SELECTED INFORMATION FOR THE U.S. ELECTRIC POWER INDUSTRY AND THE POTENTIAL OF GEOTHERMAL ENERGY

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ABSTRACT

The electric power industry in the United States has annual revenues of about $200 billion and is an extremely important part of our industrial infrastructure. However, this industry generates a significant portion of our air pollution, causing damage to the worldwide ecosystem. Development of energy resources that cause little or no environmental damage is a growing priority, both in the U.S. and elsewhere. The Department of Energy and the Environmental Protection Agency recognize the great potential of geothermal energy to contribute to a cleaner energy future, and both are undertaking programs to promote increased use of clean energy technologies.

INTRODUCTION

Electricity is a form of energy, not a source of energy. It is produced in a generator driven by an engine that consumes a primary source of energy such as fossil or nuclear fuels. Converting fossil fuels to electrical power entails energy loss of nearly 70 percent, most of which is rejected as waste heat. Although one may consider electricity to be expensive and even wasteful compared with direct uses of thermal energy, it provides high value because it is versatile, furnishing light, heat or mechanical power, it requires no storage but is available on demand, and users pay only for energy they actually consume. Electricity provides roughly 15 percent of the net energy consumed in the United States, but due to conversion losses, electric power production accounts for 36 percent of all U.S. primary energy consumption.

The electric-power industry is large by any standard, and very important to our economy. It produces about $200 billion per year in sales in the United States. The geothermal portion of this industry, while small by comparison with the whole, is nevertheless an important and growing component that has significant economic impact on the regions in which geothermal electricity is generated and used, and significant environmental advantages for the ecosystem of the entire earth.

My objective in this paper is to bring together selected information for helping to further our understanding of the role and potential of geothermal energy in electrical power generation in the United States. We begin by reviewing data on the utility industry as a whole, then present data on 12 selected Western states. We then consider projections for generation of electricity from the so-called "renewable" resources and the environmental and other advantages from increased use of renewable energy resources. Most data were obtained by selecting from the impressive array of information available from the Energy Information Administration (EIA), an independent statistical and analytical unit within the U.S. Department of Energy (DOE). Complementary information came from other units of DOE and from the Environmental Protection Agency (EPA). The sources are cited at the end of this article, and I recommend them for further reading.

CONSUMPTION OF ENERGY IN THE U.S.

Data on the consumption of energy in the United States in 1990 are shown in Table 1 (EIA, 1993b, Table 2). The numbers are in quads, an abbreviation for "quadrillion BTU", or 10^{15} BTU. For comparison, 1 quad is equivalent to

Table 1

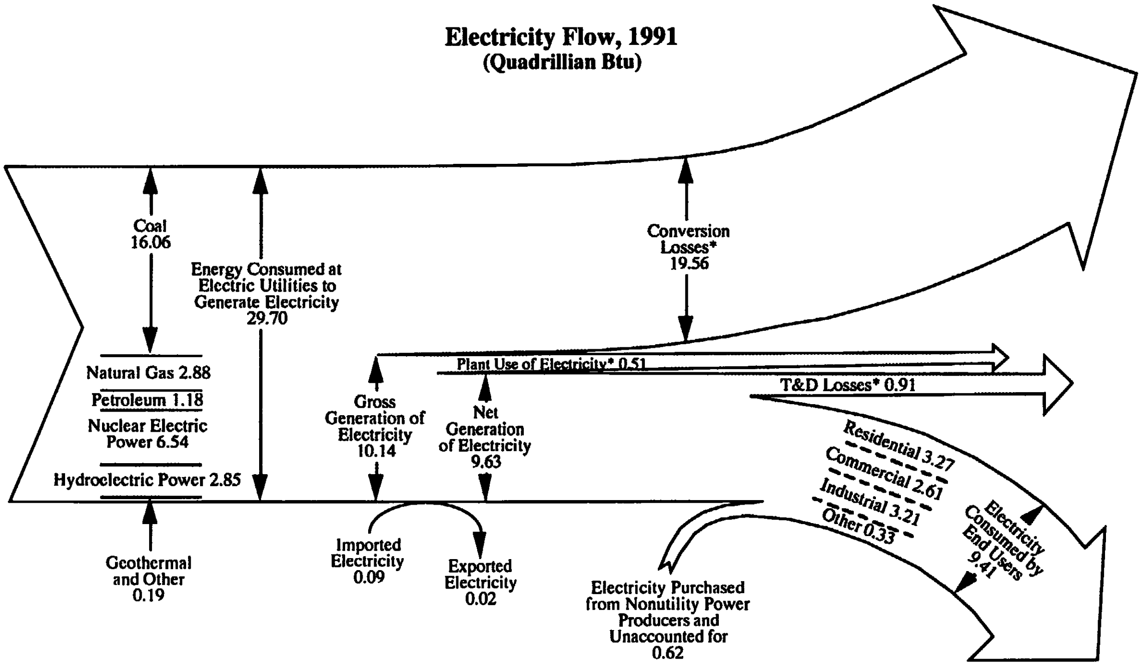
U.S. Energy Consumption, 1990
Quadrillion Btu

