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With Data For 1997

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Preface

This is the fourth annual report published by the Energy Information Administration (EIA) which presents information on renewable energy consumption, capacity, and electricity generation data; U.S. solar thermal and photovoltaic collector manufacturing activities; and U.S. geothermal heat pump manufacturing activities. It updates and provides more detail on renewable energy information than what's published in the Energy Information Administration's (EIA) *Annual Energy Review 1997*.

The renewable energy resources included in the report are: biomass (wood, wood waste, municipal solid waste, ethanol, and biodiesel); geothermal; wind; solar (solar thermal and photovoltaic); and hydropower. However, hydropower is also regarded as a "conventional" energy source because it has furnished a significant amount of electricity for more than a century. Therefore, the contribution of hydropower to total renewable energy consumption is discussed, although hydropower as an individual energy source is not addressed. Since EIA collects data only on terrestrial (land-based) systems, satellite and military applications are not included in this report.

The first chapter provides an overview of renewable energy use and capability from 1993 through 1997. It discusses renewable energy consumption, and electric capacity and generation data. Chapter 2 presents current (through 1997) information on the United States solar energy industry. EIA collected this information on the Form EIA-63 A, "Annual Survey of Solar Collector Manufacturers," and the Form EIA-63 B, "Annual Survey of Photovoltaic Module/Cell Manufacturers," covering the 1997 calendar year. Chapter 3 presents, for the first time, information on the United States geothermal heat pump industry. This information was collected on the Form EIA-902, "Annual Geothermal Heat Pump Manufacturers Survey," and covers the calendar years, 1994-1997.

Appendix A describes EIA surveys that include information on renewable energy sources. Appendix B discusses renewable energy data and its limitations. Appendix C presents documentation for the geothermal heat pump manufacturers survey. Appendix D provides a list of Internet addresses for web sites that include renewable energy information. Appendix E lists State agencies that provide energy information, including information on renewable energy. A glossary of renewable energy terms is also included.

The Energy Information Administration was established formally by the Department of Energy Organization Act of 1977 (Public Law 95-91). The legislation requires EIA to carry out a comprehensive, timely, and accurate program of energy data collection and analysis. It also vests EIA with considerable independence in fulfilling its mission.

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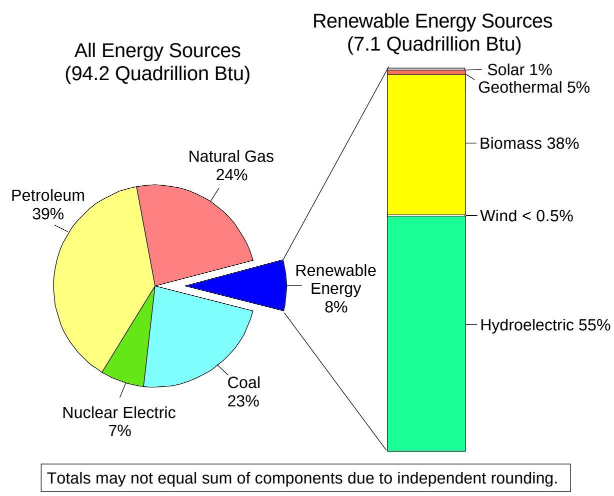
Highlights

Renewable Energy Consumption

Renewable energy consumption declined 3 percent between 1996 and 1997 to 7.1 quadrillion Btu, accounting for 8 percent of total U.S. energy consumption (Figure H1 and Table H1). Hydropower and biomass continued to dominate the renewable energy market, with 55 percent and 38 percent shares, respectively. With hydropower consumption flat between 1996 and 1997, most of the year-to-year drop was due to a decrease in biomass energy consumption due to a warmer than expected heating season. In addition, geothermal energy consumption declined 9 percent. Wind and solar energy together contributed a small but steady 0.1 quadrillion Btu.

Figure H1. U.S. Energy Consumption by Source, 1997



Sources: Energy Information Administration (EIA), *Annual Energy Review 1997*, DOE/EIA-0384(97) (Washington, DC, July 1998), Table 1.3. **1997 Renewable Energy:** Consumption values based on the sum of electricity consumption from EIA, *Electric Power Annual 1997, Volume II*, DOE/EIA-0348(97)/2 (Washington, DC, October 1998), and non-electricity consumption based on analysis by the Office of Coal, Nuclear, Electric and Alternate Fuels.

Renewable energy consumption in the transportation sector (ethanol in motor gasoline) experienced an increase of 23 trillion Btu, or 31 percent. Renewable energy consumption decreased in all other sectors, particularly residential and industrial. Total renewable energy consumption (including net imports) for electricity generation declined 1 percent overall, despite a 4-percent rise to 95 gigawatts in renewable electric generating capacity. Most of the capacity gain was accounted for by a 3,358-megawatt increase in conventional hydroelectric generating capacity. Biomass generating capacity rose 171 megawatts, while wind capacity declined 57 megawatts, as retirements exceeded additions.

Solar Manufacturing Activities

Shipments

Shipments of photovoltaic (PV) cells and modules continued their record growth in 1997, increasing 31 percent. Correspondingly, the value of these shipments increased 34 percent. The growth in shipments is due largely to a strong export market, which represented 73 percent of shipments in 1997, compared with 63 percent in 1996.

Photovoltaic cells and modules shipments totaled 46 peak megawatts in 1997, compared with 35 peak megawatts in 1996. This marks the twelfth consecutive annual increase in shipments. The value of shipments grew to $175 million in 1997 from $131 million in 1996. The average annual rate of increase in shipments over the past 12 years has been 21 percent. Overall unit peak watt price showed a 2-percent increase from 1996 to 1997.

Shipments of solar thermal collectors increased 7 percent in 1997 to 8.1 million square feet from 7.6 million square feet in 1996. The average price of solar thermal collectors decr eased by 9 percent, resulting in a decrease in the value of shipments to $29 million in 1997 from $29.8 million in 1996.

Other major findings about the photovoltaic and solar thermal collector manufacturing activities include:

- Single crystal silicon PVs led the way in growth from 22 peak megawatts in 1996 to 30 peak megawatts in 1997, while cast and ribbon

Table H1. U.S. Renewable Energy Consumption by Energy Source, 1993-1997
(Quadrillion Btu)

Energy Source	1993	1994	1995	1996	1997
Conventional Hydroelectric Power[a]	R3.147	R2.969	R3.472	R3.914	3.932
Geothermal Energy[b]	R0.393	R0.395	R0.339	R0.352	0.322
Biomass[c]	2.784	2.838	2.846	R2.938	2.723
Solar Energy[d]	0.071	0.072	0.073	0.075	0.074
Wind Energy	0.031	0.036	0.033	R0.035	0.035
Total Renewable Energy	**R6.426**	**R6.309**	**R6.763**	**R7.315**	**7.086**

[a]Hydroelectricity generated by pumped storage is not included in renewable energy.
[b]Includes grid-connected electricity, geothermal heat pump and direct use energy.
[c]Includes wood, wood waste, peat, wood sludge, municipal solid waste, agricultural waste, straw, tires, landfill gases, fish oils, and/or other waste.
[d]Includes solar thermal and photovoltaic.
R = Revised data.
Notes: See Appendix B, "Renewable Data Limitations," for a detailed explanation of data issues. Totals may not equal sum of components due to independent rounding.
Sources: **1993-1995:** Energy Information Administration (EIA), *Annual Energy Review 1997*, DOE/EIA-0384(97) (Washington, DC, July 1998), Table 1.3. **1996 and 1997:** Consumption values based on the sum of electricity consumption from EIA, *Electric Power Annual 1997, Volume II*, DOE/EIA-0348(97)/2 (Washington, DC, October 1998), and non-electricity consumption based on analysis by the Office of Coal, Nuclear, Electric and Alternate Fuels.

crystalline silicon PVs increased from 12 peak megawatts in 1996 to 14 peak megawatts in 1997. Overall, crystalline silicon PVs accounted for 96 percent of shipments in 1997.

- PV shipments to the commercial sector experienced the greatest rate of growth from 1996 to 1997, rising 57 percent. The industrial and residential sectors showed growth rates of 42 percent and 30 percent respectively. Utility sector shipments grew 19 percent.

- The use of PVs in grid-interactive electricity generation increased over 70 percent, while sales for remote electricity applications decreased 21 percent. Shipments to Original Equipment Manufacturers (OEMs) increased 118 percent. OEMs integrate PVs into devices that are used in the areas of telemetry, instrument controls and monitoring, remote quality testing, and measurement of flows and pressures. PVs represent a value added electricity source for remote usage of diverse manufactured goods.

- Ninety-three percent of shipments of solar thermal collectors were low temperature types in 1997 as compared to 90 percent in 1996. Ninety-one percent were used in the residential sector in 1997, and 93 percent were installed as pool heaters.

Industry Developments

The Department of Energy launched the Million Solar Roofs Program in mid-1997. The initiative contains four core components that use existing funding and legislative authorities. These components include: "aggressive" federal procurement in cost-effective applications; enhancement of access to and blending of several existing federal loan programs with long-term amortization; use of five existing technology grant programs for "buy down"; and the establishment of an interagency team to ensure results and coordinate maximum efficiency. By 2010, these systems are expected to be self- sustaining.

Siemens Solar Industries announced delivery of a record-efficient, 1-kilowatt (peak) thin-film photovoltaic array to the National Renewable Energy Laboratory (NREL). The 28-module array has an average module power of 39 watts peak (Wp) and an efficiency of 9 percent. The modules incorporate Siemens' newest improvement in copper-indium-diselenide-based thin-film technology, which was developed with support from NREL's Thin -Film PV Partnership Program. The best module of the array produced 40.6 Wp for a record efficiency of 11.1 percent.

The Sacramento Municipal Utility District's (SMUD) board of directors approved a 10-megawatt (peak) photovoltaic program for 1998-2002. The $22 million in contracts approved were expected to create major PV module and inverter factories in 1998. Projects included building-integrated PVs in Grass Valley, a $19.3-million supply contract with Energy Photovoltaics, and the purchase of 8 MWe of power inverters from Trace Engineering.

AstroPower Inc. announced it bested its previous sunlight-to-electricity conversion efficiency record and fabricated a 16.6 percent efficient thin-film silicon solar cell under a collaboration with the NREL. The record was set on a laboratory-scale device measuring 1 square centimeter as part of the Department of Energy's Photovoltaic Manufacturing Technology Initiative. The prior record, set a few years ago, was 14.6 percent.

The Department of Defense stated that it offers the potential of nearly 20,000 photovoltaic applications in 33 categories, according to an analysis prepared by the Photovoltaic Review Committee. Applications include a building guard station, remote building operations, cathodic protection, communications equipment, lights, meteorological stations, navigational assistance, housing, instrumentation, observation tower, radar equipment, security, transportable power and water pumping.

Geothermal Heat Pump Manufacturing Activities

For the first time in this report the Energy Information Administration (EIA) is presenting the results of its "Annual Geothermal Heat Pump Manufacturers Survey." This survey was completed by approximately 18 known manufacturers of geothermal heat pumps. Results indicated that for 1994 through 1997, a cumulative total of 209,000 units were shipped.

1. Renewable Data Overview

1997 In Review[1]

Total Consumption

Renewable energy consumption declined 3 percent to 7.086 quadrillion British Thermal Units (Btu) between 1996 and 1997, as hydropower imports decreased and exports increased from 1996 (Table 1). Excluding net imports, renewable energy consumption declined about 1.5 percent. Hydropower contributed 55 percent of renewable energy consumption in 1997 (Figure 1).[2] Since 1993, renewable energy consumption has grown at a 2.5-percent annualized rate, compared with 1.9 percent for total U.S. energy consumption.

