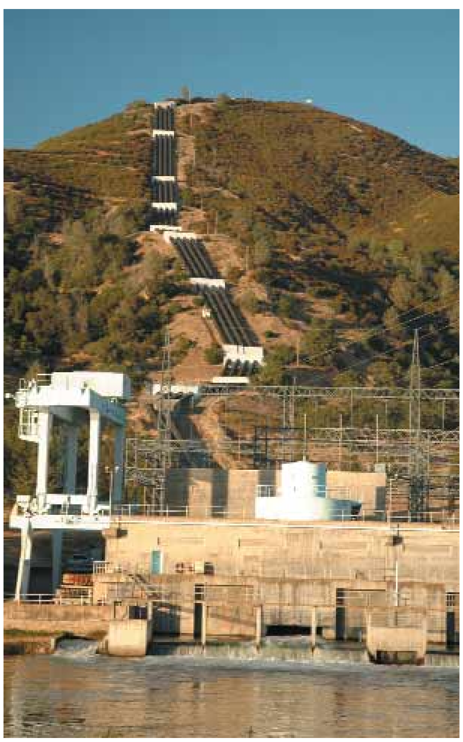
CHAPTER 9

Impact of restoration on hydropower production and revenues

Restoring Hetch Hetchy Valley will reduce power generation on the Tuolumne River, with a consequent loss of revenue from energy sales as well as a need to replace the forgone energy with some combination of new generating capacity and demand-side resources.

The loss of generation at the Tuolumne River hydroelectric facilities of the San Francisco Public Utilities Commission (SFPUC) would be as much as 690 million KWh, or 40 percent of average annual energy production. With modifications to the SFPUC's facilities, however, the average annual loss could be as low as 339 million KWh/year. Depending on whether water is diverted downstream or upstream of Don Pedro dam, output at the Don Pedro powerhouse—owned by the Turlock and Modesto Irrigation Districts (TID and MID)—could increase by up to 54 million KWh per year (+10 percent) or decline by 8 million KWh (–1.4 percent).



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Moccasin Powerhouse is one of three hydroelectric plants the SFPUC operates on the Tuolumne River. If Hetch Hetchy Valley is restored, Moccasin would still be able to produce electricity when the river is flowing. On average, annual output would decline by about 30 percent.

Several options are available to replace the lost energy, including increased investments in energy efficiency, expansion of dynamic pricing programs, and the development of new renewable or natural-gas-fired power plants. Regarding the latter, a survey of recent forecasts indicates that a reasonable estimate of the levelized cost of energy from new renewable or gas-fired baseload plants is \$55/MWh. Demand-side options, meanwhile, offer cost-effective means of reducing the energy and capacity needs currently met by the SFPUC's hydropower facilities. All together, replacement energy costs for the SFPUC facilities would range from \$18.6 to \$38.0 million per year, and monetary values for impacts on Don Pedro's output would range from an annual loss of \$440,000 to a gain of nearly \$3 million.

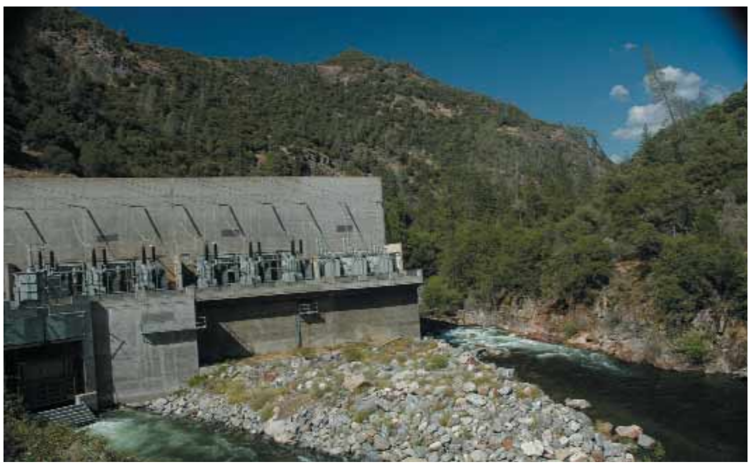
Impact of restoration on hydropower operations

Restoration would reduce power production at the SFPUC's Kirkwood and Moccasin powerhouses, while generation at TID and MID's Don Pedro powerhouse could either increase or decrease slightly. Generation at the SFPUC's Holm Powerhouse would not be affected by restoration because that facility operates with water from Cherry and Eleanor Reservoirs.

The greatest impact of decommissioning O'Shaughnessy Dam would occur at Kirkwood. Some of Kirkwood's 118 MW of capacity could be retained by constructing a small diversion dam at the site of O'Shaughnessy Dam and capturing run-of-river flows in the Canyon Tunnel. This would require modification, or perhaps replacement, of the existing tunnel that now conveys water to the Kirkwood Powerhouse.[1] The loss of storage behind O'Shaughnessy Dam would also reduce production at Moccasin because generation would be limited to those times of year when there is sufficient natural flow in the Tuolumne River. Hydropower production at TID and MID's Don Pedro powerhouse could either rise or fall slightly, depending on where San Francisco diverts and stores water under the different restoration alternatives.

The TREWSSIM model that simulated water storage and deliveries under alternative restoration scenarios was also used to develop estimates of energy impacts. The analysis assumed that whether or not Hetch Hetchy Valley is restored, the SFPUC would continue to operate the system on a "water first" basis, even if that meant forgoing opportunities to increase energy revenues by optimizing hydroelectric operations. During the energy shortages of 2000–2001, for instance, when the SFPUC had to spend millions on expensive spot-market power purchases, it adhered to this operating principle.[2] The analysis also assumed that Kirkwood remains a baseload facility while San Francisco uses Moccasin to generate peaking power when needed. But the analysis ignored ancillary service revenues because SFPUC staff stated that its plants do not participate in those markets.[3]

The modeling results vary only slightly across the restoration alternatives that were considered. What matters most is whether Kirkwood can be operated as a run-of-river plant. A small diversion structure near the current O'Shaughnessy Dam could retain much of the existing hydropower generation while simultaneously permitting restoration of Hetch Hetchy Valley. Output at Moccasin Powerhouse is not affected by Kirkwood's availability.



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Top: The SFPUC's Kirkwood Powerhouse generates electricity using water that flows from Hetch Hetchy Reservoir via the Canyon Tunnel. With modifications to the tunnel, Kirkwood could continue to produce nearly two thirds of its current output under a restoration scenario. Otherwise Kirkwood would become inoperable and have to be retired. Bottom: The Dion R. Holm Powerhouse, which produces about 40 percent of the SFPUC system's annual hydropower output, would be unaffected by restoration of Hetch Hetchy Valley. It generates energy using water from two of the Tuolumne's tributaries, Cherry and Eleanor Creeks.

