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The Potential Benefits of Geothermal Electrical Production from Hydrothermal Resources

by
C. H. Bloomster
R. L. Engel

June 1976

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Pacific Northwest Laboratories

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ELECTRICAL PRODUCTION FROM HYDROTHERMAL
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THE POTENTIAL BENEFITS OF GEOTHERMAL ELECTRICAL PRODUCTION FROM HYDROTHERMAL RESOURCES

C. H. Bloomster and R. L. Engel

SUMMARY

The potential national benefits of geothermal electric energy development from the hydrothermal resources in the West are estimated for several different scenarios. The U.S. electrical economy is simulated by computer using a linear programming optimization technique. Under most of the scenarios, benefits are estimated at \$2 to \$4 billion over the next 50 years on a discounted present value basis. The electricity production from hydrothermal plants reaches 2 to 4% of the national total, which will represent 10 to 20% of the installed capacity in the West. Installed geothermal capacity in 1990 is estimated to be 9,000 to 17,000 MWe. The geothermal capacity should reach 28,000 to 65,000 MWe by year 2015.

Our "most likely" scenario yields the lower values in the above ranges. Under this scenario geothermal development would save the utility industry \$11 billion in capital costs (undiscounted); 32 million separative work units; 64,000 tons of U_3O_8 ; and 700 million barrels of oil.

The most favorable scenario for geothermal energy occurs when fossil fuel prices are projected to increase at 5%/year. The benefits of geothermal energy then exceed \$8 billion on a discounted present value basis.

Geothermal energy is now competitive with nuclear and fossil fuels in the West, but only the highest quality hydrothermal resources are competitive. The rate of growth in installed capacity from these competitive resources is constrained, from an economic standpoint, only by their availability. However, improvements in geothermal technology which reduce costs by 10 to 35% could more than double the quantity of economically competitive geothermal resources and thus extend the national benefits.

Supply curves were developed for hydrothermal resources based on the recent U.S. Geological Survey (USGS) resource assessment, resource characteristics, and projected power conversion technology and costs.

Geothermal plants were selected by the optimizing technique to fill a need for "light load" plants. This infers that geothermal plants may be used in the future primarily for load-following purposes.

INTRODUCTION

Although nuclear and coal powerplants are expected to supply most of the new electrical generation capacity during the remainder of the century, new energy sources are being developed to supplement and replace these conventional resources. Of these, geothermal energy is particularly promising for early introduction. A recent assessment of the USGS⁽¹⁾ indicates that substantial geothermal energy resources exist. The most likely of these for early development are the hydrothermal and dry steam resources in the West. Many of these have already been identified and their energy conversion technology appears imminent.

In a study, funded by the Energy Research and Development Administration, Battelle Pacific Northwest Laboratories (BNW) has evaluated the competitive status and potential national and regional economic impact of these hydrothermal and dry steam resources. Our objective was to determine the optimum allocation of energy resources and technologies to meet the projected U.S. electricity demand over the next half century. We considered several potential supply and demand scenarios for nuclear, fossil, and geothermal fuels using current and projected energy conversion technologies.

To evaluate the long-range role of geothermal energy, we used a computer simulation system which estimates the optimum pattern of future electrical supply. The simulation optimizes the long-range development of electrical generating capacity in the U.S. on a multiregional basis.^(2,3) The model simulates a decision making process based on the economics of the utility industry for determining what types of powerplants to build and when to build them. The decision criterion is the minimization of present worth system cost including both construction and operating costs, subject to many decision-limiting constraints. Linear programming is the optimization technique used in this simulation.

Despite the ethereal-sounding number assigned to this report, the scenarios portrayed are intended to represent the range of mundane possibilities. This odyssey is limited to electrical uses of dry steam and

hydrothermal resources in the American West over the next half century. Hot dry rock and geopressured resources were not included; successful commercial development of these geothermal resources would extend the national benefits. Application of low temperature hydrothermal resources to non-electric uses would extend the benefits still further. The results and all costs for fossil, nuclear, and geothermal powerplants are expressed in constant (1974) dollars.

DESCRIPTION OF SCENARIOS

Thirteen different potential supply and technology scenarios for the three energy resources were developed. These are shown in Table 1. The geothermal resources included only the dry steam and hydrothermal resources in the Western Systems Coordinating Council (Figure 1). The addition of geothermal capacity in the West, however, has national impact through reducing the demand (and indirectly the cost) for nuclear and fossil energy supplies and services.

Five base cases (without geothermal) were needed to evaluate the 13 cases with geothermal. Base Case 1 uses fossil and nuclear costs at the end of 1974 with projected cost increases for meeting tighter safety and environmental standards; this base case applies to geothermal Cases 1, 2, 3, 5, 7 through 10, and 13. Base Case 2 is identical to base Case 1 except fossil fuel prices are increased at 2%/year; this base case applies to geothermal Case 4. Base Case 3 is identical to base Case 1 except the capital costs of the nuclear and fossil plants are increased by \$50/kWe; this base case applies to geothermal Case 6. Base Case 4 is identical to base Case 1 except fossil fuel prices are increased at 5%/year; this base case applies to geothermal Case 11. Base Case 5 is identical to base Case 1 without the Liquid Metal Fast Breeder Reactor (LMFBR); this base case applies to geothermal Case 12. By comparing results of a geothermal case with results of its associated base case, the impact of geothermal energy can be estimated.

TABLE 1. Major Features of Twelve Geothermal Cases

Case #	Nuclear Assumptions	Fossil Assumptions	Geothermal Assumptions (a)
1	Reference	Reference	590 MWe Centuries for each category of geothermal resource.
2	Reference	Reference	Maximum resource estimate
3	Reference	Reference	Most likely resource estimate
4	Reference	Fuel Costs Rising 2% per year	Most likely resource estimate
5	Reference	Reference	Most likely resource estimate, capital and fixed operating and maintenance costs reduced 10%, variable operating and maintenance costs increased 10%. This simulates a 10% increase in the load factor or a 6% decrease in geothermal power costs.
6	Capital Cost Increased \$50/kWe	Capital Cost Increased \$50/kWe	Most likely resource estimate
7	Reference	Reference	1/10 most likely resource estimate
8	Reference	Reference	USGS "Identified" in 1980 USGS "Total" in 2020 Linear between 1980 and 2020
9	Reference	Reference	Dry steam only "Identified" in 1980 USGS "Identified" in 1985 USGS "Total" in 2020 Linear between 1980 & 1985 & between 1985 and 2020.
10	Reference	Reference	Same as Case 9 except only heavy load allowed for geothermal plants.
11	Reference	Fuel Costs rising 5%/year	Same as Case 9
12	Reference without LMFBR	Reference	Same as Case 9
13	Reference	Reference	Available geothermal resource constrained on maximum capacity and not energy availability

(a) Cases 1 through 7 are based on the BNW resource estimates and Cases 8 through 12 are based on the USGS geothermal energy estimates using \$300,000 wells (see Table 4).

WSCC - Western Systems Coordinating Council
 MARCA - Mid-Continent Area Reliability Coordination Agreement
 SWPP - Southwest Power Pool
 ERCOT - Electric Reliability Council of Texas
 MAIN - Mid-America Interpool Network
 ECAR - East Central Area Reliability Coordination Agreement
 SERC - Southeastern Electric Reliability Council
 MAAC - Mid-Atlantic Area Coordination Agreement
 NPCC - Northeast Power Coordinating Council

FIGURE 1. Regional Electric Reliability Councils in the United States

The total U.S. electrical energy demand used in this study is taken from ERDA's Planning and Analysis Case A, which assumed a 4.8% growth rate in energy shown in Table 2.⁽⁴⁾ The model time bounds were from 1968 to 2040. The objective was to minimize total cost discounted at 8.8% to the beginning of 1974.

TABLE 2. ERDA Case A - Projection of Capacity and Energy

<u>Year</u>	<u>Gigawatts (GW)</u>	<u>10⁹ kW-hr</u>
1980	655	2812
1990	1040	4646
2000	1575	7174

GEOHERMAL INPUT

The dry steam and hydrothermal resources in the Western Systems Coordinating Council (WSCC) were grouped into 10 categories based on equivalent costs of power production. These isocost categories (Figure 2) were based on cost of power calculations using the GEOCOST⁽⁵⁾ model. Representative resource conditions and powerplant types were selected to typify each isocost category. The cost data for the representative plants in each of the 10 categories are shown in Table 3. The first three columns are the fixed, variable, and total cost of power for geothermal plant operation at a uniform 80% load factor; the last two columns are the cost of power for plant operation at "heavy load" and "light load," respectively.

"Heavy load" assumes a load factor of 75% for the first 15 years, falling gradually to 50% during the last 15 years (Figure 3). "Light Load" assumes a load factor of 55% for the first 15 years, falling gradually to 30% during the last 15 years. Plant life is 30 years. These heavy and light load factors were developed previously to simulate the historic life cycle operating characteristics of conventional powerplants.⁽⁴⁾ The formulation of the linear programming model made it necessary to simulate the geothermal plants in the same manner. A mix of heavy and light load plants is needed to simulate the average load factor in utility systems.