Table 1. U.S. Energy Consumption by Energy Source, 1993-1997
(Quadrillion Btu)

Energy Source	1993	1994	1995	1996	1997
Fossil Fuels					
Coal	R19.837	R20.027	R20.090	R21.011	21.439
Coking Coal (Net Imports)	0.017	0.024	0.026	*	0.018
Natural Gas[a]	20.827	21.288	22.163	R22.560	22.588
Petroleum[b]	33.841	34.735	34.663	R35.864	36.314
Total Fossil Fuels	**R74.522**	**R76.073**	**R76.943**	**R79.434**	**80.360**
Nuclear Electric Power	**6.519**	**6.837**	**7.177**	**R7.168**	**6.686**
Hydroelectric Pumped Storage[c]	**R-0.042**	**-0.035**	**-0.028**	**R-0.032**	**-0.042**
Renewable Energy					
Conventional Hydroelectric Power[d]	R3.147	R2.969	R3.472	R3.914	3.932
Geothermal Energy[e]	R0.393	R0.395	R0.339	R0.352	0.322
Biomass[f]	2.784	2.838	2.846	R2.938	2.723
Solar Energy[g]	0.071	0.072	0.073	0.075	0.074
Wind Energy	0.031	0.036	0.033	R0.035	0.035
Total Renewable Energy	**R6.426**	**R6.309**	**R6.763**	**R7.315**	**7.086**
Total Energy Consumption	**R87.368**	**R89.250**	**R90.864**	**R93.871**	**94.151**

[a]Includes supplemental gaseous fuels.
[b]Petroleum products supplied, including natural gas plant liquids and crude oil burned as fuel.
[c]Represents total pumped-storage facility production minus energy used for pumping.
[d]Hydroelectricity generated by pumped storage is not included in renewable energy.
[e]Includes grid-connected electricity, geothermal heat pump and direct use energy.
[f]Includes wood, wood waste, peat, wood sludge, municipal solid waste, agricultural waste, straw, tires, landfill gases, fish oils, and/or other waste.
[g]Includes solar thermal and photovoltaic.
R = Revised data.
* = value less than 0.0005 quadrillion Btu.

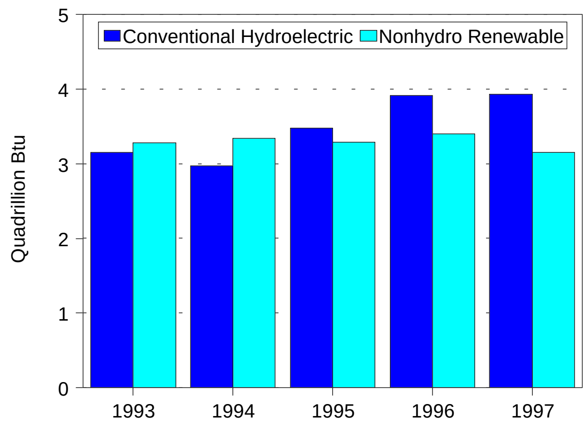
Notes: See Appendix B, “Renewable Data Limitations,” for a detailed explanation. Totals may not equal sum of components due to independent rounding.

Sources: **1993-1997:** Energy Information Administration (EIA), *Annual Energy Review 1997*, DOE/EIA-0384(97) (Washington, DC, July 1998), Table 1.3. **1996 and 1997 Renewable Energy:** Consumption values based on the sum of electricity consumption from EIA, *Electric Power Annual 1997, Volume II*, DOE/EIA-0348(97)/2 (Washington, DC, October 1998), and non-electricity consumption based on analysis by the Office of Coal, Nuclear, Electric and Alternate Fuels.

1 Calculated statistics in this chapter are based on unrounded data. In contrast, data presented in tables may be rounded.

2 All renewable consumption and production information shown in this chapter was derived from the Integrated Renewable Energy Database System (IREDS). The data values in IREDS are more precise than those shown in the tables of this report.

Figure 1. Renewable Energy Consumption by Source, 1993-1997



Sources: **1993-1995:** Energy Information Administration (EIA), *Annual Energy Review 1997*, DOE/EIA-0384(97) (Washington, DC, July 1998), Table 1.3. **1996 and 1997:** Consumption values based on the sum of electricity consumption from EIA, *Electric Power Annual 1997, Volume II*, DOE/EIA-00348(97)/2 (Washington, DC, October 1998), and non-electricity consumption based on analysis by the Office of Coal, Nuclear, Electric and Alternate Fuels.

Biomass energy consumption, which accounted for 38 percent of total renewable energy consumption, declined 7 percent from 1996. Geothermal, solar, and wind energy, which combined provided 6 percent of total renewable energy in 1997, declined 7 percent.

The renewable share of total energy consumption declined slightly from 7.8 percent in 1996 to 7.5 percent in 1997. Regarding total energy consumption, about one-half of the increase in fossil fuel energy consumption was offset by a decline in nuclear electricity generation.

Sectoral Consumption

Renewable energy consumption increased only in the transportation sector between 1996 and 1997, rising from 0.074 quadrillion Btu to 0.097 quadrillion Btu (Table 2). The energy represented here is ethanol blended into gasoline as an oxygenate in low percentage blends (under 10 percent).

Residential sector consumption declined nearly 25 percent. This was largely due to a drop in biomass energy consumption, attributed to higher-than-expected winter temperatures lowering heating demand. Residential energy consumption now includes energy consumption from geothermal (ground water) heat pumps, which amounted to 0.0075 quadrillion Btu in 1997.

Industrial sector renewable energy consumption declined 3 percent in 1997 to 2.555 quadrillion Btu. Most of the decrease was in industrial biomass consumption, which decreased nearly .070 quadrillion Btu. Also, an 11-percent decline in industrial geothermal consumption more than offset an increase in consumption for conventional hydropower.

Electric utility sector renewable energy consumption remained virtually unchanged in 1997 at 3.881 quadrillion Btu. This sector consumed 55 percent of renewable energy consumption in 1997 and includes net renewable imports.

Of the 2.207 quadrillion Btu of renewable energy not used to generate electricity, 70 percent was in the industrial sector, where considerable biomass-based process heat is used in areas such as the forest products industry (especially for paper and pulp operations). Industrial biomass process heat applications alone consumed 1.554 quadrillion Btu, 70 percent of total nonelectric renewable energy consumption. Another 25 percent is consumed in the residential sector for heating and cooling.

Electricity Generation

Energy used to generate 457 billion kilowatthours (kWh) of renewable-based, domestically-consumed electricity amounted to 4.879 quadrillion Btu (Tables 3 and 4). Domestically consumed and produced renewable generation[3] in 1997 was nearly 2 percent above 1996 levels.

Total hydropower generation rose 11.6 billion kWh in 1997, due principally to a 10.3-billion kWh increase in utility generation. On a percentage basis, nonutility (industrial[4]) hydropower rose a substantial 8 percent. These gains were due principally to greater water availability in the Northwest.

[3] "Domestic generation" equals total renewable electricity generation less net electricity imports.

[4] Although the category "industrial " is used, there are actually two subcategories, not easily distinguishable. A pure industrial facility may loosely be described as one designed principally to provide energy for a manufacturing or other product-making use, while a nonutility is a special category of facility which is usually designed to generate electric power and connect to the grid. Nonutilities are often those designated by the Federal Energy Regulatory Commission as "qualifying facilities," so-called because they meet certain criteria set forth by PURPA. However, a "pure industrial" facility may sell power to the grid, and a nonutility can generate energy for the entity's own use.

Table 2. Renewable Energy Consumption by Sector and Energy Source, 1993-1997
(Quadrillion Btu)

Sector and Source	1993	1994	1995	1996	1997
Residential/Commercial					
Biomass	0.592	0.582	0.641	R0.644	0.475
Solar	0.062	0.064	0.065	R0.066	0.065
Geothermal[a]	0.010	0.010	0.011	R0.012	0.013
Total	**R0.664**	**R0.656**	**R0.717**	**R0.722**	**0.553**
Industrial[b]					
Biomass	2.084	2.138	R2.084	R2.200	2.132
Geothermal[a]	R0.206	R0.214	R0.210	R0.217	0.194
Conventional Hydroelectric[c]	R0.119	0.136	0.152	R0.171	0.185
Solar	0.009	0.008	0.008	R0.009	0.009
Wind	0.031	0.036	0.033	R0.035	0.035
Total	**R2.449**	**R2.533**	**R2.487**	**R2.633**	**2.555**
Transportation					
Biomass[d]	**0.088**	**0.097**	**0.104**	**R0.074**	**0.097**
Electric Utility					
Biomass	0.020	0.020	0.017	R0.020	0.019
Geothermal[a]	0.158	0.145	0.099	R0.110	0.115
Conventional Hydroelectric[c]	R2.774	R2.547	R3.054	R3.422	3.528
Solar and Wind	*	*	*	*	*
Net Renewable Energy Imports[e]	R0.272	R0.310	0.284	R0.334	0.219
Total	**R3.225**	**R3.023**	**R3.454**	**R3.886**	**3.881**
Total Renewable Energy Consumption	**R6.426**	**R6.309**	**R6.763**	**R7.315**	**7.086**

[a]Includes geothermal heat pump and direct use energy. The Industrial and Electric Utility sectors also include grid connected electricity.
[b]Includes generation of electricity by cogenerators, independent power producers, and small power producers.
[c]Hydroelectricity generated by pumped storage is not included in renewable energy.
[d]Ethanol blended into gasoline.
[e]Includes only net imports of electricity known to be from renewable resources (geothermal and hydroelectric).
R= Revised data.
*Less than 0.0005 quadrillion Btu.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **1993-1995:** Energy Information Administration (EIA), *Annual Energy Review 1997*, DOE/EIA-0384(97) (Washington, DC, July 1998), Table 10.2. **1996 and 1997:** Electricity Consumption—EIA, *Electric Power Annual 1997, Volume II,* DOE/EIA-0348(97)/2 (Washington, DC, October 1998). Non-electricity Consumption (except imports)—Based on analysis by the Office of Coal, Nuclear, Electric and Alternate Fuels. **Net Renewable Energy Imports, 1993-1997:** Based on analysis by the Office of Coal, Nuclear, Electric and Alternate Fuels.

Electricity generation from all other renewable sources fell; after rising in 1996, total geothermal generation dropped to 14.6 billion in 1997, a decline of 6 percent. Nonutility geothermal generation decreased 10 percent, while utility generation[5] managed a small gain. Generation from biomass declined to 58 billion kWh, largely due to a 4-percent drop in nonutility generation. Solar generation declined about 1 percent in 1997, despite the fact that utility solar generation increased 9.8 percent. Wind-based electricity showed virtually no change. Nonutilities produce virtually all of the solar and wind electricity. (See Appendix B, "Data Description and Limitations," for an explanation of potential estimation errors in nonutility data.) Because information which EIA collects from non-utilities on the Form EIA-867, "Annual Nonutility Power Producer Report," is confidential, it is not possible to make any statements about individual plant operations.

[5] Utility geothermal generation is principally from a single geothermal field in California known as "The Geysers."