IMPACT OF RESTORATION ON SFPUC ENERGY PRODUCTION

Table 9-1 summarizes the impact of restoration on average annual hydropower production at each of the SFPUC's powerhouses for two different scenarios, as well as the Base Case

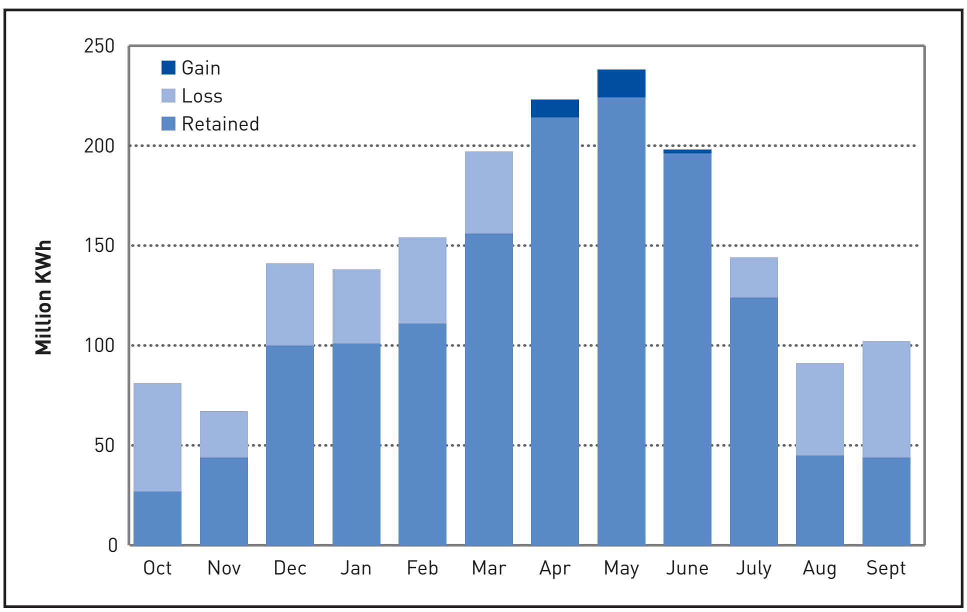
TABLE 9-1
Average annual energy impacts (million KWh)

	Kirkwood	Moccasin	Holm	Total	Change: million KWh	Change: Percent
Base case	549	427	749	1,725	NA	NA
Restored: Kirkwood run-of-river	352	286	749	1,387	–339	–19.6%
Restored: Kirkwood unavailable	—	286	749	1,035	–690	–40.0%

(which represents production with O'Shaughnessy Dam still in place). Hydropower impacts of the alternative scenarios were calculated by comparing modeled generation under each alternative to modeled generation in the Base Case. Average annual generation is estimated to decline by 339 million KWh/year if a diversion dam replaces O'Shaughnessy and both Kirkwood and Moccasin operate as run-of-river facilities. If the Canyon Tunnel is not modified to permit continued operation of Kirkwood Powerhouse, the average annual loss is 690 million KWh. Even in this case, however, San Francisco would still retain more than half of the average annual production from its Tuolumne River hydroelectric facilities.

Impacts on hydropower production would vary throughout the year. Figure 9-1 illustrates the changes in simulated average monthly generation for the entire SFPUC system if Kirkwood powerhouse can be operated as a run-of-river facility.[4] Without the dam to impound spring runoff, less electricity would be produced in most months.

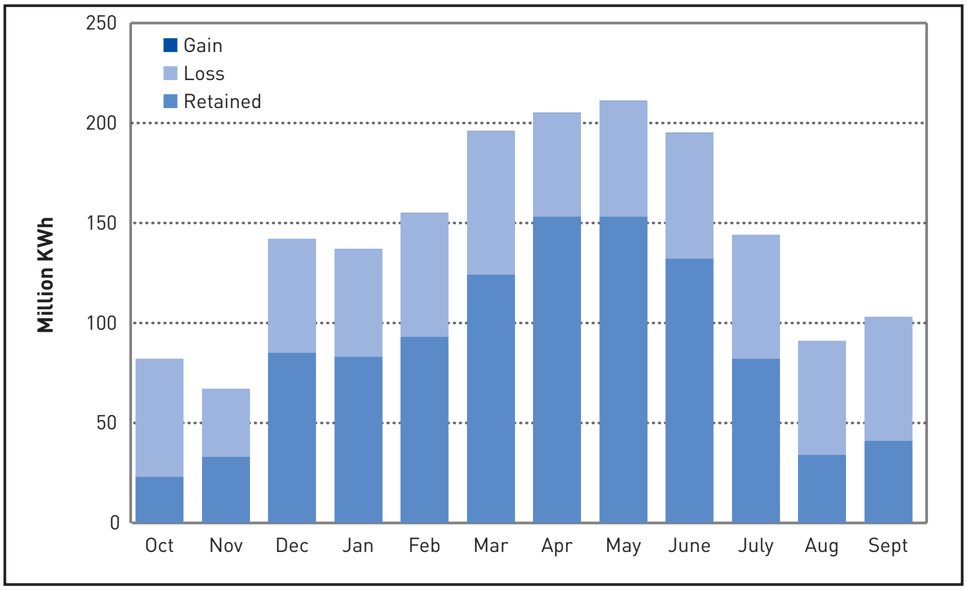
FIGURE 9-1
SFPUC system: average monthly generation
Kirkwood operated as run-of-river



If Kirkwood Powerhouse can be operated as a run-of-river facility, restoring Hetch Hetchy Valley would reduce the SFPUC's annual hydropower production by about 20 percent on average. Generation would be lower in most months, but would actually increase during the spring runoff.