Energy Source	Consumption	Percent
Petroleum	33.55	39.8
Natural Gas	19.30	22.9
Coal	19.12	22.7
Nuclear	6.16	7.3
Renewable Resources	6.26	7.4
Conventional Hydroelectric	2.97	3.5
Geothermal	0.32	0.4
Biomass	2.90	3.4
Solar	[a]0.04	b
Wind	[a]0.02	b
Total	**84.40**	**100.0**

[a]Excludes unmeasured direct use.
[b]Less than 0.05 percent
Note: Totals may not equal sum of components due to independent rounding.
Source: EIA, 1993b, Table 2

Figure 1

Electricity Flow, 1991
(Quadrillian Btu)



*Plant use of electricity is approximately 5 percent of gross generation, and transmission and distribution (T&D) losses are approximately 9 percent of gross generation.

Notes: • Data are preliminary. •Sum of components may not equal totals due to independent rounding.
Sources: EIA, 1992, Diagram 5 and Tables 91, 92, 95, 114, and A7.

the thermal energy released in the combustion of 172 million barrels (42 gallons per barrel) of average crude oil. To provide the energy consumed annually in the United States entirely from crude oil would require a pool-full of crude 2 miles on a side and 700 feet deep. The figures in Table 1 include consumption for all uses — transportation, heating and cooling of buildings, industrial processes, lighting and many other uses. The data show that fossil forms of energy (coal, oil and natural gas) provided more than 85% of the total amount, and that geothermal energy provided 0.38%.

Figure 1 (from EIA, 1992, Diagram 5) shows the 1991 use of primary energy for electrical power consumption in the United States. Of the 29.7 quads consumed for power production, 69% went for losses in the conversion, transmission and distribution processes, 11% was used in the residential sector, 9% was used in the commercial sector, and 11% was used in the industrial sector. Transportation uses of electricity were minor. Geothermal energy contributed 0.19 quads, or 0.64% of the energy input to power production.

PROFILE OF THE ELECTRIC POWER INDUSTRY

The electric power industry is comprised of several types of companies, each having its specific function. An understanding of these companies far beyond that presented in this paper is important for anyone working in the geothermal industry because it reveals the complexity of the environment in which we attempt to operate at a profit. In summary:

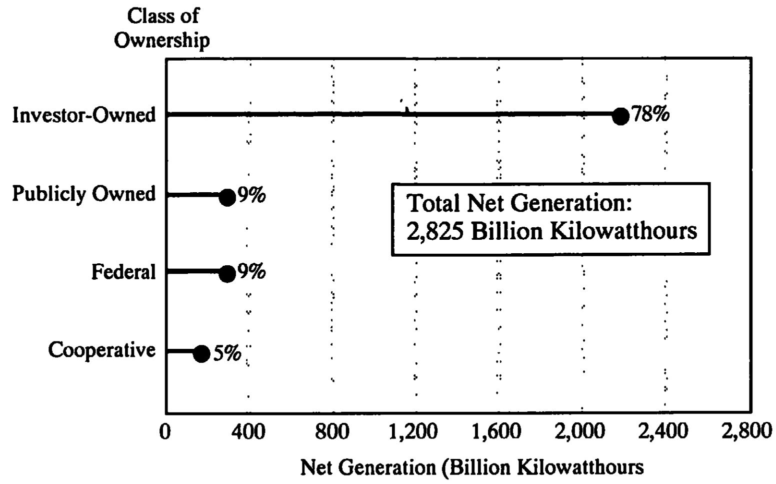
1. Investor-owned utilities (IOUs) provide basic services for the generation, transmission and distribution of electricity. Like other private businesses, the objective of an IOU is to produce a return for investors. It is granted a monopoly and required to provide services for all consumers in its assigned area. The 265 IOUs in the United States account for three-quarters of all electricity generated and sold. IOUs involved in the generation of electricity from geothermal resources include Pacific Gas and Electric at The Geysers and Utah Power (a subsidiary of Pacificorp) at Roosevelt Hot Springs.

