per unit of energy or kWh was fixed in advance for up to 10 years.

In addition to known and certain energy prices for these projects for up to 10 years, these contracts also offered fixed and known capacity prices for up to 30 years. As a result of these contracts, about 10,000 MW of renewable generation and gas-fired cogeneration were added to the system between the years 1985 and approximately 1990. About half of that capacity, approximately 5,000 MW, was from renewable power generation projects. The 1980s and early 1990s saw California as the leader in the development of renewable generation in the U.S. and beyond.

In 1996, the California legislature passed the electricity restructuring legislation known as Assembly Bill 1890 (AB 1890) that began the end of the integrated utility environment in electricity markets in California. It opened the market for retail competition, during a four year transition period beginning January 1998 and ending in 2002. Prior to the passage of this bill, the CPUC had already begun investigating the approaches to restructuring the electricity market with less

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- The program design should strive for economic efficiency. This meant that the amount of funding spent to accomplish the goal of supporting renewable energy in competitive markets should be minimized.
- The program should create incentives for and pressure on renewable energy projects to increase their competitiveness in the open electricity market.

The renewable strategy underlying the design and implementation of California's Renewable Energy Program can be considered a total market strategy, in the sense that it operates on both the demand and supply sides of the market. The renewable funding flows to the market through five accounts. Each account was designed to reflect the needs of the particular category or segment of the renewables market that it was designed to serve.

On the supply side, the Existing Renewable Resources Account was allocated $243 million to support existing renewable projects. The New Renewable Resources Account, allocated $162 million, provides financial incentives for the development of new renewable projects that are generally more efficient and lower costing than existing generation that operated up to this point.

On the demand side, the Customer Credit Account was allocated $75.6 million and issues cents per kilowatt-hour credits to customers who opt to purchase renewable energy in the open market. The Emerging Renewable Resources Account;' allocated $54 million, was created to encourage customers to install their own renewable generating systems on-site, primarily to offset their own load rather than selling to the grid. Finally, the last account on the demand side was the Consumer Education Account, which strives to educate users of renewable energy about the availability of such an opportunity and the financial support available to them if they opt to purchase renewable energy. The Consumer Education Account was allocated $5.4 million.

## 5. CONCLUSIONS AND POLICY IMPLICATIONS

The analysis in this paper has shown that the share of renewables in California's power sector has increased steadily. The growth has been volatile, however, due to the vagaries of fossil fuel markets and the phasing out of financial incentives at the federal and state levels. The economics of renewable electricity generation would improve if and when capital costs are significantly lowered. However, the continued low price of fossil fuels is adversely impacting the penetration of renewables, which may continue to overwhelm the competitive position of renewable generation to fossil generation, even in the face of declining capital costs.

California's support for renewables culminated in the enactment of California's AB 1890, which required the California Energy Commission to develop a program to encourage renewable electricity generation technologies. It directed the collection of $540 million from investor-owned utility ratepayers from 1998 to 2002 to support existing, new, and emerging renewable electricity generation technologies. Unless legislation to extend the program is enacted in time, renewable project revenues will be based on significantly lower energy prices than previously available. This will have a serious financial impact on current renewable suppliers, as market prices may not cover the independent suppliers' current long-run marginal generation costs, and could deter the entry of other small renewable electricity generators.

The state of California is likely to continue its policies to promote renewable-based electricity production. Justifications for this continuation include the clear links between renewables and air quality and environmental objectives. In addition, renewable electricity generating technology benefits California's export capabilities and helps the state's private sector to secure dynamic niche markets as well as links to the international energy markets.

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