FIGURE 9-2

SFPUC system: average monthly generation Kirkwood unavailable



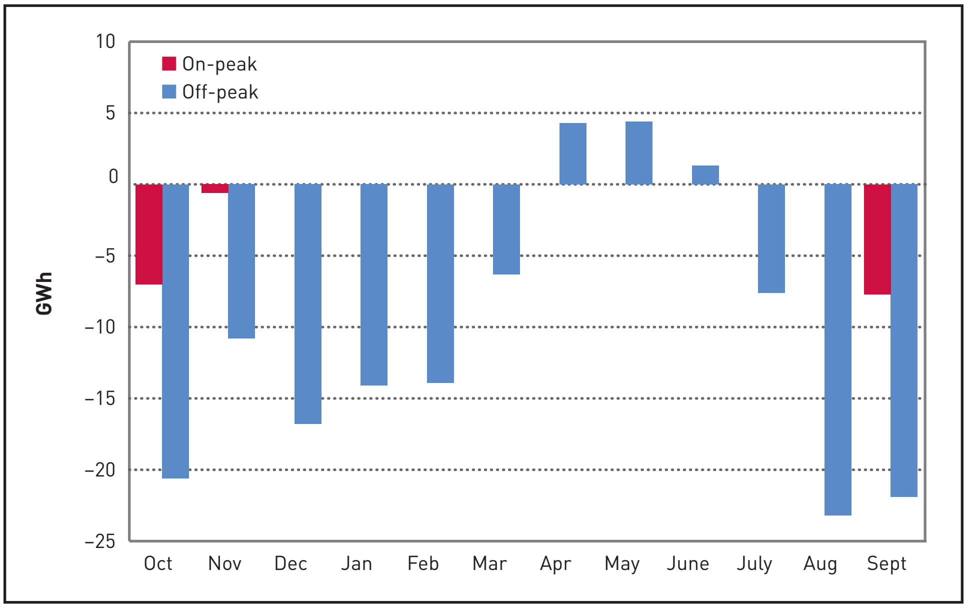
If the Canyon Tunnel cannot be modified to permit continued operation of Kirkwood Powerhouse, restoration would lower the SFPUC's annual hydropower production by about 40 percent on average. Generation losses would be fairly evenly distributed, with percentage impacts greatest in late summer and early fall.

The greatest reductions would occur in September and October, while average generation would actually increase slightly in April and May. Figure 9-2 shows how lost generation would be distributed throughout the year if Kirkwood were completely unavailable. In absolute terms, generation losses would be fairly evenly distributed, with percentage impacts greatest in late summer and early fall.

An important consideration is how the lost energy production would be distributed between on-peak and off-peak periods. Power is more valuable during on-peak periods, especially in the summer months. This analysis focuses on Moccasin powerhouse, in that water-supply operations and physical limitations constrain Kirkwood powerhouse to base-load operation.[5] The availability of the regulating Priest Reservoir permits San Francisco to shape generation at Moccasin. The analysis assumes that San Francisco reserves all available flows for peaking, with off-peak energy produced only in months when flows exceed the amount needed to operate Moccasin at capacity (during peak hours). Restoration would not affect this facility, but it would constrain San Francisco to generate at times when the river is flowing.

Figure 9-3 shows how the monthly losses in generation at Moccasin might be distributed between peak and off-peak periods. In most months, run-of-river flows would still be sufficient to run Moccasin at capacity during all peak hours, but significant on-peak reductions would occur in September and October. The cost of replacing on-peak energy during these months is likely to be much higher than replacing off-peak or base-load generation at other times of year; however, these losses account for no more than 5 percent of the change in annual output and would

FIGURE 9-3
Projected change in average monthly generation Moccasin operated as run-of-river



Without Hetch Hetchy Reservoir, the SFPUC would still be able to use Moccasin Powerhouse to generate valuable on-peak energy at most times of year. Lost on-peak energy production in September and October would be costly to replace, but accounts for less than 5 percent of the total reduction in output for the SFPUC system.

not significantly increase annual replacement-energy costs. Off-peak generation would be lower in most months, but would increase in April-June. Actual operations could follow a different decision rule than is assumed in this analysis, resulting in a more modest reduction in production of on-peak energy.

IMPACT OF RESTORATION ON SFPUC'S DEPENDABLE CAPACITY

Like water resource planners, power system operators are particularly concerned with the ability of generating resources to meet users' needs during critical periods. For hydroelectric resources this means determining the rate at which a power plant can produce electricity during system peak periods (i.e., the handful of hours during late summer afternoons when customer demand is highest). Table 9-2, based on TREWSSIM simulations, shows how the average monthly capacity of Kirkwood and Moccasin are reduced as a result of restoring Hetch Hetchy Valley. On average, Moccasin is able to operate at its full 100 MW capacity during on-peak hours in most months. Significant reductions occur in September and October, requiring the SFPUC to obtain replacement capacity of up to 64 MW. If Kirkwood can operate as a run-of-river facility, average capacity losses range up to 44 MW, with gains realized during the spring runoff. If Kirkwood is completely unavailable, average capacity losses peak at 89 MW in June, tapering off to 31 MW by November.

Because hydropower production varies with the availability of water to generate energy, system planners pay particular attention to how much energy can be produced during peak periods in dry years. One approach to assessing a hydropower facility's dependable capacity, in fact, is based on its production during the most adverse hydrologic conditions encountered over the period of record. For central California, this is August and September of 1977, the driest year of the 20th century.

Table 9-3 summarizes results from the TREWSSIM model that compare the availability of Moccasin and Kirkwood under 1977 hydrology, with and without O'Shaughnessy Dam. For each powerhouse, the table documents its availability for peaking, the number of hours it could operate at its full capacity during the month, and the rate at which it could produce a steady stream of baseload energy. Table 9-3 shows that for Moccasin, capacity impacts would be greater in the driest years than on

TABLE 9-2
Average available generating capacity by month (MW)

	Moccasin (peak hours*)			Kirkwood unavailable (baseload operation**)			Kirkwood run-of-river (baseload operation**)		
	Base	Restored	Change	Base	Restored	Change	Base	Restored	Change
October	100	42	–58	43	—	–43	43	6	–37
November	100	95	–5	31	—	–31	31	15	–16
December	100	100	—	54	—	–54	54	22	–33
January	100	100	—	54	—	–54	54	24	–30
February	100	100	—	65	—	–65	65	25	–40
March	100	100	—	87	—	–87	87	43	–44
April	100	100	—	77	—	–77	77	83	+6
May	100	100	—	85	—	–85	85	98	+12
June	100	100	—	89	—	–89	89	88	–1
July	100	100	—	75	—	–75	75	57	–18
August	100	100	—	46	—	–46	46	15	–32
September	100	36	–64	44	—	–44	44	5	–38

Notes: *Peaking capability, 12:00–6:00 PM weekdays. **Baseload capability, round-the-clock operation.

TABLE 9-3
Impact of restoration of SFPUC hydropower capacity under adverse hydrology

	(1) Total monthly energy production (million KWh)		(2) Average hourly rate of energy production (MW)		(3) Hours available to operate at rated capacity	
Moccasin Powerhouse rated capacity: 100 MW	**August**	**September**	**August**	**September**	**August**	**September**
Base	31.7	32.6	42.6	43.8	306.8	314.8
Restored	1.4	1.0	1.9	1.3	13.8	9.7
Kirkwood Powerhouse rated capacity: 118 MW	**August**	**September**	**August**	**September**	**August**	**September**
Base	29.8	30.7	40.1	41.2	288.5	296.7
Restored: Kirkwood operates as ROR	1.2	0.8	1.6	1.1	11.7	8.2
Restored: Without Kirkwood	0.0	0.0	0.0	0.0	0.0	0.0

(2) = (1)/number of hours in month
(3) = (1)/nameplate generating capacity of powerhouse

average. For Kirkwood, dry-year capacity losses are comparable to average impacts. With O'Shaughnessy Dam in place, even with 1977 hydrology, Moccasin would be available to operate over 300 hours in each of those months, more than enough to assure its availability on all weekday afternoons. Without O'Shaughnessy Dam's storage capacity, Moccasin could not be depended on for peaking operation under adverse hydrologic conditions. Transforming Moccasin into a run-of-river facility would thus eliminate the powerhouse's entire rated capacity of 100 MW under the most adverse hydrology.