2. Publicly-owned utilities are non-profit, local-government agencies established to serve communities at cost. There are approximately 2,000 such utilities, and they include municipals, public power districts, state authorities, irrigation districts and other such organizations. Publicly-owned utilities involved in geothermal power generation include Northern California Power Agency (NCPA), Central California Power Agency (CCPA) and Sacramento Municipal Utility District (SMUD), all operating at The Geysers, and the City of Provo, Utah, which operates power plants at the Cove Fort field.

3. Federal utilities produce electricity and sell it mostly at wholesale to publicly-owned utilities and other non-profit

Figure 2

U.S. Electric Utility Net Generation by Class of Ownership, 1991



Notes: Total may not equal sum of components because of independent rounding. QF = Qualifying Facility.
Source: EIA, 1993a, Figure 2.

organizations. Federal utilities are administered by the Department of Energy. They generate electricity mainly from hydroelectric resources. The electricity from the 10 Federal utilities is marketed by several Federal administrations, among them the Bonneville Power Administration (BPA). The Tennessee Valley Authority (TVA) is the largest Federal power producer and it sells electricity in both the wholesale and retail markets. No Federal utility presently generates electricity from geothermal resources, although BPA has expressed interest in purchasing geothermal power.

4. Cooperative electric utilities are owned by and provide electricity to their members. Incorporated under state laws, they are governed by an elected board of directors. There are about 950 electric cooperatives in the U.S. None of them generate electricity from geothermal resources, although some are partners in geothermal-generating enterprises.

5. Non-utility power producers (or non-utility generators (NUGs)) are comprised of (a) cogenerators and small power producers recognized under the Public Utilities Regulatory Policy Act of 1978 (PURPA) as "qualifying facilities" (QFs), and (b) independent power producers (IPPs), which generate power and sell it at wholesale, usually to utilities. Cogenerators are facilities that produce electricity plus a second form of useful thermal energy, such as steam, for industrial or other proposes. Under PURPA, a small power producer generates electricity using geothermal, biomass, wind or solar resources and sells the electricity to a utility. Fossil fuels can be used in this process, but renewable resources must provide at least 75 percent of the energy input. A number of IPPs and QFs are engaged in generation and sale of electricity using geothermal resources. Among them are the limited partnerships, companies and other entities generating power at Coso, East Mesa, Salton Sea, Mammoth, and Wendel-Amadee, all in California; Desert Peak, Dixie Valley, Beowawe, Steam Boat, Stillwater, all in Nevada; and Puna, Hawaii.

UTILITY DATA

Figure 2 shows the net utility generation of electricity in the U.S. classified by ownership (from EIA, 1993a, Figure 2). Investor-owned utilities greatly predominate, with the other classes each accounting for a small, nearly equal amount.

Table 2 indicates the contribution of the several fuel types to net summer capacity and net electricity generation for utilities in the U.S. (non-utility generators are not included). Summer capacity is used because it reflects the maximum capacity diminished by the adverse effects of higher summer temperatures on cooling efficiency. In 1991, the installed capacity at U.S. utilities was 693,000 megawatts, and the net generation was 2,800 billion kilowatt-hours. (Total installed capacity in the U.S. was about 740,000 megawatts.) Coal was by far the most important fuel at utilities, followed by nuclear, hydroelectric, gas and oil. Less than 1 percent of the total was contributed by other energy sources — geothermal, wood, waste, wind and solar. This table also gives a simple capacity factor, derived by dividing the net generation by the product of the net capacity times 8760 hours per year. The low capacity factors for combustion turbines and internal combustion generators reflect the fact that they are often used for peaking power. The low hydroelectric capacity factor reflects to some extent the drought of recent years. The last column in the table shows that planned additions to generating capacity are greatly dominated by the fossil fuels, including a notable expansion in use of natural gas consistent with today's low gas prices.

Table 2

U.S. Electric Utility Generation by Fuel Type, 1991

Primary Energy Source	1991 Capability[2] (megawatts)	1991 Net Generation (10^6 kwh)	Simple Capacity Factor, %	Planned Additions 1992-2001 (megawatts)
Fossil Steam	**445,099**	**1,905,223**	**48.9**	-
Coal	299,611	1,551,167	59.1	10,222
Petroleum	45,360	108,176	27.2	
Gas	100,128	245,880	28.0	
Combustion Turbine/Internal Combustion	**52,790**	**21,578**	**4.7**	25,413
Petroleum	27,235	3,287	1.3	
Gas	25,555	18,291	8.2	
Hydroelectric	**92,031**	**275,519**	**34.2**	2,483
Nuclear	**99,589**	**612,565**	**70.2**	3.490
Other[1]	**3,507**	**10,137**	**33.0**	2,647
U.S. Total	**693,016**	**2,825,023**	**46.5**	**44,255**

[1]Geothermal, refuse, waste heated steam, wood, wind, solar.
[2]Net summer capability.
Source: EIA, 1993a, Tables 2, 4, 11.