Table 3. Renewable Energy Consumption for Electricity Generation by Energy Source, 1993-1997
(Quadrillion Btu)

Source	1993	1994	1995	1996	1997
Industrial Sector[a]					
Biomass	R0.575	R0.592	R0.593	R0.599	0.578
Geothermal	0.204	0.212	0.207	R0.214	0.191
Hydroelectric	R0.119	0.136	0.152	R0.171	0.185
Solar	0.009	0.008	0.008	0.009	0.009
Wind	0.031	0.036	0.033	R0.035	0.035
Total	**R0.938**	**R0.984**	**R0.993**	**R1.028**	**0.998**
Electric Utility Sector[b]					
Biomass	0.020	0.020	0.017	0.020	0.019
Geothermal	0.158	0.145	0.099	0.110	0.115
Conventional Hydroelectric	R2.774	R2.547	R3.054	R3.422	3.528
Solar and Wind	*	*	*	*	*
Total	**R2.953**	**R2.713**	**R3.170**	**R3.552**	**3.662**
Imports and Exports					
Geothermal (Imports)	0.018	0.025	0.019	0.014	*
Conventional Hydroelectric (Imports)	0.294	R0.314	0.297	R0.345	0.289
Conventional Hydroelectric (Exports)	R0.041	0.029	0.032	0.024	0.070
Total Net Renewable Energy Imports	**R0.272**	**R0.310**	**0.284**	**R0.334**	**0.219**
Total	**R4.163**	**R4.007**	**R4.448**	**R4.915**	**4.879**

[a]Includes generation of electricity by cogenerators, independent power producers, and small power producers.
[b]Excludes imports.
R = Revised data.
*Less than 0.5 trillion Btu.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Energy Information Administration, Form EIA-759, "Monthly Power Plant Report," and Form EIA-867, "Annual Nonutility Power Producer Report," personal communication with Dave Walker of Natural Resources Canada (Ottawa, Canada, March 1998). Federal Energy Regulatory Commission, Form FE-781R, "Annual Report of International Electricity Export/Import Data."

Electricity imports decreased 16 percent to 28 billion kWh in 1997. With U.S. electricity exports nearly tripling to 6.8 billion kWh, net electricity imports dropped by one-third to 21 billion kWh in 1997. This was the principal reason that total renewable electricity generation dropped 0.4 percent, compared with the 2-percent gain in electricity generated and consumed domestically. Total renewable energy consumption in 1997 for electricity generation (including net imports) was 4.879 quadrillion Btu. The 436 billion kWh of renewable electricity generation domestically produced and consumed was about 12 percent of the U.S. total.[6]

In the utility sector, there are 6 or fewer plants in each of the categories. In the case of wind, the Solano plant operated by Sacramento Municipal Utility District (SMUD) generates about 99 percent of total utility wind generation. For solar, there were 4 plants that generated electricity in 1997. One plant, Solar 2, operated by Sacramento Municipal Utility District (SMUD), increased output by two-thirds in 1997, providing about 56 percent of utility solar generation. As a result, utility sector solar generation rose, despite the fact that output from two of the three other solar/PV generating plants decreased.

Resource accessibility largely determines where renewable electricity is generated. Access to water power makes Washington the leading producer of renewable energy, accounting for 24 percent of total renewable electricity produced in 1997 (Tables 5 and 6).

A second major factor influencing the use of renewables is State policies promoting renewable energy. The combined effect of resource availability and energy policy makes California the second-largest producer of renewable electricity generation. In 1997, 13 percent of utility renewable generation nationwide occurred in California.

[6] EIA estimates total electricity generation in 1997 to be 3,494 billion kilowatthours. See Energy Information Administration, *Electric Power Annual 1997, Vol*ume II, DOE/EIA-0348(97)/2 (Washington, DC, October 1998).

Table 4. Electricity Generation From Renewable Energy by Energy Source, 1993-1997
(Thousand Kilowatthours)

Source	1993	1994	1995	1996	1997
Industrial Sector (Gross Generation)[a]					
Biomass	R55,745,781	57,391,594	R57,513,666	R57,937,058	55,886,586
Geothermal	9,748,634	10,122,228	9,911,659	R10,197,514	9,110,297
Hydroelectric	11,510,786	13,226,934	14,773,801	R16,555,389	17,904,653
Solar	896,796	823,973	824,193	R902,830	892,892
Wind	3,052,416	3,481,616	3,185,006	R3,399,642	3,384,576
Total	**R80,954,413**	**85,046,345**	**R86,208,325**	**R88,992,433**	**87,179,004**
Electric Utility Sector (Net Generation)[b]					
Biomass	R1,986,535	R1,985,463	R1,647,247	R1,912,472	1,861,532
Geothermal	7,570,999	6,940,637	4,744,804	5,233,927	5,469,110
Conventional Hydroelectric	269,098,329	247,070,938	296,377,840	R331,058,055	341,273,443
Solar	3,802	3,472	3,909	3,169	3,481
Wind	243	309	11,097	10,123	5,977
Total	**R278,659,908**	**R256,000,819**	**R302,784,897**	**R338,217,746**	**348,613,543**
Imports and Exports					
Geothermal (Imports)	877,058	1,172,117	884,950	649,514	10,313
Conventional Hydroelectric (Imports)	28,558,134	30,478,863	28,823,244	33,359,983	27,990,905
Conventional Hydroelectric (Exports)	3,938,973	2,806,712	3,059,261	2,336,340	6,790,778
Total Net Imports	**25,496,219**	**28,844,268**	**26,648,933**	**31,673,157**	**21,210,440**
Total Renewable Electricity Generation	**R385,110,540**	**R369,891,432**	**R415,642,155**	**R458,883,336**	**457,002,987**

[a]Includes generation of electricity by cogenerators, independent power producers, and small power producers.
[b]Excludes imports.
R = Revised data.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Energy Information Administration, Form EIA-759, "Monthly Power Plant Report"; Form EIA-867, "Annual Nonutility Power Producer Report"; and *Electric Power Annual 1997, Volume II*, DOE/EIA-0348(97)/2 (Washington, DC, October 1998). Personal communication with Dave Walker of Natural Resources Canada (Ottawa, Canada, March 1998). U.S. Department of Energy, Office of Fossil Energy, Form FE-781R, "Annual Report of International Electricity Export/Import Data."

California's share of nonutility renewable electricity was even larger at 22 percent (Table 6). California promoted renewable energy strongly in the 1980's with renewable tax credits and other measures. In addition, California has the vast majority of the Nation's developed geothermal energy resources, as well as significant wind, solar, biomass (wood and waste), and hydroelectric resources.

Utilities in Oregon, which has sizable water power resources, produced the third-largest amount of electricity from renewables. New York contributed 8 percent, virtually all from water power. No other State contributed more than about 4 percent of total U.S. utility renewable generation.

Nonutility renewable generation outside California is more evenly spread. One reason is that nonutility plants are usually smaller than utility plants, having been built in many instances to service a single facility (e.g., pulp and paper manufacturing plant). Thus, many more resource locations are available, particularly for biomass and hydropower. After California, the States with the most nonutility electricity generation in 1997 were Florida, Maine, Louisiana, New York, Alabama, and North Carolina. The nonutility sector produces virtually all of the biomass-, wind-, and solar-powered electricity generation. Florida leads the Nation in nonutility biomass-generated power.

Renewable Generating Capacity

By the end of 1997, renewable generating capacity increased 3.7 percent to 95.3 gigawatts (Table 7). Hydroelectric capacity had the largest increase (3.4 gigawatts) between 1996 and 1997. Renewable capacity at the end of 1997 was nearly 3 percent greater than it was at the end of 1993, when it stood at 92.6 gigawatts.

Table 5. Renewable Electric Utility Net Generation, 1997
(Thousand Kilowatthours)

	Hydro-electric	Geothermal	Solar/ PV	Wind	MSW Landfill Gas	Wood and Wood Waste	Other Waste[a]	Total	Percent
Alabama	11,520,637	--	--	--	--	--	--	11,520,637	3.3
Alaska	1,098,953	--	--	--	--	--	--	1,098,953	0.3
Arizona	12,049,393	--	--	--	--	--	--	12,049,393	3.5
Arkansas	3,511,260	--	--	--	--	--	--	3,511,260	1.0
California	38,783,138	5,300,592	3,269	5,859	--	--	--	44,092,858	12.6
Colorado	1,897,813	--	--	--	--	--	--	1,897,813	0.5
Connecticut	374,110	--	--	--	450,749	--	--	824,859	0.2
Delaware	--	--	--	--	--	--	--	--	--
Dist. of Col.	--	--	--	--	--	--	--	--	--
Florida	241,280	--	--	--	--	--	--	241,280	0.1
Georgia	4,228,269	--	--	--	--	--	--	4,228,269	1.2
Hawaii	18,791	--	--	--	--	--	--	18,791	--
Idaho	13,511,728	--	--	--	--	--	--	13,511,728	3.9
Illinois	16,773	--	--	--	--	--	23,595	40,368	--
Indiana	561,593	--	--	--	--	--	--	561,593	0.2
Iowa	794,739	--	--	118	22,360	--	--	817,217	0.2
Kansas	--	--	--	--	--	--	--	--	--
Kentucky	3,380,233	--	--	--	--	--	--	3,380,233	1.0
Louisiana	--	--	--	--	--	--	--	--	--
Maine	1,779,887	--	--	--	--	--	--	1,779,887	0.5
Maryland	1,588,375	--	--	--	--	--	--	1,588,375	0.5
Massachusetts	788,540	--	--	--	--	--	--	788,540	0.2
Michigan	1,592,707	--	--	--	--	--	--	1,592,707	0.5
Minnesota	697,224	--	--	--	425,416	3,917	--	1,126,557	0.3
Mississippi	--	--	--	--	--	--	--	--	--
Missouri	1,593,309	--	--	--	41,704	--	--	1,635,013	0.5
Montana	13,348,499	--	--	--	--	--	--	13,348,499	3.8
Nebraska	1,672,419	--	--	--	--	--	624	1,673,043	0.5
Nevada	2,567,451	--	--	--	--	--	--	2,567,451	0.7
New Hampshire	1,165,007	--	--	--	--	--	--	1,165,007	0.3
New Jersey	--	--	--	--	--	--	--	--	--
New Mexico	258,810	--	--	--	--	--	--	258,810	0.1
New York	29,004,673	--	--	--	--	17,793	--	29,022,466	8.3
North Carolina	3,894,248	--	--	--	--	--	--	3,894,248	1.1
North Dakota	3,319,577	--	--	--	--	--	--	3,319,577	1.0
Ohio	507,368	--	--	--	--	--	--	507,368	0.1
Oklahoma	2,921,206	--	--	--	--	--	--	2,921,206	0.8
Oregon	46,283,275	--	--	--	--	--	--	46,283,275	13.3
Pennsylvania	1,778,998	--	--	--	--	--	--	1,778,998	0.5
Rhode Island	--	--	--	--	--	--	--	--	--
South Carolina	2,901,794	--	--	--	--	--	--	2,901,794	0.8
South Dakota	9,012,260	--	--	--	--	--	--	9,012,260	2.6
Tennessee	10,073,313	--	--	--	--	--	--	10,073,313	2.9
Texas	1,784,629	--	212	--	--	--	--	1,784,841	0.5
Utah	1,330,578	168,518	--	--	--	--	--	1,499,096	0.4
Vermont	896,312	--	--	--	--	150,345	--	1,046,657	0.3
Virginia	939,569	--	--	--	--	--	--	939,569	0.3
Washington	103,644,592	--	--	--	--	353,256	--	103,997,848	29.8
West Virginia	377,192	--	--	--	--	--	--	377,192	0.1
Wisconsin	2,182,208	--	--	--	12,085	213,980	145,708	2,553,981	0.7
Wyoming	1,380,713	--	--	--	--	--	--	1,380,713	0.4
Total	**341,273,443**	**5,469,110**	**3,481**	**5,977**	**952,314**	**739,291**	**169,927**	**348,613,543**	

[a]Agricultural waste, straw, tires, fish oils, paper pellets, tall oil, sludge waste, and waste alcohol.
--=Not applicable.
Note: Totals may not equal sum of components due to independent rounding.
Sources: Energy Information Administration, Form EIA-759, "Monthly Power Plant Report," and Form EIA-860, "Annual Electric Generator Report."