FIGURE 2. Geothermal Isocost Regions for Hydrothermal Resources

TABLE 3. Cost of Power for Representative Geothermal Powerplants

(Mills/kW-hr)

Category	Plants Operating at 80% Load Factor			"Heavy Load"	"Light Load"
	Fixed Cost	Variable Cost	Total Cost	Total Cost	Total Cost
Dry Steam	11.7	1.6	13.3	15.6	21.3
HTLS1	12.4	2.4	14.8	17.2	23.2
HTLS2	14.4	3.1	17.5	20.3	27.3
HTLS3	16.8	4.7	21.5	24.7	32.8
HTLS4	18.0	5.2	23.2	26.6	35.3
HTLS5	19.7	6.0	25.7	29.5	39.0
HTLS6	22.6	7.2	29.8	34.2	45.1
HTLS7	24.0	7.3	31.3	35.9	47.5
HTLS8	26.5	8.3	34.8	39.9	52.6
HTLS9	29.4	9.5	38.9	44.5	58.6

FIGURE 3. Plant Load Duration Curves

SUPPLY CURVES FOR HYDROTHERMAL RESOURCES

A critical requirement for these analyses is the supply curve (price-quantity relationship) for hydrothermal resources. The recent assessment of geothermal resources by USGS⁽¹⁾ provides an initial basis for deriving a supply curve. They made quantitative estimates of the geothermal energy potential. However, they estimated the prices qualitatively: reserves, paramarginal resources, and submarginal resources.

We developed more discriminative price estimates based on variations in resource quality from which we derived more quantitative supply curves. In previous work, we determined that the cost of geothermal energy production was primarily dependent on the resource temperature, the well flow rate, and the well cost.⁽³⁾ Applying the GEOCOST model and using a consistent set of economic assumptions, we developed systematic relationships among these three factors and the cost of power.

Although USGS estimated the temperature and quantity of energy available at each identified resource location, well flow rates and the well costs were also needed to derive supply curves. Existing data on well flow rates from hydrothermal wells in New Zealand and Mexico^(6,7,8) were fit to a log normal frequency distribution (Figure 4). This frequency distribution was later assumed to apply to all hydrothermal resources. Since geothermal well costs in 1974 were reported to average between \$300,000 and \$500,000,⁽⁹⁾ we derived price quantity relationships for both cases, using USGS's temperature and energy estimates for identified resources, our frequency distribution for well flow rate, and the isocost curves shown in Appendix A. We also used USGS's estimated relationship between identified and undiscovered resources.

The price-quantity relationships for geothermal energy used in this study are summarized in Table 4. Supply estimates derived from USGS data are shown in the first four columns following the category column. Resource availability estimates based on \$500,000 wells were not used because they could be approximated by previous cases which used the initial BNW resource availability estimates.

FIGURE 4. Frequency Distribution of Hydrothermal Well Flow Rates

TABLE 4. Resource Availability Estimates
(MWe - Centuries)

Category	BNW Estimates Derived from USGS Data				Initial BNW Estimates (\$300,000 Wells)		
	\$300,000 Wells		\$500,000 Wells		Minimum	Most Likely	Maximum
	Identified Only	Identified Plus Undiscovered	Identified Only	Identified Plus Undiscovered			
Dry Steam	477	954	477	954	208	983	1572
HTLS1	469	2814	200	1200	197	1965	4912
HTLS2	544	3264	230	1380	157	1572	4126
HTLS3	598	3588	250	1500	167	1670	4323
HTLS4	132	792	230	1380	128	1277	3340
HTLS5	548	3288	560	3360	88	884	2358
HTLS6	201	1206	380	2280	108	1080	2751
HTLS7	201	1206	380	2280	108	1080	2947
HTLS8	960	5760	65	390	246	2456	6485
HTLS9	106	636	400	2400	177	1768	4716

We derived the initial BNW resource availability estimates prior to publication of the USGS Circular 726. We had developed them with combined frequencies of reported temperatures and flows for hydrothermal resources and estimates of the number and size of hydrothermal systems. These initial BNW relationships were used in Cases 2-7. Since they nicely bracket the estimates derived from the USGS data, they provide useful comparisons for determining the sensitivity of the results to the resource availability. In particular, since the BNW "most likely" estimate is intermediate between the two estimates based on the USGS data with high and low well costs, it is probably near "the" most likely estimate of the geothermal supply curve. The sensitivity of the analytical results to uncertainties in the supply curve can be evaluated by comparing the results between those cases which differ only in the estimates of the geothermal supply curve.

The maximum resource estimate might be realized either through more favorable conditions in nature; e.g., higher well flow or resource sizes, or through advanced technology which stimulated higher well flows, reduced well drilling costs, increased conversion efficiencies, or resulted in other cost reducing improvements. Of these, improvements in power conversion efficiency and reduction in drilling costs would probably most increase the commercially recoverable reserves.

These supply curve estimates are subject to a number of uncertainties; the temperature, the electrical potential estimate, the flow rate distribution, and the relationship between undiscovered and identified resources. The precautionary statement to the USGS assessment is appropriate to these estimates:

"Although these new resources rest on a much improved scientific base, they should not be taken as final appraisals that are valid indefinitely into the future. They are limited to data available...in 1975 and will need to be revised...as more data and better methods of evaluation become available." (1)

The BNW maximum and minimum estimates, however, appear to be broad enough to cover the current range of uncertainty.

We excluded the identified resources in national parks from this analysis. We also excluded the Salton Sea resource because its fluid composition leads to sharply higher costs than for the neutral, low salinity hydrothermal resources included in this study. Our recent analyses indicate that the proposed technologies for the Salton Sea resource would lead to power costs about 30% higher than other hydrothermal resources of comparable temperature. Therefore, the costs for the Salton Sea resource would probably fall primarily in the HTLS 2-7 categories. Including the identified Salton Sea resource with the same provision for inferred unidentified resources used for the other hydrothermal resources would increase the geothermal supply in these categories an average of at least 10%.

CONSTRAINTS ON RESOURCE AVAILABILITY

For Case 1, it was assumed that 590 MWe centuries of dry steam resource were available in 1974 and 590 MWe centuries of each of the other geothermal resources were available in 1980. For Cases 2-7, which are based on the initial BNW resource estimates, the rate of dry steam resource availability is constrained linearly from the planned capacity at the Geysers in 1980 to the assumed resource limit in 2020, while the rate of resource availability of the hydrothermal classes is constrained linearly from 100 MWe at the start of 1980 to the assumed resource limit in 2020.

Cases 8-12 are based on the USGS energy estimates using \$300,000 wells. In Case 8, the rate of availability for all geothermal classes is constrained linearly from the USGS "identified" in 1980 to the USGS "total" in year 2020. In Cases 9-12, the rate of dry steam resource availability is constrained linearly from the planned capacity at the Geysers in 1980 to the USGS "identified" in 1985 and then to USGS "total" in 2020. All other classes are constrained from 0 at the beginning of 1980 to USGS "identified" in 1985 and to USGS "total" in 2020. In Case 13, the geothermal resource availability constraint was placed on installed capacity instead of energy. The energy supply used in Case 9 was converted from MWe-centuries to MWe using the energy consumption for heavy load plants. Thus, heavy load and light load plants were weighted equally against the capacity constraint.

The cumulative geothermal energy availability input for the 13 cases is shown in Appendix B.

NUCLEAR AND FOSSIL INPUT

This section summarizes the more important nuclear and fossil input assumptions. A detailed description of nongeothermal input data is contained in Reference 1.

PROBLEM DEFINITION PARAMETERS

The model time bounds were from 1968 to 2040, using two-year intervals until year 2000 and then five-year intervals until year 2040. The objective was to minimize total cost discounted at 8.8% to the beginning of 1974. We used three fossil fuel price levels in each of the nine National Electric Reliability Councils (NERC) regions and included new technologies into the simulation according to the estimated dates of their likely availability.

The following are the optional constraints applied to all cases.

Technology Introduction Constraints - HTGR and LMFBR technology introduction limits were four and two gigawatts allowed respectively the first two-year period. Each technology could double each two-year period for four periods and was not constrained after that.

Technology Phaseout Constraints - Fossil, LWR, and HTGR technologies had phaseout constraints which limit the rate of reduction in installed capacity for a technology.

Committed Construction Constraints - LWR and fossil construction were fixed by region through the year 1983.

Market Share Constraints - HTGR construction limits were 15% of the nuclear construction in each time period between 1980 and 2000.

Material Balance Constraints - Two fissile materials, uranium 233 and fissile plutonium, had material balance stockpile constraints.

Import/Export Constraints - Uranium, thorium and other fissile materials were not allowed to be imported or exported.

REGIONAL ENERGY DEMAND

An important input is energy demand. The total U.S. energy demand used in this study is ERDA's Planning and Analysis Case A,⁽⁴⁾ which assumed a 4.8% growth rate in energy from 1975 (Table 2). The total energy demand is allocated to NERC regions using NERC forecasts reported to the Federal Power Commission in 1974 and normalized to the U.S. total. Energy demand is represented in our regional linear programming (LP) model as a building schedule for new thermal generating plants within each geographic region. Each plant is assumed to operate for a 30-year lifetime at one of the predetermined load histories previously described.

The simulation is designed to represent only new plant additions, but since the consumption and exchange of nuclear fuel is important, the model time line begins at 1968. Any older nuclear plants were assumed to start in 1968. Pre-1974 plants have zero cost in this simulation.