Table 3

U.S. Electricity Utility Sales and Revenues by Sector

	Sales (10^9 kwh)	Revenues ($ billions)	Average Revenue (¢ per kwh)
Residential	955	76.8	8.0
Commercial	766	57.7	7.5
Industrial	947	45.7	4.8
Other	94	6.1	6.5
Totals	**2,762**	**186.3**	**6.7**

Source: EIA, 1993a, Tables 24, 25.

Table 3 shows electric utility sales in 1991 by sector. Residential and industrial consumption predominate, with commercial consumption being somewhat less. In terms of revenues, however, the industrial sector contributes relatively less because of the lower rates they are charged. Note that utilities are annually a $186 billion business in the United States.

NON-UTILITY DATA

Figure 3 shows the division of the 48,171 megawatts of installed capacity in the non-utility sector. Cogenerators have by far the largest share of installed capacity at 73%. Geothermal non-utility generators are numbered among the small power producer QFs and the independent power producers.

Adding the utility and non-utility installed capability in the United States, we obtain a total summer capability of 741,187 megawatts in 1991.

Table 4 (from EIA, 1993a, Table 65) gives summary statistics for non-utility power producers. The contribution from geothermal energy is clearly seen in this table. With an installed capacity of 1,048 megawatts, geothermal power stations delivered 7,651 million kilowatt-hours, for an average single capacity factor of 83.3%. Some 60% of the power was used by the facilities within which it was generated, with the remainder being sold.

Table 4

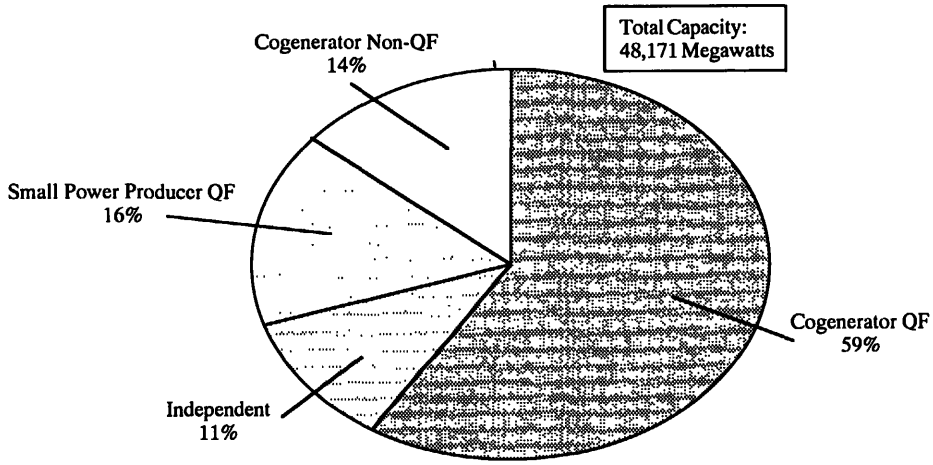
Summary Statistics for U.S. Nonutility Power Producers with Installed Capacity of 5 or More Megawatts, 1991

Item	1991
Gross Generation (million kilowatthours)	248,448
Coal[1]	40,587
Petroleum[2]	7,814
Natural Gas[3]	131,340
Hydroelectric	6,243
Geothermal	7,651
Solar	779
Wind	2,606
Wood[4]	33,785
Waste[5]	13,956
Nuclear[6]	80
Other[7]	3,609

[1]includes coal, anthracite culm and coal waste.
[2]Includes petroleum, petroleum coke, diesel, kerosene, and petroleum sludge and tar.
[3]Includes natural gas, butane, ethane, propane, waste heat and waste gases.
[4]Includes wood, wood waste, peat wood liquors, railroad ties, pitch and wood sludge
[5]Includes municipal solid waste, agricultural waste, straw, tires, landfill gases and other waste.
[6]Nuclear reactor and generator at Argonne National Laboratory used primarily for research and development in testing reactor fuels as well as for training. The generation from the unit is used for internal consumption.
[7]Includes hydrogen, sulfur, batteries, chemicals, fish oil and spent sulfite liquor.

Figure 3

Share of Installed Capacity at U.S. Nonutility Generating Facilities of 5 or More Megawatts by Type of Facility, 1991



Notes: Total may not equal sum of components because of independent rounding. QF = Qualifying Facility.
Source: EIA, 1993a, Figure 14.