Table 6. Nonutility Gross Generation From Renewables, 1997
(Thousand Kilowatthours)

	Hydro-electric	Geothermal	Solar/PV	Wind	MSW Landfill Gas	Wood and Wood Waste	Other Waste[a]	Total	Percent
Alabama	W	--	--	--	--	3,564,202	W	3,818,463	4.4
Alaska	--	--	--	--	--	W	W	W	W
Arizona	--	--	--	--	--	W	--	W	W
Arkansas	W	--	--	--	--	1,457,855	W	1,468,800	1.7
California	W	W	892,892	3,232,012	1,727,305	3,156,740	378,624	19,309,009	22.1
Colorado	W	--	--	--	--	--	W	139,426	0.2
Connecticut	W	--	--	--	1,500,512	--	W	1,795,765	2.1
Delaware	--	--	--	--	--	--	--	--	--
Dist. of Col.	--	--	--	--	--	--	--	--	--
Florida	W	--	--	--	W	2,610,377	536,163	6,471,579	7.4
Georgia	W	--	--	--	W	2,886,172	29,999	2,981,383	3.4
Hawaii	97,515	W	--	W	W	W	232,692	990,407	1.1
Idaho	1,038,127	--	--	--	--	W	W	1,520,715	1.7
Illinois	87,607	--	--	--	273,156	W	W	1,121,083	1.3
Indiana	--	--	--	--	127,003	--	--	127,003	0.1
Iowa	W	--	--	--	W	W	W	80,282	0.1
Kansas	W	--	--	--	--	--	--	W	W
Kentucky	--	--	--	--	--	W	--	W	W
Louisiana	W	--	--	--	--	W	108,238	4,492,512	5.2
Maine	W	--	--	--	W	2,970,602	239,175	5,415,000	6.2
Maryland	--	--	--	--	617,659	W	W	776,747	0.9
Massachusetts . .	347,722	--	--	--	2,066,741	W	W	2,570,988	2.9
Michigan	W	--	--	--	919,499	1,649,094	W	2,739,027	3.1
Minnesota	339,431	--	--	W	321,607	428,270	W	1,152,506	1.3
Mississippi	--	--	--	--	--	W	W	1,788,550	2.1
Missouri	--	--	--	--	--	--	W	W	W
Montana	W	--	--	--	--	W	--	W	W
Nebraska	--	--	--	--	--	--	--	--	--
Nevada	W	W	--	--	--	--	--	1,595,259	1.8
New Hampshire	W	--	--	--	196,141	831,584	W	1,498,464	1.7
New Jersey	W	--	--	--	1,217,197	--	W	1,262,662	1.4
New Mexico	--	--	--	--	--	--	--	--	--
New York	W	--	--	--	1,453,770	641,913	W	4,218,710	4.8
North Carolina . .	1,784,824	--	--	--	W	1,675,805	W	3,542,552	4.1
North Dakota . . .	--	--	--	--	--	--	W	W	W
Ohio	--	--	--	--	--	622,140	--	622,140	0.7
Oklahoma	--	--	--	--	--	W	--	W	W
Oregon	W	--	--	--	W	517,790	--	1,041,512	1.2
Pennsylvania . . .	W	--	--	--	1,872,143	574,332	W	2,936,356	3.4
Rhode Island . . .	W	--	--	--	W	--	--	W	W
South Carolina . .	56,929	--	--	--	W	1,615,098	W	1,742,140	2.0
South Dakota . . .	--	--	--	--	--	--	--	--	--
Tennessee	W	--	--	--	W	435,826	W	1,472,973	1.7
Texas	W	--	--	W	W	837,247	35,186	1,616,783	1.9
Utah	W	--	--	--	--	--	--	W	W
Vermont	W	--	--	--	--	W	--	383,983	0.4
Virginia	W	--	--	--	1,074,411	1,563,708	W	2,771,992	3.2
Washington	549,491	--	--	--	W	429,138	W	1,187,590	1.4
West Virginia . . .	W	--	--	--	--	--	--	W	W
Wisconsin	W	--	--	--	156,854	628,200	W	1,109,544	1.3
Wyoming	--	--	--	--	--	--	--	--	--
Total	**17,904,653**	**9,110,297**	**892,892**	**3,384,576**	**17,444,030**	**35,217,908**	**3,224,648**	**87,179,004**	

[a]Agricultural waste, straw, tires, fish oils, paper pellets, tall oil, sludge waste, and waste alcohol.
--=Not applicable.
W = Data withheld to avoid disclosure of proprietary company data.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form EIA-867, "Annual Nonutility Power Producer Report."

Table 7. U.S. Electric Generating Capacity, 1993-1997
(Megawatts)

Source	1993	1994	1995	1996	1997
Hydroelectric[a]	R77,405	R78,042	78,563	R76,437	79,795
Geothermal	2,978	3,006	2,968	R2,893	2,854
Biomass	10,045	10,465	R10,263	R10,531	10,702
Solar/Photovoltaic	340	333	333	333	334
Wind	1,813	1,745	[b]1,731	R1,677	1,620
Total Renewables	**R92,582**	**R93,591**	**R93,857**	**R91,868**	**95,303**
Nonrenewables[c]	R662,373	R670,423	R675,660	R684,004	683,210
Total	**R754,955**	**R764,014**	**R769,517**	**R775,872**	**R778,513**

[a]Excludes pumped storage, which is included in "Nonrenewables."
[b]Excludes 6.6 megawatts of utility capacity and 35 megawatts of nonutility capacity that were not captured by EIA sources.
[c]Includes hydrogen, sulfur, batteries, chemicals, spent sulfite liquor, and hydroelectric pumped storage.
R = Revised data.
Note: Capacity ratings for nonrenewables have been revised to reflect estimated net summer capability rather than nameplate capacity. The methodology for estimating net summer capability from reported nameplate capacity is presented in Energy Information Administration, *Inventory of Power Plants in the United States as of January 1, 1997*, DOE/EIA-0095(97), p. 286.
Sources: Energy Information Administration, Form EIA-860, "Annual Electric Generator Report," and Form EIA-867, "Annual Nonutility Power Producer Report."

Biomass Energy

U.S. biomass energy consumption declined sharply between 1996 and 1997, reflecting generally lower energy demand due to milder temperatures during the heating season. The industrial and residential sectors continued to represent the primary sectors of consumption (Table 8). However, a significant decline occurred in residential sector activity, based on new EIA survey information.[7] A more moderate decrease in energy usage was observed in the industrial sector (Figure 2), where energy intensity is relatively fixed for given industries according to their manufacturing profiles.

Wood, Wood Waste, and Energy Crops

Table 9 lists residential woodburning activity by region in cord[8] and Btu terms. Pellet fuel[9] is consumed mainly in the residential and commercial sectors. The energy represented by pellet fuel consumption is embedded in the residential sector statistics presented here. The comparison of pellet fuel statistics with overall residential sector wood consumption indicates:

- Pellet fuel consumption has grown to the extent that it now comprises about one-fourth of total residential woodburning.
- The regional pattern of pellet fuel sales and residential wood consumption are different (Figure 3 and Table 9).
- Pellet stove sales remained steady during the 1996/1997 and 1997/1998 heating seasons in spite of the overall decline in residential consumption (Figure 4).

Strong pellet sales in the Mountain and Pacific regions reflect the influence of strict environmental regulation. Industry literature indicates that growing sales in the Northeast are to a large extent due to more intensive recent marketing efforts. While the pellet industry is currently established on residential sales, it has stated expansion of sales to industrial customers to be an important industry goal.

Biomass cultivation for all purposes—food, energy, and feedstocks—is closely affected by weather. The 1990's, to date, have seen a number of significant weather events

7 Energy Information Administration, Residential Energy Consumption Survey 1994. Data for non-survey years is estimated by taking into consideration factors such as annual Heating Degree Days and other residential energy consumption characteristics.
8 By U.S. Forest Service convention, 1 cord = 128 cubic feet in volume (4 ft. x 4 ft. x 8ft.). By EIA convention, 1 cord contains the approximate equivalent of 20 million Btu.
9 Wood pellets are manufactured from finely ground wood fiber. They are typically 1/4 inch to 5/16 inch in diameter by about 3/4 inch in length and weigh more than 40 pounds per cubic foot.

Table 8. Biomass Energy Consumption by Sector and Census Region, 1993-1997
(Trillion Btu)

Energy Source	1993	1994	1995	1996	1997
Wood Energy[a]	**2,228**	**2,266**	**R2,250**	**R2,335**	**2,103**
Sector					
Residential	548	537	596	595	433
Commercial	44	45	45	49	42
Industrial	1,625	1,673	R1,598	R1,679	1,617
Electric Utility	11	11	11	12	11
Census Region					
Northeast	277	278	R343	R348	328
Midwest	222	223	R269	R269	226
South	1,405	1,437	R1,024	R1,074	957
West	324	328	R615	R644	592
Waste Energy[b]	**468**	**475**	**492**	**R529**	**523**
Source					
Municipal Solid Waste	390	394	408	R447	449
Combustion	318	323	333	R359	359
Landfill Gas	72	71	75	88	90
Manufacturing	78	81	81	82	74
Census Region					
Northwest	151	171	173	R188	191
Midwest	85	76	88	R80	88
South	130	134	134	R158	151
West	102	95	96	R103	93
Alcohol Fuels (Ethanol)	**88**	**97**	**104**	**74**	**97**
Census Region					
Northwest	*	*	3	R7	9
Midwest	61	68	74	R43	56
South	14	16	10	R8	11
West	11	12	17	R16	21
Biomass Energy Consumption	**2,784**	**2,838**	**R2,846**	**R2,938**	**2,723**

[a]Assuming an average energy yield of 17 million Btu per ton.
[b]Municipal solid waste, manufacturing waste, refuse-derived fuel, and methane recovered from landfills.
* = Less than 0.5 trillion Btu.
Note: The annual season runs from April 1 through March 31.
Source: Energy Information Administration, *Annual Energy Review 1997,* DOE/EIA-0384(97) (Washington, DC, July 1998), Table 10.3.

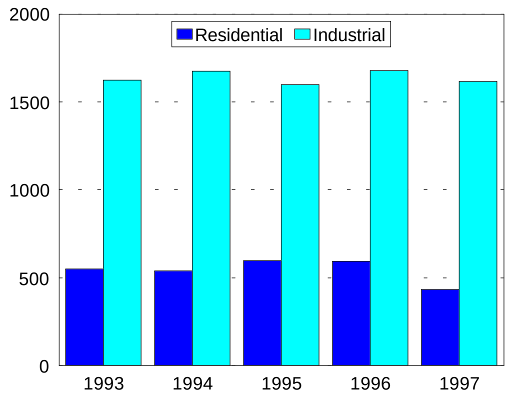
including droughts, floods, damaging winds, and weather-connected phenomena such as forest fires resulting from extended drought. Planting and harvesting have been affected in some regions by drought or flood. Winter storms in the Northeast during the past year resulted in large-scale damage to trees, creating greater than expected supply of wood for energy.