COST ESTIMATES

Fossil and nuclear plant capital costs used in this study are listed in Table 5. The cost increase in the late 1970's is due to assumed increasing requirements for safety and environmental controls. Extra control for plutonium recycle capability and yet unknown safeguard requirements were assumed to increase costs (in constant dollars) more than standardization or increased plant size will decrease costs. Fossil-fueled plants were also assumed to incur environmentally driven cost increases such as those associated with SO₂ removal. We assumed that continued pressure to reduce other emissions will cause plant costs to rise, while economies resulting from plant size increases are likely to be small in the future. The LMFBR plant costs were assumed to decrease after year 2000 due to increased plant size and standardization.

Uranium supply was priced as an increasing step function of consumption (Table 6). The fossil fuel prices for each region were from last

quarter 1974 Federal Power Commission (FPC) price data (Table 7). The heat rate assumed for fossil-fueled plants was 9,000 Btu/kW-hr. Several types of nuclear fuel processing costs were specified (Table 8).

TABLE 5. Fossil and Nuclear Capital Costs (\$/kW) (1974 dollars)

	<u>LWR & HTGR</u>	<u>LMFBR</u>	<u>Fossil (by NERC Region)</u>				
			<u>ECAR NPCC</u>	<u>WSCC SWPP</u>	<u>MARCA SERC</u>	<u>MAIN ERCOT</u>	<u>MAAC</u>
1974	320		250	250	250	250	250
1980	544		451	457	463	471	449
1990	575	675	482	488	494	502	479
2000	583	685	490	496	502	510	487

TABLE 6. U_3O_8 Price Availability (1974 dollars)

<u>Thousand Tons Available</u>	<u>At \$/lb</u>
400	16
500	20
500	25
500	40
1000	60
1000	80
1000	100
1000	110
1000	120
3000	125

Tax rates which were applied to all powerplants in this study were:

Property tax rate	0.032
Federal income tax rate	0.500
State income tax rate	0.030
Gross revenue tax rate	0.040

TABLE 7. Fossil Fuel Cost by Region (1974 dollars)

<u>Region</u>	<u>Cost*</u> <u>¢/mbtu</u>	<u>Percent**</u> <u>of</u> <u>Supply</u>
ECAR	83	33.4
	95	33.4
	167	33.2
WSCC	35	33.4
	60	33.3
	203	33.3
MARCA	35	28.4
	60	39.0
	191	32.6
NPCC	108	44.4
	132	36.4
	208	19.2
SWPP	40	33.2
	90	33.1
	175	33.7
MAAC	117	31.7
	160	38.8
	206	29.5
MAIN	80	34.5
	95	33.9
	190	31.6
SERC	80	33.3
	127	33.3
	182	33.4
ERCOT	25	33.7
	70	32.5
	180	33.8

*Derived from 1974 FPC data.

**Supply function steps based on historical cost distribution from Battelle-Northwest Powerplant File.

TABLE 8. Price Schedule Assumptions of Nuclear Fuel Cycle*

<u>Time</u>	<u>Fuel Fabrication (\$/kg HM)</u>				<u>Reprocessing \$/kg</u>		
	<u>LWR U</u>	<u>LWR Pu</u>	<u>LMFBR</u>	<u>HTGR</u>	<u>LWR</u>	<u>LMFBR</u>	<u>HTGR</u>
1980	80	100-140		240	110		
1990	70	80-100	300	160-260	90		120
2000	60	65-80	190	140-170	85	100	115

*Assumed constant costs: uranium enrichment, \$75/kg SWU; UF₆ conversion, \$2.12/kg; U²³³ and Pu storage, \$.50/g/year; thorium oxide, \$11/kg.

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NAME		ADDRESS		CITY		STATE	
111	1234	5678	9012	3456	7890	1234	5678
222	3456	7890	1234	5678	9012	3456	7890
 

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RESULTS

SOLUTION SUMMARY

Geothermal powerplants in the dry steam, HTLS 1, and HTLS 2 categories are immediately competitive with nuclear and fossil powerplants. The discounted benefits and the year of introduction of the competitive geothermal categories for the 13 geothermal cases are shown in Table 9. In Cases 1, 2 and 8, the introduction date of the HTLS 2 category is delayed slightly, because of the greater initial availability of dry steam and HTLS 1 resources in those cases. In all cases, except Case 11, the HTLS 3 category is not competitive until 1998. The HTLS 4 category is also competitive in 1998 in Cases 4-6; these cases each contain cost assumptions favorable to geothermal energy or unfavorable to nuclear or fossil energy compared to the other cases.

TABLE 9. Solution Summary

<u>Case</u>	<u>Discounted Benefit (\$ Billion)</u>	<u>Year of Introduction for Geothermal Classes</u>					
		<u>Dry Steam</u>	<u>HTLS1</u>	<u>HTLS2</u>	<u>HTLS3</u>	<u>HTLS4</u>	<u>HTLS5</u>
1	2.7	1974	1980	1986	1998		
2	3.9	1974	1980	1984	1998		
3	2.1	1974	1980	1980	1998		
4	3.0	1974	1980	1980	1998	1998	
5	2.5	1974	1980	1980	1998	1998	
6	2.9	1974	1980	1980	1998	1998	
7	.7	1974	1980	1980	1998		
8	3.2	1974	1980	1984	1998		
9	2.8	1974	1980	1980	1998		
10	2.3	1978	1980	1980	1998		
11	8.5	1974	1980	1980	1980	1980	1980
12	3.4	1974	1980	1980	1998		
13	2.3	1978	1980	1980	1998		

In Case 11, the HTLS 3, 4, and 5 categories are competitive in 1980 only. Case 11 assumes a 5% annual fossil fuel cost increase; this case is most favorable for geothermal. However, the selection of HTLS categories 3-5 in 1980 resulted from the nuclear capacity input constraint. Through 1983, nuclear capacity is constrained to the currently planned construction schedule for nuclear plants; because of the long lead time for construction, only currently committed nuclear plants are permitted through 1983. Afterwards, when the constraint on nuclear capacity is removed, geothermal categories 4 and 5 are not competitive with nuclear plants until 1998.

A similar explanation pertains in the delay until 1978 of the introduction of new dry steam capacity in both Case 10, which allows only "heavy load" geothermal plants, and Case 13, which favors "heavy load" geothermal plants. The input schedule of planned nuclear capacity fills all the need for "heavy load" plants prior to 1978.

The benefits from geothermal energy in these cases ranged from \$0.7 to \$8.5 billion. The greatest benefit, \$8.5 billion, occurred in Case 11. Under this scenario, geothermal energy replaces fossil fuels which are rising in cost at 5%/year. The lowest benefit, less than \$0.7 billion, occurred in Case 7 which had the minimum geothermal resource availability assumptions. (Recall that for each case both the size and rate of availability of geothermal energy were constrained by the resource availability assumptions described previously.) All other scenarios yielded benefits ranging from \$2 to \$4 billion. The benefit was nearly \$4 billion in Case 2 which had the maximum geothermal resource availability assumptions. The benefit was \$3.4 billion in the scenario without the breeder reactor (Case 12).

The potential advantage of accelerated geothermal development is illustrated by Cases 8 and 9. In Case 8 the entire hydrothermal resource identified by the USGS was assumed to be available in 1980. In Case 9 the rate of availability of the same identified resource was constrained through 1985. The accelerated development of these "identified" resources yielded an increased benefit of \$400 million.

INSTALLED CAPACITY

Table 10 lists the installed capacity of geothermal plants for all cases. In Case 2, installed geothermal capacity is highest and reaches 65,000 MWe in 2015. In Case 7 with the minimum resource estimate, installed geothermal capacity reaches less than 3,000 MWe. The installed capacity for all plant types for all cases is shown in Appendix C.

LOAD FACTOR

For the most part, geothermal plants were selected by the optimization technique to fill the need for "light load" plants (Table 11). Even though geothermal plants have low variable operating costs, their low capital costs and the resource constraint in terms of total energy availability favored the designation of geothermal plants to meet the "light load" need. The maximum total installed capacity is higher with "light load" plants than "heavy load" plants because the resource is "stretched" according to the ratio of the integrated load factors.

In Case 13, a constraint was placed on available geothermal capacity instead of energy. Under this constraint, the optimization technique overwhelmingly selected "heavy load" geothermal plants. This illustrates that selection of "light load" plants in the other cases was based on achieving a higher installed geothermal capacity. The results of Case 10, which allowed only heavy load geothermal plants, showed over \$500 million less benefit than Case 9. Case 9 was identical to Case 10 except that geothermal plants could be both heavy and light load.

The distribution of heavy and light load geothermal plants for all cases is tabulated in Appendix D.

GEOHERMAL ENERGY PRODUCTIONS

The energy produced by geothermal plants for all cases is listed in Table 12, and the percent of energy produced by geothermal plants is listed in Table 13. The energy produced by geothermal plants reaches 2 to 4% of the U.S. total in all cases except Case 7 which reaches only 0.4%. The maximum geothermal resource, Case 2, results in almost 4% of the U.S.