Table 9-3 shows that *even with O'Shaughnessy Dam in place*, Kirkwood can only reliably produce at a rate of about 40 MW under 1977 hydrologic conditions. This amount is about a third of its installed capacity. Under run-of-river operation without O'Shaughnessy Dam, Kirkwood's dependable capacity of 40 MW is almost completely lost. A review of historical operating data shows that Kirkwood actually produced only half the modeled energy generation during August and September 1977, although it has managed to run at close to 40 MW in other critically dry years. Thus the loss of dry-year capacity at Kirkwood could be as low as 20 MW.

IMPACT ON DON PEDRO HYDROPOWER OPERATIONS

Restoration of Hetch Hetchy Valley could either increase or decrease hydropower production at TID and MID's Don Pedro powerhouse. Two key factors are how much, and where, Tuolumne water is diverted to the Bay Area. Table 9-4 summarizes their impacts, under current and projected future demand, by comparing the base case with two different alternatives for restoration of the valley. Construction of an intertie with the SFPUC's aqueduct at or upstream of Don Pedro Reservoir, with the current level of demand, would lower flows through the Districts' powerhouse relative to the base case, reducing average annual hydropower production; under the projected 2030 level of demand, flow and production would grow modestly. In contrast, downstream diversions would increase flows and generation non-trivially for both periods. No matter where the intertie is located, an increase in Tuolumne River diversions to meet projected growth in demand would reduce flows through Don Pedro powerhouse and lead to a decrease in hydropower production relative to output at the current level of diversions. This is because more water would be diverted above the intertie at Early Intake.

To assign a monetary value to the projected changes in Don Pedro's hydroelectric output, it is important to know the time of year when they occur and whether the Districts' ability to generate during peak hours is affected. With extensive storage and a regulating

TABLE 9-4
Impact of restoration on average annual Don Pedro generation

	Current demand			Projected 2030 demand		
	Annual generation	Change from base		Annual generation	Change from base	
Alternative	(million KWh)	(million KWh)	Percent	(million KWh)	(million KWh)	Percent
Base	574	NA	NA	544	NA	NA
Downstream diversion	605	+31	+5.4%	598	+54	+9.9%
Upstream diversion	566	−8	−1.4%	549	+5	+0.9%

dam downstream, Don Pedro is configured to take advantage of opportunities to produce on-peak energy, however many considerations govern operation of the dam and its hydroelectric facilities. TREWSSIM monthly modeling results indicate that the relatively small reduction in hydropower production projected for an upstream intertie would be evenly spread throughout the year, so losses in on-peak energy revenues would likely be minimal. In contrast, if the intertie were built downstream of the dam, increases in hydropower production would be concentrated in late summer months when power is most valuable. The financial benefit to TID and MID would be even greater if the incremental water could be used to augment energy production during the peak afternoon period.

Options for replacing forgone Hetch Hetchy energy and capacity

In addition to lowering San Francisco's power-sales revenues, a reduction in hydroelectric generation from the Tuolumne would also oblige the SFPUC to find alternate ways of meeting users' energy requirements. This burden would be shared by the Turlock and Modesto Irrigation Districts, which currently purchase a significant portion of the Hetch Hetchy-derived energy. Even after their current contracts with San Francisco expire, TID and MID will retain their Raker Act entitlements to continue making such purchases for their pumping and municipal loads.

This section describes potential approaches for replacing the forgone hydroelectric generation, taking into account the stated objectives of San Francisco and the Districts for meeting their customers' future energy needs (see discussion in Chapter 4). While a complete assessment of the available alternatives is beyond the scope of this study—it would require detailed historical and projected data on energy generation and consumption and on purchase patterns involving all of San Francisco's and the Districts' electricity sources—the discussion that follows is based on publicly available statistics and is intended to provide an overview of the feasibility, environmental performance and relative cost of potential sources of replacement energy.

Four options are considered: increased investments in energy conservation, expanded use of dynamic pricing, and construction of new renewable or natural-gas fired-power plants. For generation alternatives, the analysis focuses on new baseload facilities. California's demand for electricity is currently forecast to grow at 2.2 percent per year over the next decade[6] and new generating capacity may be needed as soon as 2006,[7] well before restoration of Hetch Hetchy Valley is likely to begin. Therefore it is reasonable to assume that the forgone Hetch Hetchy energy and capacity would be replaced with electricity from new facilities. And because most of the lost hydroelectric production is either baseload or off-peak energy, it is also reasonable to assume that power will be replaced by new baseload units. In addition, because some on-peak energy may be needed to replace output from Moccasin powerhouse in late summer, the cost of energy from new gas-fired peaker plants is also discussed briefly.

ENERGY EFFICIENCY

The need to replace some, or perhaps all, of the lost Hetch Hetchy energy could be eliminated by investing in energy efficiency, especially as the untapped energy efficiency potential in California remains vast. Based on analyses conducted by its own staff and a leading consulting firm, the California Energy Commission (CEC) has concluded that increasing public investment in energy efficiency over the next 10 years may yield some major payoffs. The state could cut its annual energy use by as much as 30,000 million KWh while shaving up to 10 percent (5,900 MW) off statewide system peak demand—*and at no net cost.*[8] That is, the net present value of avoided future electricity bills[9] exceeds the up-front expense of installation and equipment. To put it simply, up to a point it costs less to install energy-saving equipment than to build and run new power plants.