Table 5

Net Summer Generating Capability at Electric Utilities in Selected Western States, 1991
(megawatts)

	Coal	Oil/Gas Steam	Oil/Gas Turbine or IC	Nuclear	Hydroelectric	Other	Total
Alaska	56	0	1,169	0	237	85	1,547
Arizona	5,070	1,509	1,805	3,810	2,717	0	14,911
California	0	21,400	2,737	4,746	12,761	1,955	43,599
Hawaii	0	1,149	369	0	3	0	1,521
Idaho	0	0	56	0	2,226	0	2,282
Montana	2,260	70	50	0	2,436	13	4,829
Nevada	2,692	731	671	0	1,031	0	5,125
New Mexico	3,901	966	121	0	58	0	5,046
Oregon	530	0	454	1,104	8,988	160	11,236
Utah	4,271	166	91	0	236	21	4,785
Washington	1,360	86	678	1,100	20,974	46	24,244
Wyoming	5,545	0	15	0	266	0	5,826
Total	25,685	26,077	8,216	10,760	51,933	2,280	124,951

Source: EIA, 1993a, Tables 5, 6, 7, 8.

ELECTED STATE UTILITY DATA

Since electric power generation from geothermal resources will continue to be a Western endeavor until the vast thermal energy in the crust, which occurs everywhere, can be used for this purpose, we present data for 12 selected Western states in this section. These states were chosen because they each have potential for generation of electricity from geothermal resources.

Table 5 shows the net summer generating capability at electric utilities in the 12 Western states classified by fuel type (from EIA, 1993a, Tables 5, 6, 7 and 8). The wide variation in preferred fuel types among the states is noteworthy. California, Hawaii and Idaho are shown to have no coal plants (the new coal-fired plant on the Hawaiian Island of Oahu is not indicated in the EIA data). By contrast, coal predominates in Arizona, Nevada, New Mexico, Utah and Wyoming. Hydroelectric power is important in Arizona, Idaho, Montana, Nevada, California, Oregon and Washington, and

Table 6

Net Sales and Revenues for Electric Utilities in Selected Western States, 1991

	Sales 10^6 kwh	Sales $ millions	Average Revenue ¢/kwh
Alaska	4,256 –	417 ↑	9.8 ↑
Arizona	41,848 ↑	3,283 ↑	7.8 –
California	208,650 ↓	19,661 ↑	9.4 ↓
Hawaii	8,524 ↑	786 ↑	9.2 ↑
Idaho	18,046 ↑	694 ↑	3.8 ↑
Montana	13,407 ↑	555 ↑	4.1 ↑
Nevada	16,625 ↑	932 ↑	5.6 ↑
New Mexico	14,084 ↑	1,005 ↑	7.1 –
Oregon	43,651 ↑	1,854 ↑	4.2 –
Utah	15,907 ↑	869 ↑	5.5 –
Washington	92,714 ↑	3,124 ↑	3.4 –
Wyoming	11,757 –	499 –	4.2 –
Total	**489,469**	**33,781**	**6.9**

Arrows indicate increases (↑) or decreases (↓) in the figure compared to 1990.

Source: EIA, 1993a, Tables 26, 28, 29.

predominates in the three latter states. States with nuclear power plants include Arizona, California, Oregon and Washington (the shut-down of the Trojan nuclear plant in Oregon is not reflected in these 1991 data). California has the lion's share of the "Other" category, which includes renewable use and geothermal power generation. The total net summer generation capability in these Western states is 125,000 megawatts, with California having nearly one-third of this capacity.

Table 7

Fossil-Fuel Consumption for Utility Electric Power Generation in Selected Western States, 1991

	Coal 10^3 Short Tons	Petroleum 10^3 bbls	Gas 10^6 cu ft
Alaska	298 ↑	769 ↑	31,330 ↓
Arizona	16,116 ↑	159 ↓	23,282 ↓
California	0 -	1,037 ↓	449,014 ↓
Hawaii	0 -	12,696 ↓	0 -
Idaho	0 -	1 ↓	0 -
Montana	10,223 ↑	41 ↓	268 ↓
Nevada	7,892 ↑	447 ↓	21,738 ↓
New Mexico	12,809 ↓	67 ↓	28,100 ↑
Oregon	1,831 ↑	23 ↓	10,856 ↑
Utah	12,829 ↓	82 ↓	5,190 ↑
Washington	5,184 ↑	16 ↓	139 ↓
Wyoming	23,115 ↓	122 ↑	76 ↑
Total	**90,297**	**15,460**	**569,993**

Arrows indicate increases (↑) or decreases (↓) in the figure compared to 1990.

Source: EIA, 1993a, Table 16.