TABLE 10. Geothermal Operating Capacity (GWe)

<u>Year</u>	<u>Case 1</u>	<u>Case 2</u>	<u>Case 3</u>	<u>Case 4</u>	<u>Case 5</u>	<u>Case 6</u>	<u>Case 7</u>	<u>Case 8</u>	<u>Case 9</u>	<u>Case 10</u>	<u>Case 11</u>	<u>Case 12</u>	<u>Case 13</u>
1975	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	-	0.70	0.70	0.
1985	6.84	8.68	4.54	4.56	4.48	4.62	1.87	9.97	6.64	6.99	8.21	8.25	7.22
1995	11.25	28.00	12.77	10.08	12.07	13.32	2.32	23.68	20.25	15.10	16.27	19.99	14.32
2005	14.16	54.61	23.83	27.83	25.90	28.66	2.82	41.82	39.10	30.69	42.63	37.36	30.80
2015	8.03	65.03	27.60	35.96	31.24	34.93	2.22	42.37	44.69	31.73	55.10	52.55	31.61

TABLE 11. Case 3 Installed Geothermal Capacity by Class and by Load Factor (GWe)

<u>Year</u>	<u>Dry Steam</u>		<u>HTLS 1</u>		<u>HTLS 2</u>		<u>HTLS 3</u>		<u>Total</u>		<u>Heavy + Light</u>
	<u>Heavy Load</u>	<u>Light Load</u>	<u>Heavy Load</u>	<u>Light Load</u>	<u>Heavy Load</u>	<u>Light Load</u>	<u>Heavy Load</u>	<u>Light Load</u>	<u>Heavy Load</u>	<u>Light Load</u>	
1980	.440	.800	0	.240	0.020	.320	0	0	0.460	1.360	1.820
1990	.440	2.060	0	3.850	0.020	3.050	0	0	0.460	8.96	9.420
2000	.440	3.450	0	7.220	0.020	5.750	3.220	0.560	3.680	16.980	20.660
2010	0	4.040	0	10.350	0	8.100	3.220	0.560	3.220	23.050	26.270
2020	0	4.040	0	9.780	0	7.770	3.220	0.560	3.220	22.150	25.370

TABLE 12. Energy Generated by Geothermal Plants (GW/yr)

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13
1975	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.0	0.22	0.22	0
1980	2.12	0.90	0.86	0.86	0.84	0.86	0.72	1.07	0.88	0.96	1.35	0.88	0.89
1985	4.05	4.60	2.39	2.41	2.35	2.43	1.09	5.64	3.56	4.45	4.83	4.34	4.40
1990	6.26	4.18	4.76	4.29	4.40	4.77	1.22	9.04	6.74	7.90	7.30	7.68	7.68
1995	6.48	15.35	6.74	5.44	6.26	6.90	1.24	13.29	10.97	10.81	9.03	11.03	10.22
2000	7.44	25.81	10.76	12.31	11.52	12.77	1.50	20.97	18.67	18.44	19.51	17.60	17.50
2005	6.82	30.66	12.68	15.07	13.95	15.53	1.38	23.54	21.93	21.44	23.74	20.38	20.42
2010	4.52	32.70	13.12	15.69	14.91	16.63	1.11	23.28	22.68	22.00	25.76	22.91	20.29
2015	3.17	32.29	13.34	17.74	15.48	17.32	1.05	21.10	22.19	21.16	28.33	25.74	18.72
2020	1.48	30.53	12.25	17.20	14.75	16.45	0.97	18.88	20.38	19.82	28.12	26.19	16.83

TABLE 13. Percent of Total U.S. Electric Energy That Is Generated by Geothermal Plants

Year	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11	Case 12	Case 13
1975	0.13	0.13	0.13	0.13	0.14	0.13	0.13	0.13	0.13	0.0	0.13	0.13	0
1980	1.16	0.41	0.40	0.39	0.39	0.39	0.33	0.49	0.40	0.44	0.61	0.40	0.40
1985	1.37	1.55	0.81	0.81	0.80	0.82	0.37	1.90	1.20	1.50	1.63	1.46	1.48
1990	1.52	2.23	1.16	1.04	1.08	1.16	0.30	2.20	1.64	1.92	1.78	1.87	1.87
1995	1.21	2.85	1.25	1.01	1.17	1.28	0.23	2.47	2.04	2.01	1.68	2.05	1.90
2000	1.07	3.70	1.54	1.76	1.64	1.83	0.21	3.01	2.68	2.64	2.80	2.52	2.51
2005	0.77	3.47	1.43	1.70	1.58	1.76	0.16	2.66	2.48	2.42	2.69	2.30	2.30
2010	0.40	2.92	1.17	1.40	1.33	1.48	0.10	2.08	2.02	1.96	2.30	2.04	1.81
2015	0.22	2.29	0.95	1.26	1.10	1.23	0.07	1.50	1.58	1.50	2.01	1.83	1.33
2020	0.08	1.72	0.69	0.97	0.83	0.93	0.05	1.06	1.15	1.12	1.59	1.48	0.95

electricity generation being produced by geothermal energy, while Cases 3-6 with the BNL "most likely" geothermal resource availability, result in almost 2% of the energy produced from geothermal resources. Cases 8-12, based on the USGS supply estimates, result in almost 3% of the energy produced from geothermal resources. The geothermal percentage decline in the later year for the other cases is caused by consumption of the competitive geothermal resources and the total resource availability constraints.

Table 14 lists the percents of electric energy in region WSCC that is provided by geothermal plants. In Case 2, the maximum geothermal resource case, geothermal reaches nearly 20% of the installed capacity while in the "most likely" geothermal availability cases, geothermal is less than 10%. The cases based on the USGS geothermal assessment peak at 13 to 16% of the energy in the western region.

Table 15 lists the percentage of geothermal plant startups by 10-year periods in region WSCC. In Case 2, geothermal plants reach 28% of the total startups in 1990-1999. In Case 3, geothermal plants reach 13% of the new startups in 1980-1989. The high early peak for Case 8 shows the rate of growth which might be achievable if constraints on the resource availability are removed for the USGS identified resources. A complete listing of new plant startups for all plant types and cases is given in Appendix E.

POTENTIAL ECONOMIC IMPACTS

The potential impact of geothermal energy on the economy resulting from Case 3 (Table 16) would be a savings of (1) \$11 billion to the utility industry in construction capital, (2) 32 million separative work units, (3) 64 thousand tons of natural uranium, and (4) 700 million barrels of oil assuming that all fossil plants replaced by geothermal were oil-fired. For Case 2 (Table 17) geothermal energy results in a savings of \$24 billion to the utility industry in construction capital, 62 million units of uranium enrichment, 115 thousand tons of natural uranium, and 6,500 million barrels of oil if all fossil plants displaced were oil-fired. The savings shown in Table 16 or 17 are additive, since both fossil and nuclear plants are being displaced.

TABLE 14. Percent of Electrical Energy in Region
WSCC Produced by Geothermal Energy

<u>Year</u>	<u>Case 1</u>	<u>Case 2</u>	<u>Case 3</u>	<u>Case 4</u>	<u>Case 5</u>	<u>Case 6</u>	<u>Case 7</u>	<u>Case 8</u>	<u>Case 9</u>	<u>Case 10</u>	<u>Case 11</u>	<u>Case 12</u>	<u>Case 13</u>
1980	5.59	2.37	2.27	2.28	2.25	2.26	1.91	2.84	2.33	2.55	3.58	2.33	2.36
1985	8.05	9.16	4.76	4.79	4.73	4.84	2.16	11.21	7.08	8.85	9.62	8.62	8.74
1990	8.55	12.54	6.50	5.85	6.01	6.51	1.67	12.35	9.21	10.78	9.95	10.49	10.49
1995	6.55	15.51	6.81	5.50	6.32	6.97	1.25	13.43	11.09	10.92	9.13	11.14	10.32
2000	5.62	19.51	8.13	9.32	8.70	9.65	1.13	15.85	14.11	13.90	14.76	13.29	13.21
2005	4.00	18.00	7.44	8.85	8.18	9.11	.81	13.81	12.87	12.57	13.93	11.96	11.98
2010	2.03	14.69	5.89	7.04	6.69	7.47	.50	10.45	10.18	9.88	11.57	10.30	9.12
2015	1.12	11.42	4.72	6.28	5.48	6.13	.37	7.46	7.85	7.49	10.02	9.13	6.64
2020	.41	8.49	3.41	4.79	4.10	4.58	.27	5.25	5.67	5.51	7.83	7.30	4.69

TABLE 15. Percent of New Thermal Plant Startups in Region
WSCC That Are Geothermal Plants for Selected Cases

<u>Period</u>	<u>Case 2</u>	<u>Case 3</u>	<u>Case 4</u>	<u>Case 8</u>	<u>Case 9</u>	<u>Case 11</u>	<u>Case 12</u>
1975-1979	4	4	4	3	3	3	3
1980-1989	22	13	11	25	19	21	20
1990-1999	28	11	16	20	20	19	16

TABLE 16. Impact of Geothermal Energy for Case 3

Year	Geothermal Capacity Operating (GWe)	Operating Nuclear Capacity Displaced (GWe)	Operating Fossil Capacity Displaced (GWe)	Cumulative Savings in Capital Cost (Billion \$)	Cumulative Savings in Uranium Enrichment (Million SWU)*	Cumulative Savings in Uranium Ore (Thousand Tons)	Cumulative Oil Savings (Million bbl)
1980	1.98	.05	1.93	.25	.03	.05	37.
1990	9.69	5.28	4.40	2.51	2.67	4.92	248.
2000	21.46	17.30	4.16	6.75	9.79	18.5	583.
2010	25.68	24.13	1.55	8.98	19.49	41.3	755.
2020	25.48	26.27	-.80	11.46	32.01	63.6	728.