Actually, the CEC's estimate of California's untapped conservation potential is itself conservative. It is based exclusively on existing technologies that can be retrofit into existing buildings, and it does not take into account behavioral changes, the impacts of emerging technologies, or integrated redesign of buildings' energy-using systems. In any case, the CEC has recommended in its *2003 Integrated Energy Policy Report* that the state double its existing public funding for energy-efficiency and conservation programs in order to cut at least an additional 1,700 MW from peak demand and 6,000 million KWh from energy use by 2008.[10]

Calculating exactly how much of this potential could be realized in San Francisco and the Districts is beyond the scope of this study. Such an analysis would need to take into account local climate conditions, existing penetration of energy-efficiency technologies, and a host of other factors. However, a "ballpark estimate" may be obtained by scaling San Francisco's and the Districts' share of statewide energy use to the estimated statewide savings. This calculation yields 1,137 million KWh per year in potential energy savings by 2008[11]—an amount that significantly exceeds the potential loss of 339-690 million KWh/year of Hetch Hetchy energy derived in this study. While practical constraints make it unlikely that the replacement of Hetch Hetchy power could be entirely eliminated by new investments in energy efficiency, the calculation at least shows that increased energy efficiency could certainly offset some of the need to build new power plants, and at lower cost.

Moreover, investments in energy efficiency need not be confined to San Francisco or to TID and MID's service territories in order that demand for Hetch Hetchy energy be displaced. The same intensively interconnected grid that permits the City and the Districts to draw electricity from all over the West also permits them, in principle, to benefit from energy savings realized elsewhere. Thus the SFPUC, TID and MID could cost-effectively sponsor investments in energy efficiency in surrounding communities as one additional way to "replace" Hetch Hetchy power. Investing locally, however, may prove more attractive, as it would create jobs within the community; numerous workers, both skilled and unskilled, would be needed to retrofit buildings, install energy controls, replace inefficient old appliances, and service heating and cooling equipment.

DYNAMIC PRICING

Another demand-side resource with significant untapped potential in California is dynamic pricing. The CEC and the California Public Utilities Commission (CPUC) are currently working to develop programs in which electricity customers—large commercial facilities, most likely—would face electricity prices that vary with market conditions. Rates would be highest during peak periods (when power is the scarcest), giving program participants the incentive to cut their energy use at that time. Unlike current interruptible tariffs, in which a small number of very large customers drastically cut their energy use when supplies run short, dynamic pricing encourages a large number of customers to make smaller, less-disruptive cutbacks.

TABLE 9-5
Recent proposals for renewable generation in the Western U.S.

	California (million KWh/year)	Neighboring states (million KWh/year)	Other WECC* (million KWh/year)	Total (million KWh/year)
Wind	17,021	24,893	5,270	47,184
Geothermal	6,961	2,249	867	10,077
Biomass and Biogas	2,146	175		2,321
Solar CSP	263	110		373
Total (rounded)	**26,390**	**27,430**	**6,135**	**59,955**

Source: California Energy Commission, *Public Interest Energy Strategies Report,* December 2003. Table 5-3, p. 94.
*Western Electricity Coordinating Council

Dynamic pricing is essentially a peaking resource, displacing the need for new peaker plants that run infrequently (i.e., only a few hundred hours per year during high-load periods). It can be an important component in plans to replace the loss in on-peak energy and dependable capacity that would result if Hetch Hetchy Valley is restored. According to CEC forecasts of the resources required to meet California's future energy demands, dynamic pricing can pare five percent from system peak demand statewide.[12] Applying this estimate to recent peak load statistics for San Francisco, TID and MID—along with the same caveats noted in the preceding section—suggests that as much as 95 MW of peak energy use could be displaced with dynamic pricing in these regions.[13]

FPL ENERGY, LLC

Opened in 2003, FPL Energy's 162-MW High Winds Energy Center in Solano County will provide electricity to the cities of Sacramento, Pasadena, Anaheim, Glendale, Azusa, Colton and others.

RENEWABLE ENERGY

Renewable energy—wind, geothermal and solar—is another viable option for replacing the hydroelectric generation foregone with the restoration of Hetch Hetchy Valley. These alternatives already account for nearly a tenth of California's annual energy production, and they are poised to gain a bigger share as the state's investor-owned utilities comply with a new law that requires them to meet 20 percent of their customers' needs with renewable energy by 2017. While no generation technology is completely free of adverse environmental impacts, wind and solar facilities produce no emissions and geothermal plants emit mainly steam.[14] An important concern about wind energy in particular is the deaths of birds, especially raptors, that collide with turbine blades, but advances in turbine design and improved siting practices have significantly reduced avian mortality at new wind facilities.

California and interconnected Western states have abundant renewable-energy potential. As shown in Table 9-5, a recent CEC survey of proposals for new renewable generation in this region found that the potential for California alone is 26,390 million KWh/year. Meanwhile, new renewable facilities capable of producing 27,430 million KWh/year have been proposed in adjacent states.

Wind energy dominates the renewable resources in the West, accounting for nearly two-thirds of California's in-state renewable potential and for four-fifths throughout the region. Not all of the proposed projects will be built, as some require extensions of transmission lines that could prove prohibitively expensive. But wind-energy developers believe that several thousand megawatts of economical wind potential remains to be developed in California and neighboring states. Even older wind farms, such as the Altamont complex seen from I-580 near Livermore, may provide additional output as the original wind turbines are replaced with much more efficient new models. This approach has the advantage of making use of existing transmission lines and reducing the disruptions associated with developing new facilities.[15]

San Francisco would need to "firm up" the capacity of purchased wind energy, much as it now does with the output from its Hetch Hetchy facilities, in order to reliably satisfy demand. Just as water must be available to generate hydropower, the wind must be blowing in order for wind turbines to spin and generate electricity. Wind energy is an intermittent resource, meaning that a given facility's availability cannot be predicted in advance, as is the case with fossil-fired plants and hydropower units with storage. However, California's best wind-energy sites are blessed with fairly dependable winds that tend to blow hardest during periods of peak electricity demand. For example, Northern California's wind facilities are situated so as to exploit the strong afternoon winds that develop when intense heat in the Central Valley sucks cooler coastal air through gaps in the Coast Ranges.

MOSCONE CENTER

Installation of rooftop solar panels, efficient lighting, and energy-management systems at San Francisco's Moscone Center are projected to cut the building's annual electricity use by over 5 million KWh, yielding net savings of over $200,000 per year.

Purchasing renewable energy presents limited opportunities for local investments and job creation. This is because the availability of renewable-energy sources, such as strong winds and geothermal activity, determines the specific location of facilities. Solar power, too, is most economical in places like the Central Valley, where there are many hours of sunshine (especially during peak demand periods). San Francisco's legendary summer fog, not to mention its urban density, limit the attractiveness of developing large-scale solar-energy facilities within the City, but a recently passed $100-million bond initiative provides financing for installation of solar panels, as well as energy-efficiency technologies and wind turbines, on public buildings.