Table 6 shows data on utility electricity sales for 1991 for the 12 Western states. Arrows indicate an increase or decrease from 1990 figures. Total sales were 490 billion kilowatt-hours. I calculate the weighted-average sales price to have been 6.9 cents per kilowatt-hour, but the range is nearly a factor of three, with Washington having the lowest rates and Alaska, California and Hawaii the highest rates. Revenues generated were $34 billion. This is the size of the market place in which geothermal electrical-power generation competes. It is obviously large enough to merit our attention.

ENVIRONMENTAL POLLUTION FROM POWER GENERATION

Fossil fuels provide most of the energy for electrical power generation in the Western states, and significant quantities of these fuels are burned each year for this purpose, as shown in Table 7 (from EIA, 1993a, Table 16). The arrows in this table indicate whether the amounts were higher, lower or the same as those consumed in 1990. We see that 90 million tons of coal, 15 million barrels of oil and 570 billion cubic feet of natural gas were used for generation of electricity in the 12 Western states in 1991.

Combustion of fossil fuels produces pollutants, some of which are captured and some of which are not. Perhaps the most serious are those pollutants released to the atmosphere.

Table 8

Emissions of Atmospheric Pollutants From Fossil-Fueled Steam-Electric Generation in Selected Western States (10^3 Short Tons)

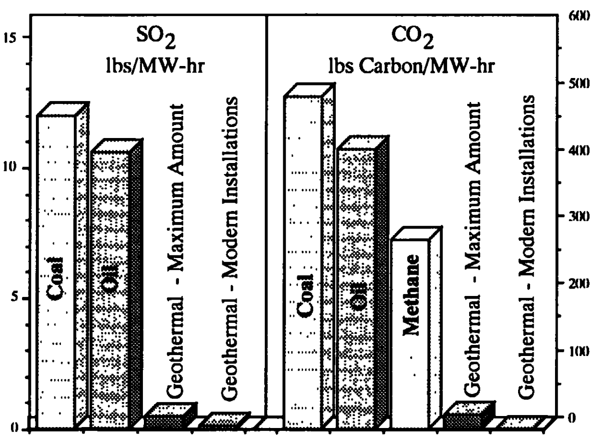
	Sulfur Dioxide	Nitrogen Oxides	Carbon Dioxide
Alaska	1	<0.5	445
Arizona	113	125	35,800
California	1	113	27,151
Hawaii	24	14	5,256
Idaho	ND	ND	ND
Montana	20	77	15,093
Nevada	52	64	19,359
New Mexico	54	118	24,503
Oregon	12	18	2,699
Utah	26	68	29,561
Washington	59	39	8,516
Wyoming	78	84	35,854
Total	440	720	204,237

Source: EIA, 1993a, Table 42

Table 8 (from EIA, 1993a, Table 42) shows data for pollutants released from steam-electric generating plants only. It does not include emissions from combustion turbines and internal-combustion engines. Comparison of Table 7 with Table 8 will assist in understanding the latter table. Most atmospheric pollution is produced from coal plants, and the big coal-consuming states produce the most sulfur dioxide and carbon dioxide. Oil and gas produce less SO_2 and CO_2 emissions, but NO_x emissions can still be high. Combustion of coal releases much more carbon dioxide than combustion of petroleum per unit of heat produced because of the higher carbon content in the molecular structure of coal. Although CO_2 is not yet classified as a criteria pollutant by the EPA, pressures for mitigation are mounting on those who release this gas because of its possible, but unproven, implication in global warming.

One fact obvious from these data is the enormous advantage that geothermal electrical-power generation has over fossil-fired generation in terms of harmful atmospheric emissions. Geothermal plants produce a factor of one-thousand or less of the pollutants emitted by fossil-fired plants, as indicated in Figure 4 (from Goddard and Goddard, 1990).

Figure 4



Source: Goddard and Goddard, 1990, GRC Transactions, 14, 643-649.

ELECTRIC POWER FROM RENEWABLE ENERGY TECHNOLOGIES

Table 9 shows the contributions to the U.S. electricity supply for 1990 from so-called "renewable" energy sources according to the Environmental Protection Agency (Chupka and Howarth, 1992, Table I-1). There are some discrepancies between the figures shown here and those given by the Energy Information Administration, which are shown in Table 10 (EIA, 1993b, Table 4). The EPA credits geothermal energy with significantly more installed capacity and net generation for 1990 than does the EIA. Both of these data sets purport to include both utility and non-utility generation. Despite the differences, some useful conclusions can be drawn from these tables.