Longer term phenomena come under the heading of climate events. Scientists are intensively studying cyclical climate events such as El Nino and La Nina. The effect of climate events on biomass and the resulting availability of biomass for energy in the United States is mixed. Scientific observation and modeling has only recently begun to estimate the U.S. regional effects of the El Nino/La Nina cycles.

While individual climate events have varying impacts on biomass availability, of greater interest is their collective influence over time. Information from the National Climate Data Center is instructive in this regard. Figure 5 illustrates the change in U.S. winter temperature normals observed during two 30-year periods of time. While this is not the only climate factor modeled, it is one that is significant to an analysis of biomass consumption for energy. The changes in winter temperature also help to explain the greater overall consumption of residential biomass energy in the Northeast and South regions (Table 9).

In the industrial sector, the largest biomass energy producer—the Pulp & Paper Industry—marked the 200th anniversary of the paper machine, but amid a trend of

Figure 2. U.S. Biomass Energy Consumption by Major Sectors, 1993-1997
(Trillion Btu)



Source: Energy Information Administration, *Annual Energy Review 1997*, DOE/EIA-0384(97) (Washington, DC, July 1998), Table 10.3

lower rates of return on investment than other major industries. A pattern of consolidation and divestiture, according to individual corporate strengths and weaknesses, has developed in response, either along the primary resource or end-product specialization lines. Wholesale power marketing and management has also emerged as a very important factor of influence. Major changes in output and product mix have begun to take place in response to strongly increased activity in foreign primary fiber commodity exports to the United States. All these factors in combination are reshaping paper and forest products industries and promise to alter significantly the profile of national industrial biomass energy production.

Wood Chip Photo goes here

Aspen wood chips are being prepared for conversion to ethanol via the simultaneous saccharification and fermentation process.

Municipal Solid Waste

Energy consumption from municipal solid waste (MSW) grew from 390 trillion Btu in 1993 to 449 trillion Btu in 1997 (Table 8). Energy from MSW is obtained by both direct combustion (i.e., waste-to-energy) and from the recovery of landfill gas. Of the 449 trillion Btu of energy consumed from MSW in 1997, 359 trillion Btu were consumed by direct combustion and 90 trillion Btu were provided by landfill gas. Approximately 16 percent of all MSW tonnage generated in the United States is disposed of through direct combustion.[10]

Table 9. Residential Wood Energy Consumption, 1997

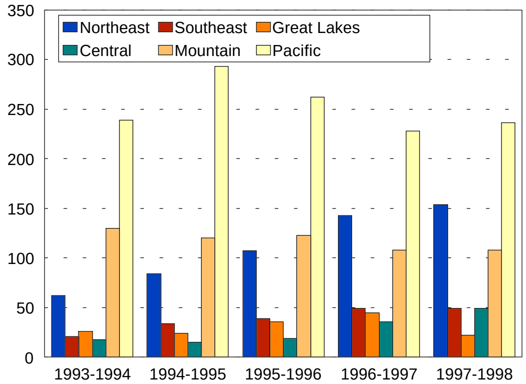
	Unadjusted Estimate		Total Adjusted Estimate[a]	
	Million Cords	Trillion Btu	Million Cords	Trillion Btu
Northeast	6.8	136	7.1	142
Midwest	4.0	80	4.2	84
South	5.2	104	5.5	109
West	4.7	94	4.9	98
Total	**20.6**	**414**	**21.7**	**433**

[a]Allows for wood burning in second homes.

Sources: **Unadjusted estimate:** Based on the Energy Information Administration, *Residential Energy Consumption Survey 1993* and Office of Energy Markets and End Use estimates. **Total adjusted estimates**: Based on the Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels estimates.

[10] Governmental Advisory Associates, Inc., *The Municipal Waste Combustion Industry In The United States—1997-98 Resource Recovery Yearbook and Directory* (Westport, CT, 1997).

Figure 3. Pellet Fuel Sales by Region, 1993-1998
(Thousand tons)



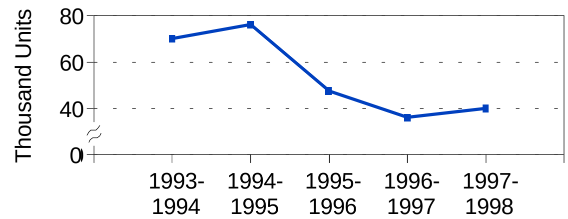
Source: Pellet Fuels Institute, DFI Newsletter, "June 1998 Market Update" (May/June 1998).

During 1997, approximately 107 waste-to-energy (WTE) facilities with a capacity to process over 100,000 tons per day were operating in the United States. About 80 percent of the projects generate electricity as the sole energy product or in conjunction with steam. The other 20 percent produce steam as the sole energy product (EIA does not collect information on steam-only facilities). The projects that generate electricity as the sole energy product or in conjunction with steam through direct combustion of MSW, have a generating capacity of approximately 2,600 megawatts, produced 16 million megawatthours of electricity in 1997, and consumed 280 trillion Btu.

Of the 133 landfill sites that recovered landfill gas in 1997, about 120 produce energy for generating facilities. These facilities have a combined generating capacity of around 832 megawatts. They produced 5 million megawatthours of electricity and consumed 42 trillion Btu of landfill gas. Facilities that burn MSW and landfill gas may also burn fossil fuels for start-up, fuel stabilization, or as a primary fuel.

The production of energy from municipal waste supplies grew very rapidly during the 1980s, largely as a result of public policy at the Federal, State, and local level that promoted the construction of WTE facilities. Virtually all electricity generated by facilities that burn MSW or landfill gas are designated as "qualifying facilities" (QF) by the Public Utility Regulatory Policies Act of 1978 (PURPA). Under PURPA, electric utilities are required to purchase power generated by QFs at the "avoided cost" of the purchasing utility. The average price per kilowatthour received by MSW and landfill gas projects is dropping as contracts are renegotiated, because the

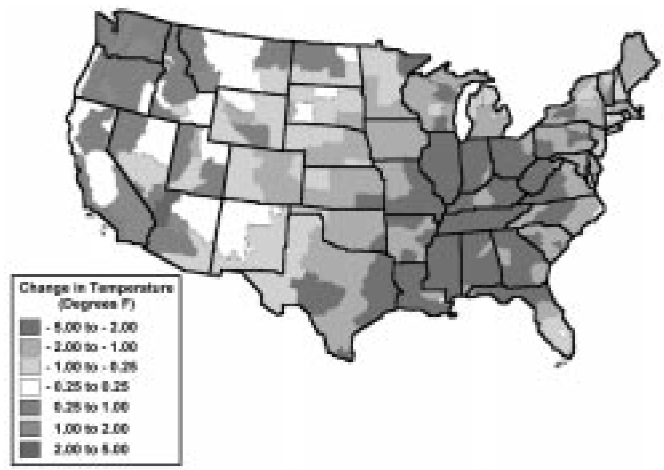
Figure 4. Pellet Fuel Appliance Sales, 1993-1998



Source: Pellet Fuels Institute, PFI Newsletter, "June 1998 Market Update" (May/June 1998).

avoided cost received for electricity from new facilities is now based on competitive fuel prices. As power sales contracts negotiated in the 1980s between QFs and utilities expire, downward pressure on energy revenues will continue. A number of electric deregulation proposals include the elimination of PURPA.

Figure 5. Change in Winter Temperature Normals
(1961-1990 minus 1931-1960)



Source: Personal communication with Richard Heim, National Climate Data Center, National Oceanic and Atmospheric Administration, September 1998.

The growth in MSW projects has been dramatically curtailed during the 1990s, with a number of smaller, inefficient projects being retired. Today, environmental policies are encouraging recycling to reduce the quality and quantity of waste streams to WTE facilities, as well as requiring costly pollution control at these facilities. Federal tax policy no longer favors investments in capital intensive products and limits the amount of municipal bonds States can issue for the construction of facilities that are privately owned. As is the case with many industries in the United States, the waste-to-energy industry is also feeling the competitive pressures of deregulation. Electricity prices are dropping, resulting in waste streams going to the cheapest disposal option, often out-of-State landfills.

Geothermal Energy

Total geothermal energy consumption dropped 9 percent in 1997 to 0.322 quads. Virtually all (97 percent) of geothermal energy was used to generate electricity. Of the remaining 0.016 quads, nearly two-thirds (0.010 quads) drove geothermal or "ground water" heat pumps, with the balance used in low-temperature industrial and agricultural applications such as crop drying.

Over 60 percent of domestic geothermal energy consumption for electricity generation (0.306 quads) is consumed in the industrial sector, principally by "nonutilities." This percentage may rise in the future, as at least one California utility is planning to divest itself of its geothermal electricity plants. Except for a single plant in Nevada and a small amount of production in Hawaii, all domestic geothermal energy is produced in California.

Industrial consumption declined 11 percent in 1997, in contrast to a 5-percent increase in utility geothermal consumption. Industrial geothermal consumption has remained stagnant since 1993, compared with a decline of 27 percent in utility geothermal consumption. Several older geothermal fields in California have been depleted beyond their economically useful life and will likely not resume operation. Imported geothermal electricity from Mexico was virtually zero in 1997, compared with 0.014 quads in 1996. Geothermal electricity generation followed the patterns of energy consumption during 1996 and 1997.

Direct use of geothermal energy is either process heat for industrial applications or energy used to heat and cool water for air temperature moderation applications, using heat pumps. EIA does not collect information on direct geothermal energy but rather uses information provided under contract to the Department of Energy's Office of Energy Efficiency and Renewable Energy by the Oregon Institute of Technology's Geo-Heat Center.[11]

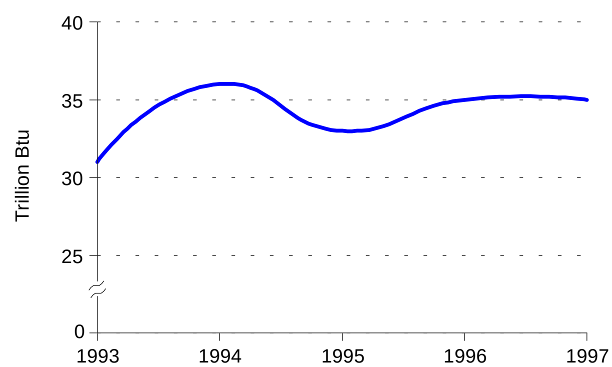
Wind Energy

Between 1993 and 1997, wind electric generating capacity decreased about 193 megawatts to 1,620 megawatts, as retirements exceeded additions. Some additions for 1997 included a few small projects that partially offset the decline:

- Kotzebue, Alaska (0.15 megawatts)
- Pacheco Pass, California (16 megawatts)
- Sibley, Iowa (1.2 megawatts)
- Searsburg, Vermont (6 megawatts).

Although capacity has declined over the past 5 years, improved efficiency has resulted in increased generation from wind—up some 12 percent over the period. Total wind energy consumption was 35 trillion Btu in 1997—an increase of 4 trillion Btu since 1993 (Figure 6).

Figure 6. Wind Energy Consumption, 1993-1997



Sources: Energy Information Administration, Form EIA-759, "Monthly Power Plant Report"; Form EIA-867, "Annual Nonutility Power Producer Report."

Indications are that 1998 will be a very active year for construction. In July 1998, capacity expanded considerably, as the Phase II 107-megawatt Lake Benton, Minnesota project came on line. Other future developments include the following within the next 1 to 2 years:[12]

- California (approximately 281 megawatts to be repowered statewide)
- Buena Vista County, Iowa (112.5 megawatts)
- Clear Lake, Iowa (42 megawatts)
- Storm Lake, Iowa (75 megawatts)

[11] See the website at http://www.oit.edu/admin/geoheat/.
[12] *Windpower Monthly* (June 1998), pp. 31-33.