NATURAL GAS

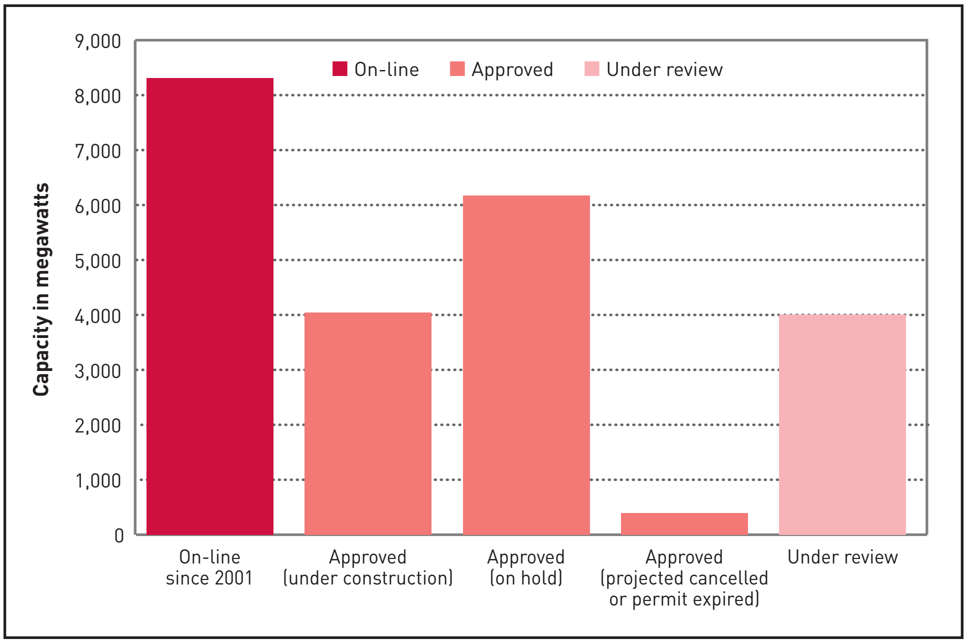
Within California, highly efficient combined-cycle natural-gas-fired power plants have accounted for much of the new baseload generating capacity added in recent years. This technology, moreover, is forecast to remain a major incremental source of energy over the next decade. The combination of state-of-the-art pollution controls and the federal Clean Air Act's requirement that all emissions of the conventional pollutants (e.g., nitrogen oxides and sulfur oxides) from new stationary sources be offset with corresponding reductions from other sources means that new gas-fired plants do not increase net emissions in an air basin. Ambient concentration of pollutants may be higher in the immediate vicinity of the plant,[16] however, and new gas-fired generation does emit greenhouse gases, though at a much lower rate than older plants. If all of the foregone Hetch Hetchy hydropower were replaced with electricity generated at a new combined-cycle gas-turbine power plant, the increase in CO_2 emissions would be 138,000-305,000 tons per year.[17] The upper bound represents less than 0.1 percent of statewide CO_2 emissions.[18]

A number of options are available to offset any increase in CO_2 emissions that results from replacing Hetch Hetchy hydropower with gas-fired energy. One approach is investing in energy efficiency projects that reduce energy used by buildings or fuel burned by vehicles. Alternatively, CO_2 emissions may be offset by paying landowners to follow management practices that increase the amount of carbon stored in forests and agricultural lands. The latter approach, known as sequestration, removes carbon from the atmosphere. A nearby example is the Oregon Climate Trust, which is employing both approaches to offset CO_2 emissions from new power plants in that state. Projects it has undertaken include the following: building energy efficiency, transportation efficiency, cogeneration, distributed generation, and permanent forest sequestration. The average cost of offsets in the Climate Trust's portfolio is $3/ton.[19]

Just 40-90 MW of combined-cycle gas-fired generating capacity could replace the energy that would be lost at Hetch Hetchy.[20] The new baseload gas-fired power plants now being built in California typically have a capacity of 500 MW, so from 8-18 percent of the capacity of just one of these new plants is all that would be needed. Meanwhile, California has added over 8000 MW of new generating capacity since the summer of 2001, most of it gas-fired, and more is in the pipeline (Figure 9-4 summarizes recent activity in construction, permit applications and proposed projects for new power plants in California). Thus the amount of Hetch Hetchy energy that needs to be replaced is dwarfed by

FIGURE 9-4

Summary of California power plant additions and permitting: 2001–2003



The amount of generating capacity needed to replace lost hydropower from the SFPUC's Tuolumne River powerhouses is dwarfed by recent and planned additions to California's fleet of power plants. California has added over 8000 MW of new capacity since summer 2001 and more is in development. Just 40–90 MW of new gas-fired capacity would be needed to replace the Hetch Hetchy energy.

Source: California Energy Commission

the quantities of new generation now being developed in the state.

Although new conservation investments and dynamic-pricing programs may reduce peak demand, or at least limit its growth, at times it may be necessary to replace on-peak energy that would have been produced at Moccasin powerhouse. Simple-cycle gas-fired peaker plants have recently been the primary source of incremental supplies of on-peak energy in California. A typical peaker plant has a capacity of 100 MW, enough to replace the peaking capability that would be lost at Moccasin during late-summer months.

A major disadvantage of gas-fired power plants is the exposure to financial risk from fluctuating natural-gas prices, though owners can reduce their risk by entering long-term gas-purchase contracts or using financial instruments such as forward and futures contracts.

Cost of replacement energy

This section surveys recently published estimates of the cost of energy both from new and existing power plants. While forecasts of spot-market energy costs are considered first, a more likely scenario is that San Francisco and the Districts would either build or purchase replacement power from a new central-station power plant.

Levelized cost estimates, which spread a power plant's initial capital cost out over its entire economic life and smooth trends and fluctuations in projected fuel costs, are presented for combined-cycle natural-gas-fired plants and new renewable facilities. These estimates enable comparisons between the two types of technologies, which have differing proportions of capital and operating costs. Results may be succinctly summarized: the 20-year levelized cost of energy both from gas and renewable facilities range from $50 to $60/MWh, supporting a value of $55/MWh for the average annual cost of replacing lost Hetch Hetchy power.

COST OF PURCHASING SPOT-MARKET ENERGY

One way to estimate the cost of replacing lost Hetch Hetchy energy is to examine projected market prices for electricity. Recent forecasts from a variety of sources are summarized in Table 9-6, which shows that short-term forecasts range from about $35 to $40/MWh. Looking farther into the future, projected electricity prices depend on assumptions about the trajectory of future natural gas prices. Base-case projections for 2012 and 2013, when replacement power might actually start to be used, range from $50 to $55/MWh. Because forecasts of spot-market prices are very sensitive to underlying assumptions about future natural gas prices, they are included (when available) with Table 9-6.