Geothermal electric-power generation ranks third in total renewable electric-power generation, after hydropower and biomass. However, the majority of the biomass generation is not grid-connected, but is used at the site of generation. Examples include electric plants that use wood waste to generate electricity for use in running saw mills and other wood-processing equipment. In terms of grid-connected electricity, geothermal energy ranks second among the renewables in the U.S., after hydropower. Hydropower, biomass and wind technologies are considered by the EPA to be relatively mature, whereas geothermal and solar technologies are considered to be relatively immature.

The EPA study of the renewable technologies (Chupka and Howarth, 1992) merits closer examination than this paper is able to present. Its objective was to identify the air-pollution prevention potential of renewable electric-power generation. The study presents a model for market penetration by the renewable technologies on a regional basis, i.e. account was taken of the pollution mitigated region-by-region depending on the type of fossil-fueled generation displaced by renewable energies. Conclusions from the study are:

1. Expanded renewable generation can prevent air pollution by displacing fossil fuels;

2. Renewable electric technologies are at an early stage of development, and due to the large number of different pathways and different technological options for significant cost reductions, there is a high probability that they will increase in cost-competitiveness compared with fossil fuels;

3. Additional investment in renewable R&D has the potential to realize larger social returns than investment in fossil-energy R&D; and,
4. Regulatory, economic, environmental and political trends will continue to encourage development of renewable energy.

Geothermal-electric power was indicated to have great potential for preventing emission of the criteria pollutants sulfur dioxide, nitrogen oxides, particulates, volatile organic compounds (VOCs) and carbon monoxide, as well as the non-regulated green-house gas carbon dioxide. Table 11 (from EPA, 1992, Table III-5) shows the final results of the EPA model predictions for an enhanced market scenario in which increased R&D and renewable-energy promotion occur. This study predicts very significant market penetration by the year 2010 for photovoltaics and solar-thermal power generation. Such optimism is not shared by the Energy Information Administration or the Union of Concerned Scientists, as discussed in the next section. Nevertheless, the EPA predicts very significant contributions to power supply and pollution mitigation from geothermal energy, as Table 11 indicates.

Table 9

Renewable Electric Technologies 1990 Contribution to Electric Supply

Technology	Capacity (MW)	Generation (GWh)	Share of Total Renewable Generation
Conventional Hydropower[a]	**71,270**	**298,010**	80.6%
Storage	50,380	197,500	
Run-of-river & diversion	20,890	100,510	
Biomass Electric[b]	**7,844**	**45,730**	12.4%
Wood and wood waste[c]	5,728	32,600	
Municipal solid waste	1,624	9,250	
Landfill and digester gas	492	3,880	
Geothermal[b]	2,929	23,070	6.2%
Wind[b]	1,392	2,190	0.6%
Solar Thermal Electric[b]	**279**	**765**	0.2%
Hybrid (natural gas)[d]	274	753	
Non-hybrid peaking	5	12	
Photovoltaics[b]	12	25	0.0%
Total Renewable Electric	83,726	369.790	100.0%
Total U.S. Electric[e]	729,400	3,014,000	
Percent Renewable	11.5%	12.3%	

[a]Hydropower data taken from Federal Energy Regulatory Commission (1990) based on average consitions, excluding Alaska.

[b]Based on data contained in The Power of the States (1990, Public Citizen). Generation based on 65% capacity factor for wood, wood waste, agricultural waste, and municipal solid waste, and 90% capacity factor for landfill and digester gas.

[c]Includes combustion of agricultural wastes.

[d]See *The Power of the States: State-by State Supplement* p. 10.

[e]Capacity and generation taken from Tables A4 and A5 of *Annual Energy Outlook 1991* by the Energy Information Administration. Figures include utility and non-utility capacity and generation.

Source: Chupha and Howarth, 1002, Table J-1.

Table 10

U.S. Electricity Generating Capacity and Net Generation, 1990, By Fuel Type

Fuel	Net Summer Capability[a] (Gigawatts)	Net Generation[b] (Billion kwh)	Simple Capacity Factor
Fossil[c]	528.7	2,100	45.3%
Storage	19.5	-2	
Nuclear	99.6	577	66.1%
Renewable	85.2	348	47.0%
Conventional Hydroelectric	72.9	288	45.1%
Geothermal	2.6	15	66.0%
Municipal Solid Waste	2.0	10	57.0%
Biomass	6.0	31	59.0%
Solar[d]	0.4	1	28.0%
Wind	1.4	2	16.0%
Total	**733.0**	**3,023**	

[a]For nonutilities, name plate capacity is used.

[b]For nonutilities, gross generation including internal station use is shown.

[c]Fossil includes coal, oil, natural gas, petroleum coke, waste gases, and water heat.

[d]Includes both solar thermal and less than 0102 billion kilowatthours grid-connected photovoltaic generation.

Source: EIA, 1993b, Table 4.