* Separative work units

TABLE 17. Impact of Geothermal Energy for Case 2

Year	Geothermal Capacity Operating (GWe)	Operating Nuclear Capacity Displaced (GWe)	Operating Fossil Capacity Displaced (GWe)	Cumulative Savings in Capital Cost (Billion \$)	Cumulative Savings in Uranium Enrichment (Million SWU)	Cumulative Savings in Uranium Ore (Thousand Tons)	Cumulative Oil Savings (Million bbl)
1980	2.15	-.10	2.25	.30	0.	0.	85.
1990	16.72	10.6	6.12	4.60	6.72	13.77	607.
2000	47.59	29.59	18.00	13.94	17.9	33.46	2173.
2010	62.18	39.37	22.81	18.46	38.61	77.08	5316.
2020	63.83	45.46	18.37	24.33	62.24	115.27	6515.

COST REDUCTION TARGETS

The cost reductions which would be required for each noncompetitive geothermal class to become competitive are shown in Table 18 for Case 3 and in Table 19 for Case 2, the highest geothermal resource. These tables show the marginal cost of power for the selected years. The marginal cost of power is the cost of power for the highest cost plant introduced in that year. In Case 3, only 13% (3.5 mills/kW-hr) cost reduction is required for the HTLS 4 category to be competitive in 1990, while a 35% reduction (12.6 mills/kW-hr) would be required for the HTLS 7 category to be competitive in 1990. These cost reductions would be the "targets" for research and development programs aimed at reducing geothermal power costs.

The year of introduction for the geothermal categories was determined by the marginal costs of nuclear and fossil power. In all scenarios the marginal costs increased with time to year 2000 as both nuclear and fossil fuel costs increased and capital costs also increased to meet more stringent environmental and safety regulations. After year 2000, marginal costs decreased when the breeder reactor became competitive.

Although all cases but one assumed the successful commercialization of the breeder reactor, the benefits from geothermal power are not particularly sensitive to this assumption. Without the breeder the benefits of geothermal energy increased only \$0.6 billion or 20% (Case 12 versus 9).

TABLE 18. Required Cost Reductions and Marginal Cost of Power
for Case 3 (All costs expressed in mills/kW-hr)

Year	Required Cost Reduction to Become Competitive								Marginal Cost of Power	
	Heavy Load				Light Load				Heavy Load	Light Load
	HTLS 4	HTLS 5	HTLS 6	HTLS 7	HTLS 4	HTLS 5	HTLS 6	HTLS 7		
1980	3.8	6.7	11.4	12.9	5.6	9.2	15.3	17.5	22.8	29.9
1990	3.5	6.3	11.0	12.6	4.1	7.8	13.9	16.0	23.1	31.3
2000	2.6	5.4	10.1	11.7	3.0	6.6	12.7	14.8	24.2	32.6

TABLE 19. Required Cost Reductions and Marginal Cost of Power
for Case 2 (All costs expressed in mills/kW-hr)

Year	Cost Reduction								Marginal Cost of Power	
	Heavy Load				Light Load				Heavy Load	Light Load
	HTLS 4	HTLS 5	HTLS 6	HTLS 7	HTLS 4	HTLS 5	HTLS 6	HTLS 7		
1980	5.3	8.2	12.9	14.4	8.1	11.8	17.9	19.9	21.3	27.2
1990	3.5	6.3	11.0	12.6	5.0	8.6	14.7	16.9	23.1	30.3
2000	2.6	5.4	10.1	11.7	3.0	6.6	12.7	14.9	24.2	32.6
2010	3.1	5.9	10.6	12.2	2.4	6.0	12.1	14.2	23.7	33.4
Cost of Power	26.6	29.5	34.2	35.9	35.3	39.0	45.1	47.5		

INTERPRETATION OF RESULTS

Geothermal energy is now competitive with nuclear and fossil fuels in the West. However, only the highest quality hydrothermal resources, those represented by the dry steam, HTLS 1 and HTLS 2 categories in this study, are currently competitive. The rate of growth in geothermal power generation, and hence the benefits from geothermal energy, is constrained principally by the ability to find, prove, and develop resources in these categories.

Under the reference fossil and nuclear assumptions, lower quality resources represented by the HTLS 3 category do not become competitive until 1998. Geothermal resources, represented by HTLS categories above 3, never become competitive unless other assumptions unfavorable to nuclear and fossil energy are introduced. On the other hand, improvements in geothermal technology, which reduce the costs by only 10 to 35% would, on their own, make the large, now uneconomic, resources represented by HTLS categories 4-7 competitive with nuclear fossil fuels.

In this study, geothermal plants primarily met the need for "light load" plants and nuclear plants primarily met the need for "heavy load" plants. We interpret this to mean that geothermal plants, in situations where well flow can be easily regulated without wasting the resource, will tend to be used for load-following purposes, while nuclear plants will tend to be base-loaded. Designation of geothermal plants to meet only the "heavy load" need decreased the benefits of geothermal energy about 25% under one comparable set of scenarios.

The potential benefits from geothermal power are very sensitive to relative changes in the price of geothermal and alternative energy sources. An increase in the price of fossil and nuclear power of approximately 1.5 mill/kW-hr (as represented by a \$50/kWe increase in capital costs) increased the benefits of geothermal power by \$800 million. A decrease in the cost of geothermal power of about 6%, the net effect in Case 5,

increased benefits by \$400 million. The largest benefits from geothermal energy, \$8.5 billion, occurred in Case 11; in this scenario fossil fuel prices increased at the rate of 5%/year. In Case 11, the HTLS 3 category was immediately competitive, replacing higher cost fossil plants.

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APPENDIX A

ISOCOSTS FOR LOW SALINITY HYDROTHERMAL RESOURCES

ISOCOSTS FOR LOW SALINITY HYDROTHERMAL RESOURCES

From parametric analyses on a wide range of low salinity hydrothermal resources the relative importance of each factor to the cost of power was determined. The dominant factors which determined geothermal power costs for low salinity, hydrothermal resources were (1) the wellhead temperature, (2) the well flow rate, and (3) the cost of the wells. These three factors tend to establish the economic value of a resource. Figures A.1-A.3 relate these factors in terms of isocosts - lines of equal power cost - for each of three different well costs: \$150,000, \$300,000, and \$500,000. Combined, these three factors are analogous to the installed unit capital cost of a powerplant. The temperature and flow rate form a measure of the power capacity from a well and the well cost is equivalent to a capital cost. Thus, for instance, a well producing 5000 kW and costing \$500,000 would be analogous to an installed capital cost of \$100/kW. Differences in timing, tax treatment, financing, and useful life do not permit identical translations between powerplant capital costs and well costs into equivalent energy costs. As an illustration of the dominant impact of well costs on the energy costs from low quality geothermal resources, if the same \$500,000 well produced only 1000 kW, then the equivalent capital cost would be \$500/kW.

To illustrate some uses of the isocost figures:

- Refer to the 20 mill/kW-hr curve on the \$300,000 per well figure (Figure A.2). This curve depicts all combinations of temperature and flow rate which would yield a 20 mill/kW-hr power cost. Thus, for example, a 200°C resource with a 500,000 lb/hr average well flow rate would be equivalent to a 175°C resource with an 800,000 lb/hr flow rate; similar comparison can be made using other isocosts.
- The effect of an increase in well drilling costs can be estimated. For instance, at \$150,000 per well (Figure A.1), a 200°C, 500,000 lb/hr resource would result in a power cost of about 17 mills/kW-hr while the same resource at \$500,000 per well (Figure A.3) would result in a power cost of 27 mills/kW-hr, an increase of 10 mills/kW-hr attributable to well costs.

FIGURE A.1. Isocosts for Hydrothermal Resources at a Well Cost of \$150,000

FIGURE A.2. Isocosts for Hydrothermal Resources at a Well Cost of \$300,000

FIGURE A.3. Isocosts for Hydrothermal Resources at a Well Cost of \$500,000

- The effect of flow stimulation can be estimated. For instance, at \$500,000 per well, an increase in the average flow rate from 500,000 to 600,000 lb/hr for the 200°C resource would decrease the cost of power about 3 mills/kW-hr (i.e., from 27 mills/kW-hr to 24 mills/kW-hr). On the other hand, the same increase in flow rate for a 150°C resource would decrease the cost of power about 8 mills/kW-hr (i.e., from 50 mills/kW-hr to 42 mills/kW-hr).

In general, the lower quality resources would always benefit more than higher quality resources from proportional increases in flow rate or decreases in well costs because a much higher fraction of their costs are associated with the wells.

Although these three factors will probably determine the relative economic value of most hydrothermal resources, many other factors will also affect geothermal power costs to a lesser extent. Of these, well replacement rate, well spacing, and fluid composition are probably the most important. The fluid composition, particularly the highly acidic brines, could have a very large impact on power costs. Thus, the value of specific geothermal resources must be determined on an individual basis. The isocost curves illustrate systematic relationships and assume that all other factors are constant. The assumed values for the more important factors were: annual well replacement rate, 0.1; well spacing, 20 acres; pH, 7; and 0.1% noncondensable gases. The isocost figures are derived from both binary (below 250°C) and flashed steam plants (above 250°C). The financing and tax assumptions are the same as used in the previous analysis, which would be typical of a large oil company operating the reservoir, an investor-owned utility operating the power-plant, and a composite tax rate typical of the western states.

APPENDIX B

GEOHERMAL RESOURCE MAXIMUM AVAILABILITY

FIGURE B-1. Geothermal Resource Maximum Availability (Cumulative) Used in Case 1.

FIGURE B-2. Geothermal Resource Maximum Availability (Cumulative) Used in Case 2. "Maximum" Resource.