Basic elements of the forecasts presented in Table 9-6 are described below:

- For the Trinity River SEIS/EIR (Supplemental Environmental Impact Statement/Environmental Impact Report), Henwood Energy Services developed hourly forecasts of market-clearing prices in Northern California in 2005 using its proprietary MARKETSYM model. These estimates were derived from Henwood's spring 2003 forecast of Western electricity markets. Purchased by utilities, power plant developers, banks and rating agencies, Henwood's forecasts are widely accepted among energy-market participants.
- In testimony submitted to the CPUC, Pacific Gas and Electric Company (PG&E) has recently developed

TABLE 9-6
Projected spot electricity and natural gas prices ($2003)

Forecast	Average annual electricity spot-market price ($/MWh)	Underlying natural gas price forecast ($/MMBtu)
Henwood Energy Services (2004)		
Dry conditions—2005	37.75	NA
Average conditions—2005	36.13	NA
Wet conditions—2005	34.84	NA
Marcus (2003)		
Projected 2005	39.00	4.50
Projected 2012	50.00	5.54
Pacific Gas and Electric Company (2004)		
High gas-price forecast—2013	73.37	7.76
Base gas-price forecast—2013	55.35	5.54
Low gas-price forecast—2013	42.57	3.32

Sources:

(1) Henwood Energy Services. February 5, 2004. *Power Impact Analysis for the Trinity SEIR/EIS Central Valley Project Phase 2 Report*, Appendix B.

(2) Marcus, William. March 2003. *Clean and Affordable Power: How Los Angeles Can Reach 20% Renewables without Raising Rates.* Report prepared for the Environment California Research and Policy Center and the Center for Energy Efficiency and Renewable Technologies.

(3) Pacific Gas and Electric Company. January 9, 2003. *Testimony Supporting PG&E's Application to Replace the Steam Generators in Units 1 and 2 of the Diablo Canyon Power Plant.* Testimony submitted to the California Public Utilities Commission in A.04-01-009.

estimates of the cost of replacing energy from its Diablo Canyon nuclear generating station. PG&E uses its own natural gas price forecast as a basis for determining future market-clearing electricity prices from Henwood's MARKETSYM model. The prices in PG&E's base analysis are somewhat higher than those currently being used by other analysts.

- Marcus adjusts the CEC's most recent electricity-market clearing-price forecast by increasing the underlying natural gas prices, thereby reflecting recent market developments.

Spot-market prices are typically higher during on-peak than in off-peak hours, and this is especially true in California during the summer months, when system-wide electricity demand is most intense. However, the price forecasts presented in Table 9-6 are annual averages that combine projections both for on-peak and off-peak periods.

Current forecasts of spot-market electricity prices provide a lower bound on the likely cost of replacing Hetch Hetchy energy because they reflect only operating costs and do not take into account the capital cost of constructing new power plants. But energy markets are widely expected to tighten in future years, necessitating the construction of new capacity.

COST OF ENERGY FROM A NEW NATURAL-GAS-FIRED POWER PLANT

A more conservative way to estimate of the cost of replacing Hetch Hetchy energy is to assume that it is all purchased from a newly built combined-cycle natural-gas-fired baseload power plant, and two recent analyses have in fact projected the levelized costs of such a facility. A 2003 CEC study estimated that the levelized cost of electricity from a new 500-MW plant in northern California would be \$52/MWh over 20 years.[21] Marcus then adjusted the CEC's estimate using an updated natural gas price forecast, obtaining a 20-year levelized cost of \$53/MWh in southern California.[22] The CEC study acknowledges that the cost of building and operating a particular project could be higher than its generic estimate, as a result of site-specific costs such as emissions-offset purchases and the establishment of connections to gas pipelines and the transmission grid.

Higher gas-price forecasts increase the levelized energy-cost estimates of gas-fired power plants. In testimony submitted to the CPUC, the Pacific Gas and Electric Company estimated the cost of replacing energy from its Diablo Canyon nuclear facility with energy from a new gas-fired power plant. PG&E's analysis used the CEC cost model mentioned above but substituted a higher forecast of future gas prices. Extrapolating back to 2005 from PG&E's base-case projection for 2013–2024 yields a levelized cost of \$57/MWh.[23]

The long-run incremental cost of gas-fired on-peak energy is considerably more expensive than baseload power. This is because peaker plants are less efficient than baseload facilities and their capital costs must be recovered over only a few hundred operating hours per year. The CEC estimates that the 20-year levelized cost of energy from a simple-cycle peaker plant would be \$157/MWh.[24]

COST OF ENERGY FROM A NEW RENEWABLE-ENERGY FACILITY

Today, wind energy is the most inexpensive renewable alternative to natural gas. After surveying the available data (including the results of recent bid solicitations by the California Power Authority and San Diego Gas and Electric for contracts ranging up to

20 years' duration), Marcus concludes that "a significant number of renewable projects can be readily developed by private-merchant plant developers at costs of $55/MWh or less." His analysis of a wind project being developed by the Los Angeles Department of Water and Power, for example, yields a 30-year levelized cost of $52/MWh.[25]

Marcus' estimates are consistent with the CEC's analysis of the comparative cost of energy from various central-station generating technologies. The CEC study pegs the 30-year levelized cost for electricity from a 100-MW wind farm at $49.30/MWh, though it notes that actual installed costs in any given location may be higher, depending on the expenses incurred in acquiring land and connecting new wind developments to the transmission grid.[26]

While most analysts predict increasing natural gas prices over time, the cost of renewable generating technologies is generally expected to fall. This has certainly occurred in recent years as these technologies' market penetration has increased, and a recent CEC report projects further reductions. The cost of wind energy is forecast to fall nearly 40 percent over the next 15 years, reaching $30/MWh by 2017.[27] At least partially offsetting this projected trend is a possible side-effect of the increased demand for wind energy caused by the California legislature's adoption of a renewable portfolio standard (RPS). This law, which requires that the state's investor-owned utilities purchase 20 percent of their electricity from renewable sources by 2017, will accelerate development of the best sites while leaving higher-cost sites to the market's latecomers.

ANNUAL COST OF REPLACEMENT ENERGY

Based on this review of available data, a reasonable estimate of the long-term costs of replacing forgone Hetch Hetchy hydropower production is $55/MWh. For the SFPUC facilities, the annual cost of replacement energy would be $18.6 to $38.0 million. This range reflects current projections of the cost of energy from new gas-fired baseload facilities and recent bids to supply renewable energy in California.

While volatile natural-gas prices may drive up the cost of gas-fired generation in the future, the cost of energy from wind facilities is forecast to decline over time. Therefore much of the forgone generation could be replaced with wind power, with gas-fired generation firming up capacity. Increased investments in energy efficiency and expanded dynamic-pricing programs may also displace energy and capacity needs at a cost less than that of energy from new generating facilities. While on-peak energy can cost significantly more to replace than off-peak or baseload power, it appears that San Francisco would retain much of its ability to generate during on-peak periods. Losses in on-peak energy production represent no more than 1.5 percent of the overall reduction in SFPUC hydropower output and would not have a significant impact on annual replacement-energy costs.