Table 11

Pollution Prevented
EPA Enhanced Market Scenario
All Regions

Technology	Incremental Generation 1990-2010 (GWh/yr)	Air Pollution Prevented 1990-2010 (thousand metric tons/yr)						
		SO_2	NO_x	Particulate Matter	CO	CH_4	CO_2	CO_2 Equivalent
Biomass Electric - Solid	344,464	2,515.4	818.2	-28.90	-480.26	2.73	320,527	351,874
Biomass Electric - MSW	37,071	220.4	48.7	-381.98	-15.15	0.27	32,119	34,029
Biomass Electric - Gas	11,547	52.4	-50.0	1.87	-33.12	3,075.03	9,195	71,671
Geothermal Electric	133,935	225.2	389.6	13.52	21.36	.55	90,213	105,874
Hydropower	45,508	271.7	176.6	10.32	6.70	.36	42,368	49,461
Photovoltaic	195,040	891.7	689.5	37.06	29.64	1.36	166,713	194,412
Solar Thermal	114,323	142.4	361.3	13.00	18.14	0.50	80,995	95,511
Windpower	139,675	602.9	567.2	33.68	20.46	1.17	134,810	157,585
Total	**1,021,563**	**4,922.1**	**3,001.3**	**-301.42**	**-432.23**	**3,081.97**	**876,940**	**1,060,417**

Negative values indicate that the technology increases emissions for the pollutant indicated

Table 12

Comparison of Electricity Forecasts, 2010

Net Generation (Billion Kilowatthours)	EIA Reference Case	UCS Reference Case	UCS Climate Stabilization Case
Conventional Hydroelectric	306.5	326	343
Geothermal	62.1	53	60
Biomass/Waste (MSW)	112.4	113	136
Solar	3.6	12	39
Wind	16.2	17	117
Total Renewables (Utilities and Nonutilities)	500.9	522	695
Total Generation	4,112.0	4,430	2,576
Percent Renewables	12.2	11.8	27.0

UCS = Union of Concerned Scientists
Source: EIA, 1993b, Table 11.

POTENTIAL GEOTHERMAL CONTRIBUTION TO POWER GENERATION

The great potential of geothermal energy has also been recognized by both the Energy Information Administration and the Union of Concerned Scientists. In a recent report (EIA, 1993b), the projected net generation from various energy sources was given, and is excerpted for presentation in Table 12. This table shows that the annual net generation from geothermal energy is expected to grow from 15 billion kilowatt-hours in 1990 to about 60 billion kilowatt-hours in 2010, for an increase of about 45 billion kilowatt-hours per year over this time span. In the same time frame, solar and wind combined are projected to grow from 3 billion kilowatt-hours in 1990 to 20 billion kilowatt-hours in 2010, for a net growth of 17 billion kilowatt-hours per year. The Union of Concerned Scientists, in an independent analysis, substantially agreed with the Energy Information Administration in its projections, as is also shown in Table 10 (UCS, 1991, as quoted in EIA, 1993b). The comparatively large growth potential of geothermal energy is clearly indicated by these figures.

In an analysis done to support the development of the National Energy Strategy, the Energy Information Administration (EIA, 1990) determined that an enhanced

Table 13

Projected Renewable Electrical Power Supplies (Quadrillion Btu)

	1990		2010		2030	
	Baseline	Excursion	Baseline	Excursion	Baseline	Excursion
Hydroelectric	3.1	3.1	3.4	4.0	3.5	5.1
Geothermal	0.2	0.2	0.9	3.3	1.8	3.9
Biomass/Wood	0.0	0.0	0.1	0.1	0.5	1.0
Municipal Solid Waste	0.2	0.2	1.0	1.2	1.1	1.4
Solar Thermal	0.0	0.0	0.1	0.4	0.7	2.6
Photovoltaic	0.0	0.0	0.0	0.0	0.3	1.0
Wind	0.1	0.1	0.2	0.2	0.7	2.9
Total	**3.6**	**3.6**	**5.7**	**9.2**	**8.6**	**17.9**

Baseline: Present level of R&D
Excursion: Enhanced level of R&D
Source: EIA, 1990, Table 2.

program in R&D would lead to a very substantial increase in the amount of geothermal power that could be brought on line. Whereas the current electrical generation is equivalent to 0.2 quads of energy, an aggressive geothermal R&D program would result in generation of 3.3 quads of electrical energy by the year 2010 (Table 13). Such an R&D program would result in development of new technology allowing economic use of a larger portion of the hydrothermal resource base and also allowing hot rock resources to begin to come on line. Clearly, the geothermal industry should be thinking of this long term potential in its internal planning and in its support for geothermal R&D.

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