The 500 kW, 34M diameter Vertical Axis Wind Turbine (VAWT) Test Bed Located at Bushland, Texas.

- Pipestone County, Minnesota (Phase III, 103.5 megawatts)
- Vansycle, Oregon (24.9 megawatts)
- Big Spring, Texas (34.8 megawatts)
- McCamey, Texas (75 megawatts)
- Foot Creek Rim, Wyoming (41.4 megawatts).

Two key factors are driving this flurry of construction activity: (1) State mandates, as in the case of Minnesota and Iowa; and (2) the nationwide rush to beat the expiration of the 1.5 cent-per-kilowatthour production tax credit offered until June 1999, pending passage of legislation for an extension. Among the companies involved in this construction, Zond Systems, Inc. is the most active with commitments of nearly 300 megawatts, using the new Z-750 series of turbines. It is followed by Seawest with about 80 megawatts committed, the FPL Group, and York Corporation.

Solar Energy

Although higher in 1997 than in 1993, solar energy consumption declined 1 percent to 74 trillion Btu between 1996 and 1997. Most of this was in the residential and commercial sector, where some older equipment reached the end of its useful life of 20 years. Most grid-connected solar electricity generation occurs at nonutility facilities, where generation decreased slightly in 1997 to 893 million kilowatthours. Utility solar generation increased over the same period, but at 3.5 million kilowatthours it remains a negligible share of total renewable generation. Ninety-four percent was generated in California (Table 10).

Table 10. U.S. Utility Net Electric Generation from Solar Energy, 1997
(Thousand Kilowatthours)

Utility	Plant (State)	Net Generation
Sacramento Municipal Utility District	Solar (California)	1,947
Sacramento Municipal Utility District	Hedge PV (California)	310
Austin Electric	Decker Creek (Texas)	212
Pacific Gas & Electric	PVUSA 1 (California)	1,012
Total		**3,481**

Note: Net generation is gross generation minus plant use.
Source: Energy Information Administration, *Electric Power Monthly May 1998,* DOE/EIA-0226(98/05) (Washington, DC, May 1998), Table 58.

2. Solar Thermal and Photovoltaic Collector Manufacturing Activities

Introduction

This chapter presents national and State-level data on the United States solar thermal collector and photovoltaic module and cell manufacturing industry. The data are reported to the EIA by U.S.-based manufacturers and importers of solar equipment on Forms EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey," and EIA-63B, "Annual Photovoltaic Module / Cell Manufacturers Survey." Historical data for comparison are presented for annual domestic shipments of solar thermal collectors during 1978 through 1997 and for photovoltaic cells and modules during 1982 through 1997 (Table 11).

Since 1978, domestic manufacturers have shipped 227,177 square feet of solar thermal collectors. The total number of domestic shipments in peak kilowatts of photovoltaic cells and modules since 1982 is 114,858 peak kilowatts. Solar collectors are estimated to have a useful life of 20 years. Throughout the chapter, the unit of measure is square feet of collector surface for solar thermal collectors and peak kilowatts for photovoltaic cells and modules.

Collector Type Descriptions

Solar thermal collectors are divided into the categories of low-, medium-, and high-temperature collectors. Low-temperature collectors provide heat up to 110° Fahrenheit through either metallic or nonmetallic absorbers and are used in applications such as swimming pool heating, and water, space, and process heating. Medium-temperature collectors provide heat greater than 110° Fahrenheit (usually 140 to 180° Fahrenheit) through either glazed flat-plate collectors that use air or liquid as the heat transfer medium or concentrator collectors that concentrate the heat of incident insolation to greater than "one sun"—essentially unobstructed, normal sunlight. Evacuated-tube collectors are included in this category. High-temperature collectors are parabolic dish and trough collectors and are used primarily by utilities and nonutility power producers in the generation of electricity for the grid. A high-temperature solar thermal collector operates at temperatures above 180 degrees Fahrenheit.

Table 11. Annual Photovoltaic and Solar Thermal Shipments, 1978-1997

Year	Domestic Shipments[a]	
	Photovoltaic Cells and Modules (Peak Kilowatts)	Solar Thermal Collectors (Thousand Square Feet)
1978	—	10,020
1979	—	13,396
1980	—	18,283
1981	—	19,362
1982	6,897	18,166
1983	10,717	16,669
1984	7,759	16,843
1985	4,099	[b]19,166
1986	3,224	9,136
1987	3,029	7,087
1988	4,318	8,016
1989	5,462	11,021
1990	6,293	11,164
1991	6,035	6,242
1992	5,760	6,770
1993	6,137	6,557
1994	8,363	7,222
1995	11,188	7,136
1996	13,016	7,162
1997	12,561	7,759
Total	**114,858**	**227,177**

[a]Total shipments minus export shipments.
[b]Estimated data.
— = Not available.
Sources: **1978-1984:** Energy Information Administration, Form EIA-63, "Annual Solar Thermal Collector and Photovoltaic Module Manufacturers Survey." **1985-1997**: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey," and Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Solar Thermal Activities

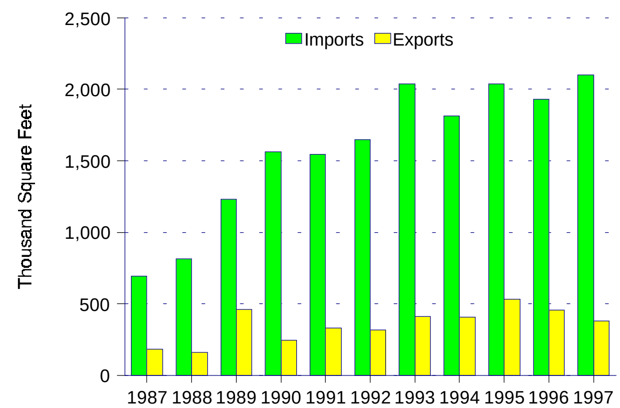
Shipments

Solar thermal collector shipments totaled 8.1 million square feet in 1997, an increase of 7 percent from the 1996 level of 7.6 million square feet (Table 12). Import shipments totaled 2.1 million square feet, while export shipments were 0.4 million square feet in 1997 (Figure 7). Shipments of low-temperature solar thermal collectors increased to 7.5 million square feet in 1997, compared to 6.8 million square feet in 1996 (Table 13). Shipments of medium-temperature collectors decreased 22 percent to 0.61 million square feet in 1997 from 0.79 million square feet in 1996. This is a continuation of a long-term decline in medium-temperature collector production. Shipments of high-temperature collectors decreased to 7,000 square feet in 1997 from 10,000 square feet in 1996.

Origins

U.S. manufacturers in five States—California, New York, New Jersey, Florida, and Hawaii—produced 98 percent of U.S.-manufactured collectors in 1997 (this represents only shipments manufactured in the United States). In 1996, four States—California, Florida, New Jersey, and New York—and Puerto Rico—produced 98 percent (Table 14). California continued to lead the United States with 38 percent of total domestic shipments in 1997, an increase from 33 percent in 1996 (Table 14). New Jersey, Florida, New York, and Hawaii shipped a combined 3.6 million square feet in 1997.

Figure 7. Import and Export Shipments of Solar Thermal Collectors, 1987-1997



Notes: Total shipments as reported by respondents include all domestic and export shipments and may include imports that subsequently were shipped to domestic or foreign customers.

Source: **1987-1997:** Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Destinations

Domestic

Nearly half of solar collector volume shipped went to Florida in both 1996 and 1997. Solar thermal collectors

Table 12. Annual Shipments of Solar Thermal Collectors, 1987-1997

Year	Number of Companies	Collector Shipments (thousand square feet)[a]		
		Total	Imports	Exports
1987	59	7,269	691	182
1988	51	8,174	814	158
1989	44	11,482	1,233	461
1990	51	11,409	1,562	245
1991	48	6,574	1,543	332
1992	45	7,086	1,650	316
1993	41	6,968	2,039	411
1994	41	7,627	1,815	405
1995	36	7,666	2,037	530
1996	28	7,616	1,930	454
1997	29	8,138	2,102	379

[a]Includes imputation of shipment data to account for nonrespondents.

Note: Total shipments as reported by respondents include all domestic and export shipments and may include imported collectors that subsequently were shipped to domestic or foreign customers.

Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table 13. Annual Shipments of Solar Thermal Collectors by Type, 1987-1997
(Thousand Square Feet)

Year	Low-Temperature		Medium-Temperature		High-Temperature Total Shipments[a,b]
	Total Shipments[a]	Average per Manufacturer	Total Shipments[a]	Average per Manufacturer	
1987	3,157	263	957	19	3,155
1988	3,326	416	732	16	4,116
1989	4,283	428	1,989	55	5,209
1990	3,645	304	2,527	62	5,237
1991	5,585	349	989	24	1
1992	6,187	387	897	26	2
1993	6,025	464	931	28	12
1994	6,823	426	803	26	2
1995	6,813	487	840	32	13
1996	6,821	487	785	41	10
1997	7,524	579	606	29	7

[a]Includes imputation of shipment data to account for nonrespondents.
[b]For high-temperature collectors, average annual shipments per manufacturer are not disclosed.
Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table 14. Shipments of Domestic Solar Collectors Ranked by Top Five Origins and Destinations, 1996 and 1997

Origin/Destination	1996 Shipments		1997 Shipments	
	Thousand Square Feet	Percent of U.S. Total	Thousand Square Feet	Percent of U.S. Total
Origin[a]				
California	1,819	33	2,308	38
Florida[b]	683	12	NA	NA
New York[c]	NA	NA	957	16
New Jersey, Florida and Hawaii[c]	NA	NA	2,656	44
New Jersey, New York and Puerto Rico[b]	2,905	53	NA	NA
Top Five Total	**5,406**	**98**	**5,921**	**98**
Destination[d]				
Florida	3,519	49	3,975	49
California	1,472	21	1,781	22
Arizona	421	6	500	6
Hawaii	220	3	204	3
Oregon[c]	NA	NA	145	2
New York[b]	219	3	NA	NA
Top Five Total	**5,850**	**82**	**6,605**	**81**

[a]Represents only shipments manufactured in the United States.
[b]Data for these states are for 1996 only.
[c]Data for these states are for 1997 only.
[d]Based on the total shipped each year to the United States and Territories.
NA = Not available.
Notes: Totals may not equal sum of components due to independent rounding. U.S. total includes territories.
Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

were shipped to 41 States, Puerto Rico, and the U.S. Virgin Islands in 1997 (Table 15). The five States that received the largest amounts of total solar thermal collector shipments in 1997 were: Florida (49 percent), California (22 percent), Arizona (6 percent), Hawaii (3 percent), and Oregon (2 percent) (Table 14). All of the collectors manufactured in Puerto Rico remained on the island. The U.S. market for solar thermal collectors continued to be highly concentrated in a few States and Puerto Rico. Factors favorable for solar energy use in these States and Puerto Rico are: (1) good solar insolation;[13] (2) high electricity costs; (3) solar-promoting incentives, such as tax credits or exemptions; and (4) a demand for low technology solar pool heaters and solar domestic hot water systems.

Export

Exports accounted for 5 percent of total shipments in 1997. A total of 11 companies exported solar thermal collectors in 1997 compared with 19 companies in 1996. Of total 1997 exports, 5 companies exported low-temperature collectors and 10 exported medium-temperature collectors. Regionally, the largest percentage of shipments were to North and South America (40 percent), followed by Europe and the Middle East (37 percent) and Asia (23 percent) (Table 16). Trading countries that received the most export shipments were Canada (22 percent), Taiwan (15 percent), Sweden (12 percent), Germany (8 percent), Korea (7 percent), Austria (6 percent), Guatemala and Belgium (both 4 percent).