FIGURE B-3. Geothermal Resource Maximum Availability (Cumulative) Used in Case 3, 4, and 6. "Most Likely" Resource.

FIGURE B-4. Geothermal Resource Maximum Availability (Cumulative) Used in Case 5. 90% of "Most Likely."

FIGURE B-5. Geothermal Resource Maximum Availability (Cumulative) Used in Case 7. 10% of "Most Likely."

FIGURE B-6. Geothermal Resource Maximum Availability (Cumulative) Used in Case 8. USGS "Identified" in 1980; USGS "Total" in 2020.

FIGURE B-7. Geothermal Resource Maximum Availability (Cumulative) Used in Cases 9, 10, 11, 12, and 13. Based on USGS "Identified Resource" Available at End of 1985; USGS "Total Resource" Available at Start of 2020.

APPENDIX C

INSTALLED CAPACITY FOR
GEOTHERMAL, NUCLEAR, AND FOSSIL PLANTS

TABLE C.1. Installed Capacity (GW_e) - WSCC Region: Case 1

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	3.1	6	54	63
1985	6.5	13	62	81
1990	11.2	27	72	110
1995	11.2	51	88	150
2000	14.9	74	120	209
2005	14.5	107	150	271
2010	11.8	158	187	357

TABLE C.2. Installed Capacity (GW_e) - WSCC Region: Case 2

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	1.1	8	57	66
1985	6.9	11	63	81
1990	14.6	22	73	107
1995	26.3	40	84	150
2000	44.5	53	111	209
2005	53.2	85	133	271
2010	61.4	127	168	356

TABLE C.3. Installed Capacity (GW_e) - WSCC Region: Case 3

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	1.1	8	58	67
1985	4.2	13	64	81
1990	8.8	27	74	110
1995	12.4	48	90	150
2000	20.1	66	123	209
2005	23.8	95	153	272
2010	26.4	143	187	356

TABLE C.4. Installed Capacity (GW_e) - WSCC Region: Case 4

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	2.0	8	58	68
1985	4.2	13	64	81
1990	7.9	29	74	111
1995	10.0	69	71	150
2000	24.2	114	70	208
2005	27.6	193	50	270
2010	30.5	287	39	357

TABLE C.5. Installed Capacity (GW_e) - WSCC Region: Case 5

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	1.1	6	55	62
1985	4.1	13	62	79
1990	8.1	27	75	110
1995	11.4	91	48	150
2000	21.2	64	123	208
2005	25.4	93	153	271
2010	29.0	140	187	356

TABLE C.6. Installed Capacity (GW_e) - WSCC Region: Case 6

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	1.1	6	56	63
1985	4.3	13	64	81
1990	8.8	27	74	110
1995	12.6	47	90	150
2000	23.4	63	123	209
2005	28.0	68	176	272
2010	32.2	137	187	356

TABLE C.7. Installed Capacity (GW_e) - WSCC Region: Case 7

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	1.1	6	56	63
1985	1.8	14	65	81
1990	2.1	31	77	110
1995	2.3	55	93	150
2000	3.2	80	126	209
2005	3.1	113	155	271
2010	2.6	164	189	356

TABLE C.8. Installed Capacity (GW_e) - WSCC Region: Case 8

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	1.2	6	56	63
1985	8.8	10	62	81
1990	14.5	23	72	110
1995	22.8	42	86	151
2000	36.8	57	115	209
2005	41.2	92	138	271
2010	45.1	138	173	356

TABLE C.9. Installed Capacity (GW_e) - WSCC Region: Case 9

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	1.1	6	56	63
1985	5.7	12	64	82
1990	11.2	26	74	111
1995	19.4	43	88	150
2000	33.0	59	117	209
2005	38.3	92	141	271
2010	43.2	137	176	356

TABLE C.10. Installed Capacity (GW_e) - WSCC Region: Case 10

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	0.9	6	57	64
1985	5.6	12	64	82
1990	10.4	24	76	110
1995	14.4	44	92	150
2000	26.0	64	119	209
2005	29.9	111	141	272
2010	32.9	148	176	357

TABLE C.11. Installed Capacity (GW_e) - WSCC Region: Case 11

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>LWR & HTGR</u>	<u>Breeder</u>	<u>Fossil</u>	<u>Total</u>
1980	1.3	6		56	64
1985	7.9	12		61	81
1990	12.8	28		70	110
1995	15.8	68	1	66	150
2100	36.2	103	4	65	209
2005	41.4	139	46	45	271
2010	49.2	170	107	30	356

TABLE C.12. Installed Capacity (GW_e) - WSCC Region: Case 12

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	1.1	6	56	63
1985	6.5	11	64	81
1990	12.8	24	74	111
1995	18.9	42	90	151
2000	31.1	52	126	209
2005	36.4	72	163	271
2010	43.9	95	218	357

TABLE C.13. Installed Capacity (GW_e) - WSCC Region: Case 13

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980	0.9	6	57	64
1985	5.8	11	64	81
1990	10.4	24	76	110
1995	14.0	44	93	151
2000	26.1	61	122	209
2005	30.0	96	146	272
2010	33.0	143	181	357

TABLE C.14. Installed Capacity (GW_e) - WSCC Region: Base Case 1

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980		6	58	64
1985		14	67	81
1990		31	79	110
1995		55	95	150
2000		82	127	209
2005		115	156	271
2010		166	190	356

TABLE C.15. Installed Capacity (GW_e) - WSCC Region: Base Case 2

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980		6	58	64
1985		14	67	81
1990		33	77	110
1995		76	75	151
2000		131	78	209
2005		207	65	272
2010		295	61	356

TABLE C.16. Installed Capacity (GW_e) - WSCC Region: Base Case 3

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980		6	58	64
1985		14	67	81
1990		32	79	111
1995		55	95	130
2000		82	127	209
2005		115	156	271
2010		166	190	356

TABLE C.17. Installed Capacity (GW_e) - WSCC Region: Base Case 4

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980		6	58	64
1985		14	67	81
1990		35	76	111
1995		78	72	150
2000		138	71	209
2005		220	51	271
2010		322	35	357

TABLE C.18. Installed Capacity (GW_e) - WSCC Region: Base Case 5

<u>Beginning of Year</u>	<u>Geothermal</u>	<u>Nuclear</u>	<u>Fossil</u>	<u>Total</u>
1980		6	58	64
1985		14	67	81
1990		32	79	111
1995		55	95	150
2000		77	132	209
2005		104	168	272
2010		135	222	357

APPENDIX D

GEOHERMAL PLANT ADDITIONS

TABLE D.1. Geothermal Plant Additions (GW_e) - WSCC Region: Case 1

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75		0.7										0.7
1976-77												
1978-79	2.4										2.4	
1980-81			0 ⁺	2.0								2.0
1982-83				1.0								1.0
1984-85				0.7								0.7
1986-87				0.3		0.8						1.1
1988-89						3.2						3.2
1990-91												
1992-93												
1994-95												
1996-97												
1998-99								3.6				3.6
2000-04												
2005-09												

TABLE D.2. Geothermal Plant Additions (GW_e) - WSCC Region: Case 2

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75	0.4	0.7									0.4	0.7
1976-77												
1978-79												
1980-81		0.4	0 ⁺	1.8								2.2
1982-83		0.5	0.8	0.5							0.8	1.0
1984-85		0.5	1.0	0.2	1.8						2.8	0.7
1986-87		0.5		0.7	1.3						1.3	1.2
1988-89		0.5		2.7		0.2						3.4
1990-91		0.5		1.7		2.4						4.6
1992-93		0.5		1.7		3.1						5.3
1994-95		0.5		1.7		1.4						3.6
1996-97		0.5		1.7		1.0						3.2
1998-99		0.5		1.7		1.8	9.3				9.3	4.0
2000-04		1.2		4.2		3.5						8.9
2005-09		1.2		4.2		3.5						8.9

TABLE D.1. Geothermal Plant Additions (GW_e) - WSCC Region: Case 1

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75		0.7										0.7
1976-77												
1978-79	2.4										2.4	
1980-81			0 ⁺	2.0								2.0
1982-83				1.0								1.0
1984-85				0.7								0.7
1986-87				0.3		0.8						1.1
1988-89						3.2						3.2
1990-91												
1992-93												
1994-95												
1996-97												
1998-99								3.6				3.6
2000-04												
2005-09												

TABLE D.2. Geothermal Plant Additions (GW_e) - WSCC Region: Case 2

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75	0.4	0.7									0.4	0.7
1976-77												
1978-79												
1980-81		0.4	0 ⁺	1.8								2.2
1982-83		0.5	0.8	0.5							0.8	1.0
1984-85		0.5	1.0	0.2	1.8						2.8	0.7
1986-87		0.5		0.7	1.3						1.3	1.2
1988-89		0.5		2.7		0.2						3.4
1990-91		0.5		1.7		2.4						4.6
1992-93		0.5		1.7		3.1						5.3
1994-95		0.5		1.7		1.4						3.6
1996-97		0.5		1.7		1.0						3.2
1998-99		0.5		1.7		1.8	9.3				9.3	4.0
2000-04		1.2		4.2		3.5						8.9
2005-09		1.2		4.2		3.5						8.9