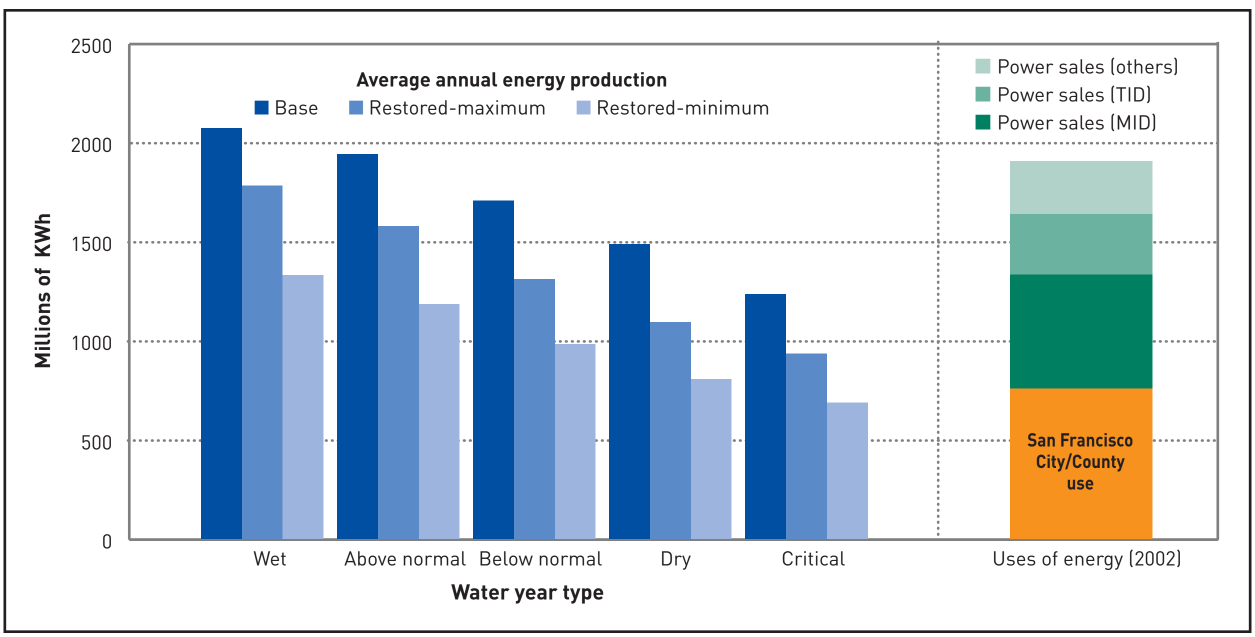
Depending on where San Francisco diverts water, restoration may either increase or decrease generation at Don Pedro. If generation decreases (upstream diversion), it is reasonable to assume that TID and MID's per-unit replacement cost would equal the estimate ($55/MWh) developed above. With a downstream diversion, the Districts could actually realize increased power-sales revenues. Given that the increased output would occur during the high-demand late-summer months, $55/MWh is a lower bound on the increased revenue to the Districts. Applying this figure to the projected changes in generation at Don Pedro (see Table 9-4), implies that the value of increased or decreased hydropower generation at Don Pedro varies between a loss of $440,000 and a gain of $3 million per year.

Financial impacts on San Francisco and the Districts

It is important to note that the replacement-energy values developed in the preceding section represent social values—the worth of lost generation resources to *all* parties that use Hetch Hetchy energy. For individual stakeholders, however, the relevant question is what share of this social value they will bear. San Francisco's Tuolumne powerhouses have been a source of inexpensive energy for the City, the Districts, and other public entities that have bought Hetch Hetchy power over the years. For the Districts, low-cost hydropower produced at Don Pedro powerhouse has sheltered them from having to purchase more expensive energy. For San Francisco, Hetch Hetchy energy has also been a source of power-sales revenues, especially after the City entered its firm power-sales contracts with the Districts in 1987. Those contracts became money-losers for the City during the price spikes of 2000–01, and San Francisco has moved to terminate them early. Even after the current contracts are terminated, however, San Francisco will retain its Raker Act obligation to sell the Districts surplus power at cost-of-service rates.

As shown in Figure 9-5, with the valley restored the SFPUC's Tuolumne River powerhouses would still provide enough energy to meet San Francisco's current public-sector needs on an annual basis in all but the driest years. In the latter half of the year, the City would need to increase the amount of energy it already purchases to augment hydroelectric out-

FIGURE 9-5
Projected annual generation vs. 2002 uses of Hetch Hetchy hydropower



Hetch Hetchy hydropower accounts for a tiny share of California's electricity supply, but is a valuable energy source for San Francisco and the Turlock and Modesto Irrigation Districts. If the valley is restored, the SFPUC's powerhouses would still provide enough energy to supply the City's current needs in all but the driest years. The City would have to buy additional power at times, and less energy would be available to sell to the Districts and others. Renewable energy and investments in energy efficiency can cost-effectively fill the gap without increasing air pollution.

Source: US DOE Form EIA-861 and EIA-412

put. In dry years, the City might also need to purchase energy at other times. Less surplus energy would be available for resale to the Districts and others.

For San Francisco, the fiscal impacts of restoration would thus be an increase in the cost of purchasing power to meet its own needs and a loss in power-sales revenues. But although the $55/MWh replacement-power cost estimate developed in the preceding section fairly reflects the cost of purchasing additional energy, it significantly overstates the per-unit revenue losses to San Francisco of forgone energy sales. Given the Raker Act requires San Francisco to sell surplus power to TID and MID at below-market cost-of-service rates, the Districts would shoulder most of the financial burden of decreased power sales as they faced the prospect of replacing Hetch Hetchy energy at market rates.

Recommendations for further analysis

This chapter has provided an initial planning-level estimate of the annual cost of replacing Hetch Hetchy's energy, based on modeled hydropower production and current projections of long-term electricity costs. Further analysis, using more detailed data, is needed in order to determine the optimal mix of alternative supply- and demand-side resources.

A more complete investigation would need to consider seasonal and daily patterns of energy use, taking into account anticipated growth. It would also need to assess existing generation resources, including power-purchase contracts. The analysis should carefully consider how energy losses would be divided between off-peak and on-peak periods, given the significant seasonal and daily price swings that occur in electricity markets. Opportunities to modify hydropower operations or facilities to increase the proportion of on-peak energy, while meeting all water-supply needs, should also be weighed. Localized assessments of energy-efficiency opportunities and of the potential to displace peak energy use through dynamic pricing should be completed as well.