Table 15. Shipments of Solar Thermal Collectors by Destination, 1997
(Square Feet)

Destination	1997	Destination	1997
Alabama	2,424	Nebraska	63
Alaska	0	Nevada	120,215
Arizona	499,752	New Hampshire	1,350
Arkansas	2,803	New Jersey	73,829
California	1,781,407	New Mexico	7,020
Colorado	35,645	New York	121,389
Connecticut	54,099	North Carolina	8,194
Delaware	0	North Dakota	0
District of Columbia	0	Ohio	58,136
Florida	3,974,505	Oklahoma	5,863
Georgia	79,601	Oregon	145,117
Hawaii	203,939	Pennsylvania	71,332
Idaho	0	Puerto Rico	70,409
Illinois	84,375	Rhode Island	0
Indiana	0	South Carolina	25,617
Iowa	759	South Dakota	0
Kansas	3,785	Tennessee	10,799
Kentucky	2,953	Texas	64,564
Louisiana	928	Utah	0
Maine	25,356	Vermont	10,584
Maryland	8,780	Virgin Islands (U.S.)	9,970
Massachusetts	28,550	Virginia	29,311
Michigan	34,976	Washington	44,788
Minnesota	35,526	West Virginia	84
Mississippi	1,687	Wisconsin	13,951
Missouri	4,448	Wyoming	66
Montana	0		
Shipments to United States/Territories			**7,758,949**
Exports			**379,401**
Total Shipments			**8,138,350**

Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

[13] Insolation refers to the amount of solar radiation reaching the earth unobstructed.

Table 16. Distribution of U.S. Solar Thermal Collector Exports by Country, 1997

Country	Percent of U.S. Exports
Asia	
Hong Kong	0.9
India	0.1
Japan	0.2
Korea	7.3
Taiwan	14.5
Total	**23.0**
Europe and Middle East	
Austria	6.0
Belgium	4.1
Denmark	1.5
France	0.4
Germany	8.3
Lebanon	1.1
Spain	1.8
Sweden	11.9
Switzerland	1.4
Turkey	0.2
Total	**36.7**
The Americas	
Antigua	0.5
Aruba	0.2
Bahamas	1.1
Belize	0.1
Bermuda	0.1
Bolivia	0.1
Bonaire	0.2
British Virgin Islands	0.4
Canada	21.8
Caribbean	3.4
Chile	1.5
Costa Rica	0.6
Ecuador	0.6
Guatemala	4.0
Honduras	0.7
Jamaica	0.5
Mexico	3.7
St. Martin	0.1
St. Vincent	0.3
Trinidad	0.2
Total	**40.1**
Total	**100.0**

Notes: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturer Survey."

Distribution

Of total shipments in 1997, 55 percent were sent directly to wholesale distributors and 31 percent were sent to retail distributors (Table 17). Direct shipments to exporters, installers, end users, and others accounted for 15 percent of total shipments in 1997.

Table 17. Distribution of Solar Thermal Collector Shipments, 1996 and 1997

Recipient	Shipments (thousand square feet)	
	1996	1997
Wholesale Distributors	4,843	4,446
Retail Distributors	1,655	2,491
Exporters	372	417
Installers	529	585
End Users and Other[a]	217	199
Total	**7,616**	**8,138**

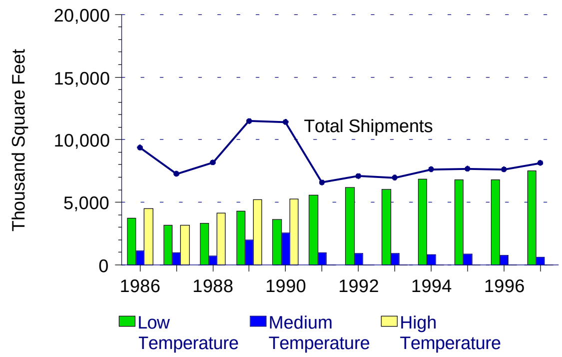
[a]Other includes minimal shipments not explained on Form EIA-63A.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Collector Types

From 1988 through 1997, annual shipments of low-temperature collectors ranged between 3.3 and 7.5 million square feet (Figure 8). In 1997, medium-temperature collector manufacturers shipped just under 0.6 million square feet, a decrease of 23 percent from 1996.

Low-temperature collectors dominated the solar thermal industry in 1997, accounting for 92.5 percent of total shipments (Table 18). Medium-temperature collectors accounted for 7.5 percent of total collector shipments in 1997. About 85 percent of these were flat plate collectors. Those that constituted subunits of thermosiphon systems or integral collector storage systems (ICS) represented 0.4 percent of total shipments. High-temperature collectors, shipped primarily for research and demonstration projects, represented about 0.1 percent of total shipments in 1997.

Figure 8. Solar Thermal Collector Shipments by Collector Type, 1986-1997



Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Values and Prices

The total value of solar thermal collector shipments was $29 million in 1997, a 3-percent decrease compared with 1996. The average price (in dollars per square foot) of low-temperature collectors decreased to $2.60 in 1997 from $2.67 in 1996, while the average price of ICS and thermosiphon collectors increased to $23.28 in 1997 from $21.63 in 1996. This increase was due primarily to increased material costs. The average price (in dollars per square foot) for flat-plate collectors in 1997 increased to $11.30 from the 1996 level of $8.57 (Figure 9). The value of shipments includes charges for advertising and warranties. Excluded are excise taxes and the cost of freight or transportation for the shipments.

Markets

In 1997, the residential sector was the largest market for solar thermal collectors. Solar thermal collectors shipped to the residential sector totaled 7.4 million square feet, 91 percent of total shipments (Table 19). This market sector primarily involves the use of low-temperature solar collectors for heating swimming pools and medium-temperature collectors for water heating in residential buildings. The second-largest market for solar thermal collectors in 1997 was the commercial sector, which accounted for 9 percent of total shipments.

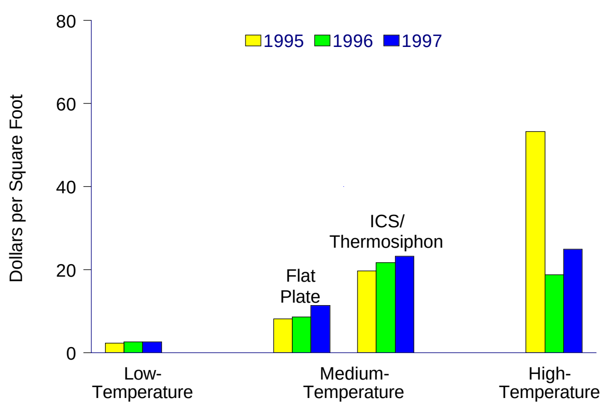
Sterling Engine Solar Dish Panels Demonstration Project Installed at the Pentagon.

Table 18. Solar Thermal Collector Shipments by Type, Quantity, Value, and Average Price, 1996 and 1997

Type	1996 Quantity (thousand square feet)	1996 Value (thousand dollars)	1996 Average Price (dollars per square foot)	1997 Quantity (thousand square feet)	1997 Value (thousand dollars)	1997 Average Price (dollars per square foot)
Low-Temperature						
Liquid and Air	6,821	18,227	2.67	7,524	19,584	2.60
Medium-Temperature						
Air	9	139	15.83	54	2,484	45.75
Liquid						
ICS/Thermosiphon	343	7,424	21.63	33	773	23.28
Flat Plate	431	3,697	8.57	516	5,835	11.30
Evacuated Tube	1	110	75.10	2	99	49.27
Concentrator	0	0	--	0	0	--
All Medium-Temperature	785	11,369	14.48	606	9,191	15.17
High-Temperature						
Parabolic Dish and Trough	10	180	18.75	7	180	25.00
Total	**7,616**	**29,776**	**3.91**	**8,138**	**28,970[a]**	**3.56**

[a]Total includes institutional research projects.
ICS = Integral collector storage.
Notes: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Figure 9. Average Price of Solar Thermal Collector Shipments by Collector Type, 1995, 1996, and 1997



Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Uses

In 1997, the largest end use for solar thermal collectors shipped was for heating swimming pools, representing 93 percent of the total square feet shipped. Swimming pools generally use low-temperature collectors. A common low-temperature pool-heating solar collector is a black plastic or rubber-like sheet with tubing through which water is circulated. The heat of the sun is transferred directly from the black absorbing material to the water circulating through the tubing to supply heat to the pool. Shipments for pool heating increased 11 percent in 1997 from the level reported in 1996.

The second largest end use in 1997 was for domestic hot water systems, which accounted for 7 percent of the total square feet shipped. Typical solar water-heating systems feature flat-plate collectors or collectors installed in an ICS or thermosiphon system. Unlike pool-heating systems, domestic solar water-heating systems nearly always have a conventional backup (e.g., gas or electric). Shipments in 1997 for hot water systems decreased 22 percent from the 1996 level.

Medium-temperature collectors also were shipped for space heating and for installation into systems that provide both space and water heating, and process heating. Almost all high-temperature parabolic dish and trough collectors were shipped for hot water heating in 1997.

System Shipments

Twenty-nine companies reported 13,951 shipments of complete solar thermal collector systems in 1997, a 55-percent increase compared with 1996 (Table 20).

Table 19. Shipments of Solar Collectors by Market Sector, End Use, and Type, 1996 and 1997
(Thousand Square Feet)

Type	Low-Temperature	Medium-Temperature					High-Temperature		
	Liquid/Air		Liquid						
	Metallic and Nonmetallic	Air	ICS/Thermosiphon	Flat-Plate (Pumped)	Evacuated Tube	Concentrator	Parabolic Dish/Trough	**1997 Total**	**1996 Total**
Market Sector									
Residential	6,791	53	24	491	1	0	0	**7,360**	**6,873**
Commercial	726	1	9	25	0	0	7	**768**	**682**
Industrial	7	0	0	0	0	0	0	**7**	**54**
Utility	0	0	*	0	*	0	0	**1**	*
Other[a]	0	1	0	0	1	0	0	**2**	**7**
Total	**7,524**	**54**	**33**	**516**	**2**	**0**	**7**	**8,138**	**7,616**
End Use									
Pool Heating	7,517	0	7	4	0	0	0	**7,528**	**6,787**
Hot Water	0	52	26	509	1	0	7	**595**	**765**
Space Heating	7	2	0	0	0	0	0	**10**	**57**
Space Cooling	0	0	0	0	0	0	0	**0**	**0**
Combined Space and Water Heating	0	0	0	3	0	0	*	**4**	**3**
Process Heating	0	0	0	0	0	0	0	**0**	**4**
Electricity Generation	0	0	0	0	0	0	0	**0**	*
Other[b]	*	0	0	*	1	0	0	**2**	**0**
Total	**7,524**	**54**	**33**	**516**	**2**	**0**	**7**	**8,138**	**7,616**

*Less than 500 square feet.

[a]Other market sectors include shipments of solar thermal collectors to other sectors such as government, including the military but excluding space applications.

[b]Other end use includes shipments of solar thermal collectors for other uses such as cooking, water pumping, water purification, desalinization, distilling, etc.

ICS = Integral Collector Storage.