TABLE D.3. Geothermal Plant Additions (GW_e) - WSCC Region: Case 3

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75		0.7										0.7
1976-77												0.7
1978-79	0.4										0.4	
1980-81		0.3		0.8	0 ⁺	0.6						1.7
1982-83		0.3		0.7								1.0
1984-85		0.3		0.4								0.7
1986-87		0.3		0.9								1.2
1988-89		0.3		0.7		2.1						3.1
1990-91		0.3		0.7		0.5						1.5
1992-93		0.3		0.7		0.5						1.5
1994-95		0.3		0.7								1.0
1996-97		0.3										0.3
1998-99		0.3		1.4		1.6	3.2	0.6			3.2	3.9
2000-04		0.7		1.7		1.3						3.7
2005-09		0.7		1.7		1.3						3.7

TABLE D.4. Geothermal Plant Additions (GW_e) - WSCC Region: Case 3 MOD

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75		0.7										0.7
1976-77												
1978-79	0.4										0.4	
1980-81		0.3		0.8	0 ⁺	0.6						1.7
1982-83		0.3		0.7		0.1						1.1
1984-85		0.3		0.4								0.7
1986-87		0.3		0.9								1.2
1988-89		0.3		0.7		2.1						3.1
1990-91		0.3		0.7		0.5						1.5
1992-93		0.3		0.7		0.5						1.5
1994-95		0.3		0.7								1.0
1996-97		0.3										0.3
1998-99		0.3		1.4		1.6	3.2	0.6			3.2	3.9
2000-04		0.7		1.7		1.3						3.7
2005-09		2.0		1.7		1.3						5.0

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TABLE D.5. Geothermal Plant Additions (GW_e) - WSCC Region: Case 4

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75		0.7										0.7
1976-77												
1978-79	0.4										0.4	
1980-81		0.3		0.8		0.7	0 ⁺					1.8
1982-83		0.3		0.7								1.0
1984-85		0.3		0.4								0.7
1986-87		0.3		0.9								1.2
1988-89		0.3		0.7		1.2						2.2
1990-91		0.3		0.7								1.0
1992-93		0.3		0.7								1.0
1994-95		0.3										0.3
1996-97												
1998-99		0.6		2.0		3.7		5.2	2.8		2.8	11.5
2000-04		0.7		1.7		1.3						3.7
2005-09		0.7		1.7		1.3						3.7

TABLE D.6. Geothermal Plant Additions (GW_e) - WSCC Region: Case 5

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75		0.7										0.7
1976-77												
1978-79	0.4										0.4	0.4
1980-81		0.2		0.7		0.6						1.5
1982-83		0.2		0.6		0.2						1.0
1984-85		0.2		0.5								0.7
1986-87		0.2		0.8		0.2						1.2
1988-89		0.2		0.6		1.6						2.4
1990-91		0.2		0.6		0.5						1.3
1992-93		0.2		0.6		0.5						1.3
1994-95		0.2		0.6		0.5						1.3
1996-97		0.2		0.6		0.5						1.3
1998-99		0.2		0.6		0.5	1.5	2.5	2.5		4.0	3.8
2000-04		0.6		1.5		1.2		1.1				4.4
2005-09		0.6		1.5		1.2		1.1				4.4

TABLE D.7. Geothermal Plant Additions (GW_e) - WSCC Region: Case 6

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75		0.7										0.7
1976-77												
1978-79	0.4										0.4	
1980-81		0.3		0.8		0.7						1.8
1982-83		0.3		0.7		0.1						1.1
1984-85		0.3		0.4								0.7
1986-87		0.3		0.9								1.2
1988-89		0.3		0.7		2.1						3.1
1990-91		0.3		0.7		0.5						1.5
1992-93		0.3		0.7		0.5						1.5
1994-95		0.3		0.7		0.5						1.5
1996-97		0.3		0.7		0.5						1.5
1998-99		0.3		0.7		0.5	2.0	2.3	2.8		4.8	3.8
2000-04		0.7		1.7		1.3		1.3				5.0
2005-09		0.7		1.7		1.3		1.3				5.0

TABLE D.8. Geothermal Plant Additions (GW_e) - WSCC Region: Case 7

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75	0.4	0.7									0.4	0.7
1976-77												
1978-79												
1980-81		0.1		0.2		0.2						0.5
1982-83				0.1		0.1						0.2
1984-85				0.1								0.1
1986-87						0.1						0.1
1988-89				0.1								0.1
1990-91				0.1		0.1						0.2
1992-93												
1994-95				0.1								0.1
1996-97												
1998-99				0.2		0.2		0.6				1.0
2000-04				0.2		0.1						0.3
2005-09				0.2		0.1						0.3

TABLE D.9. Geothermal Plant Additions (GW_e) - WSCC Region: Case 8

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
5000-00												
5000-04												
1974-75		0.7		1.0		5.2	5.8				5.8	0.7
1976-77		0.5		1.0								1.5
1978-79	0.5	0.5		1.0		0.3					0.5	1.8
1980-81		2.0	0.2	0.9		1.2					0.2	2.9
1982-83		0.2	1.9	0.9		3.4					1.9	1.1
1984-85		0.2	0.1	0.5	1.8	5.5					1.9	0.7
1986-87		0.2		1.0								1.2
1988-89		0.2		0.8		2.4						3.4
1990-91		0.2		0.8		3.6						4.6
1992-93		0.2		0.8		1.7						2.7
1994-95		0.2		0.8		0.9						1.9
1996-97		0.2		0.8								1.0
1998-99		0.2		0.8		1.9	8.3	0.9			8.3	3.8
2000-04		0.4		2.0		2.4						4.8
2005-09		0.4		2.0		2.4						4.8

TABLE D.10. Geothermal Plant Additions (GW_e) - WSCC Region: Case 9

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75		0.7										0.7
1976-77												
1978-79	0.4										0.4	
1980-81		0.5		1.1	0 ⁺	0.4					0 ⁺	2.0
1982-83		0.8	0.6	0.3							0.6	1.1
1984-85	0 ⁺	0.7	0.8		0.4						0 ⁺	1.9
1986-87		0.2		1.0								1.2
1988-89		0.2		1.0		2.2						3.4
1990-91		0.2		1.0		3.4						4.6
1992-93		0.2		1.0		1.5						2.7
1994-95		0.2		1.0		0.7						1.9
1996-97		0.2		1.0								1.2
1998-99		0.2		1.0		2.6	7.8				7.8	3.8
2000-04		0.5		2.4		2.8						5.9
2005-09		0.5		2.4		2.8						5.7

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TABLE D.11. Geothermal Plant Additions (GW_e) - WSCC Region: Case 10

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75		0.4		5.0		8.1		3.0		1.6	9.2	13.6
1976-77												
1978-79	0.9	0.5		1.0							0.9	2.4
1980-81	0.3	0.5	0.8	1.0	0.9						2.0	3.4
1982-83	0.5	0.5	0.8	1.0		0.1					1.3	2.6
1984-85	0.5	0.5	0.8	5.1	1.5	1.1					2.8	7.9
1986-87	0.1	0.5	0.7	0.0	1.0						1.8	2.0
1988-89	0.2	0.5	0.7		0.8						1.7	2.0
1990-91	0.1	0.5	0.7	0.5	0.8						1.6	2.3
1992-93	0.1	0.5	0.7	0.3	0.8						1.6	2.1
1994-95	0.2	0.5	0.7		0.8						1.7	2.4
1996-97	0.1		0.7								0.8	
1998-99	0.1		0.7		1.5		7.7				10.0	0.8
2000-04	0.3		1.7		1.9						3.9	2.0
2005-09	0.3		1.7		1.9						3.9	2.0

TABLE D.12. Geothermal Plant Additions (GW_e) - WSCC Region: Case 11

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75		0.7										0.7
1976-77												
1978-79		0.6										0.6
1980-81		0.5		0.3		1.2	0.8		0.2		1.0	2.0
1982-83	.0 ⁺	0.7	0.8	0.7							0.8	1.4
1984-85		0.7										0.7
1986-87		0.2		0.9								1.1
1988-89		0.2		2.1		1.1						3.4
1990-91		0.2		1.0		0 ⁺						1.2
1992-93		0.2		1.0								1.2
1994-95		0.2		1.0								1.2
1996-97												
1998-99		0.4		2.0		9.1	7.0		1.5		8.5	11.5
2000-04		0.5		2.4		2.8		3.1				8.1
2005-09		0.5		2.4		2.8		5.0				10.7

TABLE D.13. Geothermal Plant Additions (GW_e) - WSCC Region: Case 12

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75	0.1	0.7	0.1		0.2		0.0	0.0			0.1	0.7
1976-77	0.0		0.1								0.0	
1978-79	0.4		0.1								0.4	
1980-81	0.1	0.5	0.1	1.1	0.1	0.4					0.2	5.9
1982-83	0.1	0.8	0.6	0.3	0.2						0.6	1.1
1984-85	0.1	0.7	0.8		2.0						22.2	0.7
1986-87	0.1	0.2	0.1	1.0	0.1						0.1	1.2
1988-89	0.1	0.2	0.1	1.0	0.1	2.2					0.1	3.4
1990-91	0.1	0.2	0.1	1.0		1.1						2.3
1992-93	0.1	0.2	0.1	1.0		1.5					0.1	2.7
1994-95	0.1	0.2		1.0		1.1					0.1	2.3
1996-97		0.2		1.0		1.1						2.3
1998-99		0.2		1.0		1.1	5.0	1.5			5.0	3.8
2000-04		0.5		2.4		2.8						5.7
2005-09		0.5		2.4		2.8		2.7			2.7	5.7

TABLE D.14. Geothermal Plant Additions (GW_e) - WSCC Region: Case 13

	Dry Steam		HTLS1		HTLS2		HTLS3		HTLS4		Total	
	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load	Heavy Load	Light Load
1974-75												
1976-77												
1978-79	0.9										0.9	
1980-81	0.3		0.8			0.9					1.1	0.9
1982-83	0.5		0.7			0.2					1.2	0.2
1984-85	0.5		0.8		1.5						2.8	
1986-87	0.1		0.7		0.8						1.6	
1988-89	0.1		0.7		0.8						1.6	
1990-91	0.2		0.7		0.8						1.7	
1992-93	0.1		0.7		0.8						1.6	
1994-95	0.1		0.7								0.8	
1996-97	0.2		0.7								0.9	
1998-99	0.1		0.7		2.3		4.0	3.8			7.1	3.8
2000-04	0.3		1.7		1.9						3.9	
2005-09		0.3		1.7		1.9						3.9

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APPENDIX E

NEW PLANT STARTUPS

TABLE E.1. New Plant Startups (GW_e) - WSCC Region: Case 1

	Geothermal				Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders	
1975-79	2.8					4		21
1980-84		3.4				7		22
1985-89		0.6	4.0			14		39
1990-94						23	1	45
1995-99					3.6	20	3	60
2000-04						14	21	85
2005-09						15	40	106

TABLE E.2. New Plant Startups (GW_e) - WSCC Region: Case 2

	Geothermal				Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders	
1975-79	0.6					4		21
1980-84	1.1	3.7	0.9			5		23
1985-89	1.3	4.0	2.4			11		39
1990-94	1.2	4.2	6.2			17	1	46
1995-99	1.3	4.3	3.5	9.3		12	2	60
2000-04	1.2	4.2	3.5			6	28	85
2005-09	1.2	4.2	3.5			6	40	106

TABLE E.3. New Plant Startups (GW_e) - WSCC Region: Case 3

	Geothermal				Nuclear			Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders		
1975-79	0.8					4		16	21
1980-84	0.7	1.7	0.6			7		13	23
1985-89	0.8	1.8	2.1			14		20	39
1990-94	0.7	1.7	1.0			20	1	21	45
1995-99	0.8	1.8	1.6	3.8		17	2	33	60
2000-04	0.7	1.7	1.3			10	21	50	85
2005-09	0.7	1.7	1.3			12	40	51	107

TABLE E.4. New Plant Startups (GW_e) - WSCC Region: Case 4

	Geothermal				Nuclear			Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders		
1975-79	0.8					4		16	21
1980-84	0.7	1.7	0.7			7		13	23
1985-89	0.8	1.8	1.2			16		20	40
1990-94	0.7	1.7				40	1	2	45
1995-99	0.8	2.0	3.7	5.2	2.8	41	5		60
2000-04	0.7	1.7	1.3			39	42		85
2005-09	0.7	1.7	1.3			36	61	5	106

TABLE E.5. New Plant Startups (GW_e) - WSCC Region: Case 5

	Geothermal					Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders		
1975-79	0.8					4		16	21
1980-84	0.5	1.5	0.8			7		13	23
1985-89	0.5	1.7	1.8			14		21	36
1990-94	0.5	1.5	1.2			20	1	21	45
1995-99	0.5	1.5	1.3	4.0	2.5	15	2	33	60
2000-04	0.6	1.5	1.2	1.1		10	21	49	84
2005-09	0.6	1.5	1.2	1.5		11	40	51	107

TABLE E.6. New Plant Startups (GW_e) - WSCC Region: Case 6

	Geothermal					Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders		
1975-79	0.8					4		16	21
1980-84	0.7	1.7	0.8			7		13	23
1985-89	0.8	1.8	2.1			14		20	39
1990-94	0.7	1.7	1.2			20	1	21	46
1995-99	0.8	1.8	1.3	4.3	2.8	14	2	33	60
2000-04	0.7	1.7	1.3	1.3		9	21	50	85
2005-09	0.7	1.7	1.3	1.3		10	40	51	106

TABLE E.7. New Plant Startups (GW_e) - WSCC Region: Case 7

	Geothermal				Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders	
1975-79	0.6					4		21
1980-84	0.1	0.3	0.3			8		23
1985-89		0.2	0.1			17		38
1990-94		0.2	0.1			23	1	45
1995-99		0.2	0.2	0.6		23	3	60
2000-04		0.2	0.1			14	22	85
2005-09		0.2	0.1			15	40	106

TABLE E.8. New Plant Startups (GW_e) - WSCC Region: Case 8

	Geothermal				Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders	
1975-79	1.9					4		22
1980-84	1.4	4.2	0.9			4		21
1985-89	0.5	2.1	3.3			13		39
1990-94	0.5	2.0	5.7			18	1	46
1995-99	0.5	2.0	2.3	9.2		14	2	60
2000-04	0.4	2.0	2.4			10	27	85
2005-09	0.4	2.0	2.4			10	40	105

TABLE E.9. New Plant Startups (GW_e) - WSCC Region: Case 9

	Geothermal				Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders	
1975-79	0.8					4		21
1980-84	1.6	2.4	0.6			6		23
1985-89	0.8	2.4	2.4			14		39
1990-94	0.5	2.5	5.2			18	1	46
1995-99	0.5	2.5	3.0	7.8		14	2	60
2000-04	0.5	2.4	2.8			9	27	86
2005-09	0.5	2.4	2.8			10	40	106

TABLE E.10. New Plant Startups (GW_e) - WSCC Region: Case 10

	Geothermal				Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders	
1975-79	0.9					4		21
1980-84	1.0	2.0	1.6			5		23
1985-89	0.6	1.8	2.6			13		39
1990-94	0.4	1.7	2.0			19		44
1995-99	0.3	1.8	1.9	7.7		19	2	60
2000-04	0.3	1.7	1.9			14	25	85
2005-09	0.3	1.7	1.9			15	36	106

TABLE E.11. New Plant Startups (GW_e) - WSCC Region: Case 11

	Geothermal					Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders		
1975-79	1.0					4		16	21
1980-84	1.5	1.8	1.2	0.8	0.2	6		10	22
1985-89	0.8	3.0	1.1			16		18	39
1990-94	0.5	2.5				40	1	2	45
1995-99	0.5	2.5	9.1	7.0	1.5	36	4		60
2000-04	0.5	2.4	2.8	3.1		37	42		88
2005-09	0.5	2.4	2.8	5.0		35	62		108

TABLE E.12. New Plant Startups (GW_e) - WSCC Region: Case 12

	Geothermal					Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders		
1975-79	0.8					4		16	21
1980-84	1.6	2.4	1.4			5		12	22
1985-89	0.8	2.4	3.2			13		20	39
1990-94	0.5	2.5	3.1			18		21	45
1995-99	0.5	2.5	2.8	6.5		10		38	60
2000-04	0.5	2.4	2.8			23		56	85
2005-09	0.5	2.4	2.8	2.7		27		70	105

TABLE E.13. New Plant Startups (GW_e) - WSCC Region: Case 13

	Geothermal				Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders	
1975-79	0.9					4		21
1980-84	1.0	1.9	1.8			5		23
1985-89	0.5	1.8	2.4			13		39
1990-94	0.3	1.7	1.6			20	1	46
1995-99	0.4	1.8	2.3	7.8		15	1	59
2000-04	0.3	1.7	1.9			14	23	85
2005-09	0.3	1.7	1.9			11	40	105

TABLE E.14. New Plant Startups (GW_e) - WSCC Region: Base Case 1

	Geothermal				Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders	
1975-79						4		21
1980-84						8		23
1985-89						18		39
1990-94						23	1	45
1995-99						24	3	60
2000-04						14	22	85
2005-09						15	40	106

TABLE E.15. New Plant Startups (GW_e) - WSCC Region: Base Case 2

	Geothermal				Nuclear		Fossil	Total
	<u>Dry Steam</u>	<u>HTLS1</u>	<u>HTLS2</u>	<u>HTLS3</u>	<u>HTLS4</u>	<u>LWRs & HTGRs</u>	<u>Breeders</u>	
1975-79						4		17
1980-84						8		15
1985-89						19		20
1990-94						42	1	2
1995-99						51	5	4
2000-04						38	39	8
2005-09						32	60	13

TABLE E.16. New Plant Startups (GW_e) - WSCC Region: Base Case 3

	Geothermal				Nuclear		Fossil	Total
	<u>Dry Steam</u>	<u>HTLS1</u>	<u>HTLS2</u>	<u>HTLS3</u>	<u>HTLS4</u>	<u>LWRs & HTGRs</u>	<u>Breeders</u>	
1975-79						4		17
1980-84						8		15
1985-89						18		21
1990-94						23	1	21
1995-99						24	3	33
2000-04						14	22	49
2005-09						15	40	51

TABLE E.17. New Plant Startups (GW_e) - WSCC Region: Base Case 4

	Geothermal				Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders	
1975-79						4		21
1980-84						8		23
1985-89						21		39
1990-94						43		45
1995-99						55	5	60
2000-04						47	38	85
2005-09						46	60	106

TABLE E.18. New Plant Startups (GW_e) - WSCC Region: Base Case 5

	Geothermal				Nuclear		Fossil	Total
	Dry Steam	HTLS1	HTLS2	HTLS3	HTLS4	LWRs & HTGRs	Breeders	
1975-79						4		21
1980-84						8		23
1985-89						18		41
1990-94						24		45
1995-99						22		60
2000-04						28		84
2005-09						35		106

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