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Table 20. Shipments of Complete Solar Thermal Collector Systems, 1996 and 1997

Shipment Information	1996	1997
Complete Collector Systems Shipped	**9,013**	**13,951**
Thousand Square Feet	2,093	2,975
Percent of Total Shipments	27	37
Number of Companies	28	29
Value of Systems (thousand dollars)	**10,754**	**14,317**

Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

A complete system is a unit with a collector and all the necessary functional components, except for installation materials. It includes thermosiphon systems, integral collector storage systems, packaged systems, and system kits. The 13,951 complete systems accounted for 3.0 million square feet of collectors, an increase of 42 percent in square feet shipped above the 1996 level. The total value for the systems shipped in 1997 was $14.3 million, compared with $10.8 million in 1996.

Industry Status

In 1997, 29 companies were active in the solar thermal collector manufacturing industry. This is virtually unchanged from 1996 and interrupts a decade-long decline. However, it is a sizable decrease from prior years (Table 12). Since 1987, 30 manufacturing companies have left the market. Firms leaving the market have been principally those engaged partially in nonsolar-related businesses. This decade long decrease is due in large measure to two factors. First, the 40-percent residential energy tax credit and the 15-percent business energy tax credit expired at the end of 1985. Second, the decline in industry companies intensified with the drop in oil prices in 1986. The reinstatement of the business energy tax credit—at the 15-percent level for 1986, at the 12-percent level for 1987 through 1991, and at the 10-percent level in 1992—plus increasing oil prices after 1986, appear to have had little effect on drawing companies into manufacturing solar thermal collectors.[14]

Despite the decrease in firms producing solar collectors, those firms still in business shipped 0.5 million more square feet in 1997 than in 1996 (Table 12). Of the 29 active companies, 3 are planning to introduce new low-temperature collectors, 9 are planning new medium-temperature collectors, and 2 expect to introduce new high-temperature collectors in 1998 (Table 21).

Table 21. Number of Companies Expecting To Introduce New Solar Thermal Collector Products In 1998

New Product Type	Number of Companies
Low-Temperature Collectors	3
Medium-Temperature Collectors	9
High-Temperature Collectors	2
Noncollector Components	3

Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

At the end of 1996, 30 States were providing financial incentives for investment in the use of solar thermal collectors and photovoltaic cells and modules. The legislative actions were passed to encourage the use of an environmentally clean source of energy, to promote energy conservation through the use of renewable energy technologies, and to promote energy efficiency. Among the most common incentives were property tax exemptions and income tax credits for both the residential and business sectors.

Since 1987, the 10 largest U.S. companies that shipped solar thermal collectors have supplied not less than 95 percent of all solar thermal collectors manufactured in or imported into the United States (Table 22). In 1997, 97 percent of the approximately 7.9 million square feet of total shipments were supplied by the 10 largest companies.

Table 22. Percent of Solar Collector Shipments by the 10 Largest Companies, 1987-1997

Year	Company Rank	Shipments (thousand square feet)	Percent of Total Shipments
1987	1-5	6,371	88
	6-10	499	7
1988	1-5	7,585	93
	6-10	335	4
1989	1-5	9,748	85
	6-10	1,321	12
1990	1-5	9,955	87
	6-10	1,029	9
1991	1-5	5,429	83
	6-10	829	13
1992	1-5	6,110	86
	6-10	609	9
1993	1-5	6,135	88
	6-10	551	8
1994	1-5	6,401	84
	6-10	861	12
1995	1-5	6,525	85
	6-10	806	11
1996	1-5	6,452	85
	6-10	910	12
1997	1-5	7,183	88
	6-10	731	9

Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration: Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Employment in solar-thermal-related activities decreased 56 person-years in 1997 to 184 person-years, a 23-percent drop from the 1996 employment level of 239. Industry employment data for 1994 through 1997 are as follows:

Year	Person Years Expended
1994	402
1995	386
1996	239
1997	184

[14] In an effort to stimulate domestic energy sources, the Energy Policy Act of 1992, Section 1916, extended the 10-percent business tax credits for solar equipment indefinitely, retroactive to June 30, 1992. Investors in or purchasers of qualified solar energy property can take the credit on up to 10 percent of the investment or purchase price and installment amount. Section 1914 established a 1.5-cent per kilowatthour electricity production incentive for "qualifying facilities."

Most of the 29 reporting companies in 1997 combined manufacturing and related activities with importing of solar thermal collectors including:

- A total of 22 companies were involved in the design of collectors or systems, 12 were developing prototype collectors, and 7 were developing prototype systems (Table 23).

- There were 20 companies with wholesale distribution activities and 14 companies with retail distribution activities. Of the 29 companies, 11 offered installation of their collectors.

Table 23. Companies Involved in Solar Thermal Activities by Type, 1996 and 1997

Type of Activity	1996	1997
Collector or System Design	20	22
Prototype Collector Development	15	12
Prototype System Development	7	7
Wholesale Distribution	19	20
Retail Distribution	12	14
Installation	9	11
Noncollector System Component Manufacture	7	9

Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Solar-related sales represented 90 to 100 percent of total company sales for 19 companies in 1997 versus 21 companies in 1996 (Table 24). Solar-related sales made up less than 10 percent of total sales for 4 companies in 1997, compared with 3 companies in 1996.

Photovoltaic Module and Cell Manufacturing Activities

Photovoltaic Module and Cell Description

Photovoltaic (PV) components are divided into three categories by product type: (1) crystalline silicon cells and modules which include single-crystal, cast silicon, and ribbon silicon; (2) thin-film cells and modules made from a number of layers of photosensitive materials such as amorphous silicon; and (3) concentrator cells and modules in which a lens is used to gather and converge sunlight onto the cell or module surface.

Table 24. Solar-Related Sales as a Percentage of Total Sales, 1996 and 1997

Solar-Related Sales as a Percent of Total Sales	Number of Companies	
	1996	1997
90-100	21	19
50-89	4	5
10-49	0	1
Less than 10	3	4
Total	**28**	**29**

Source: Energy Information Administration, Form EIA-63A, "Annual Solar Thermal Collector Manufacturers Survey."

Shipments

PV module and cell shipments in 1997 surged to 46.4 peak megawatts (Table 25). Module shipments accounted for 33.6 peak megawatts, while cell shipments accounted for 12.7 peak megawatts. Module shipments increased 37 percent in 1997 from 1996, while cell shipments increased 16 percent. Total PV shipments in 1997 were 31 percent above the 1996 level. Total shipments have increased 632 percent since 1986 (Table 26 and Figure 10). Data for PV cells and modules are for terrestrial use only (i.e., excluding space applications) and have been reported each year since 1982.

Table 25. Annual Shipments of Photovoltaic Cells and Modules, 1995-1997
(Peak Kilowatts)

Item	1995	1996	1997
Cells	11,432	10,930	12,709
Modules	19,627	24,534	33,645
Total	**31,059**	**35,464**	**46,354**

Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Imports

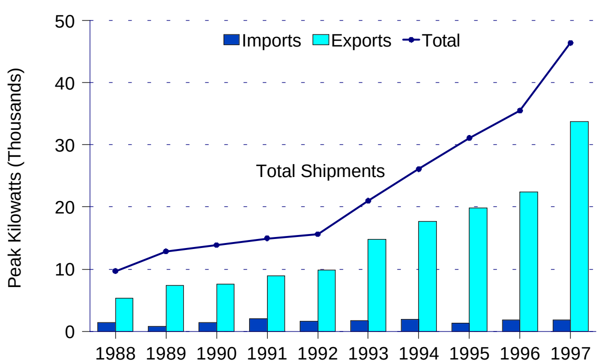
Four companies imported PV cells and modules in 1997 totaling 1.9 peak megawatts, or 4 percent of total shipments (Table 26). The predominant type of imported PV cells and modules was crystalline silicon. These imports originated in Australia, England, India, and Japan, with Japan accounting for most of the imported PV cells and modules.

Table 26. Annual Shipments of Photovoltaic Cells and Modules, 1986-1997

Year	Number of Companies	Photovoltaic Cell and Module Shipments (Peak Kilowatts)[a]		
		Total	Imports	Exports
1986	17	6,333	678	3,109
1987	17	6,850	921	3,821
1988	14	9,676	1,453	5,358
1989	17	12,825	826	7,363
1990	[b]19	[b]13,837	1,398	7,544
1991	23	14,939	2,059	8,905
1992	21	15,583	1,602	9,823
1993	19	20,951	1,767	14,814
1994	22	26,077	1,960	17,714
1995	24	31,059	1,337	19,871
1996	25	35,464	1,864	22,448
1997	21	46,354	1,853	33,793

[a]Does not include shipments of cells and modules for space/satellite applications.
[b]Includes imputed data for one nonrespondent which exited the industry during 1990.
Note: Total shipments as reported by respondents include all domestic and export shipments and may include imported collectors that subsequently were shipped to domestic or foreign customers.
Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Figure 10. Import and Export Shipments of Photovoltaic Cells and Modules, 1988-1997



Note: Total shipments as reported by respondents include all domestic and export shipments and may include imports that subsequently were shipped to domestic or foreign customers.
Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Distribution

In 1997, PV module and cell shipments totaling 31.4 peak megawatts (68 percent of total shipments) were sent directly to wholesale distributors (Table 27). Installers and end users combined received 2.8 peak megawatts (6 percent of total shipments).

PV cell manufacturers shipped 5.2 peak megawatts (11 percent of total shipments) to other companies that manufacture (assemble) cells into PV modules.

Cell and Module Types

Crystalline silicon cells and modules continued to dominate the PV industry in 1997, accounting for 96 percent of total shipments (Table 28). In particular, single-crystal silicon shipments totaled 30 peak megawatts, an increase of 38 percent compared with corresponding 1996 shipments (Figure 11). Together, cast and ribbon silicon shipments totaled 14.3 peak megawatts in 1997, a 17-percent increase over 1996. From 1996 to 1997, thin-film shipments increased 31 percent (Table 28). However, thin-film shipments represented only 4.1 percent of total shipments in 1997.

Values and Prices

The total value of photovoltaic module and cell shipments was $175 million in 1997, a 34-percent increase over the 1996 value of $131 million (Table 29). The total value includes charges for advertising and warranties, but does not include excise taxes and the cost of freight or transportation for the shipments.

The total value of crystalline silicone (single-crystal, cast, and ribbon) shipments was $164 million in 1997, a 35-percent increase compared with the corresponding 1996

Table 27. Distribution of Photovoltaic Cells and Modules, 1995-1997

Recipient	Shipments (Peak Kilowatts)		
	1995	**1996**	**1997**
Wholesale Distributors	16,413	21,424	31,385
Retail Distributors	1,181	1,457	424
Exporters	321	367	4,081
Installers	4,098	4,860	1,236
End Users	458	1,048	1,522
Module Manufacturers	5,794	5,528	5,247
Other[a]	2,793	781	2,459
Total	**31,059**	**35,464**	**46,354**

[a]Other includes categories not identified by reporting companies.
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Table 28. Photovoltaic Cell and Module Shipments by Type, 1995-1997

Type	Shipments (Peak Kilowatts)			Percent of Total		
	1995	1996	1997	1995	1996	1997
Crystalline Silicon						
Single-Crystal	19,857	21,742	29,997	64	61	65
Cast and Ribbon	9,883	12,255	14,317	32	35	31
Subtotal	29,740	33,996	44,677	96	96	96
Thin-Film Silicon	1,266	1,445	1,886	4	4	4
Concentrator Silicon	53	23	154	*	*	*
Other[a]	0	0	0	0	0	0
Total	**31,059**	**35,464**	**46,354**	**100**	**100**	**100**

[a]Includes categories not identified by reporting companies.
* = Less than 0.5 percent.
Notes: Data do not include shipments of cells and modules for space/satellite applications. Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

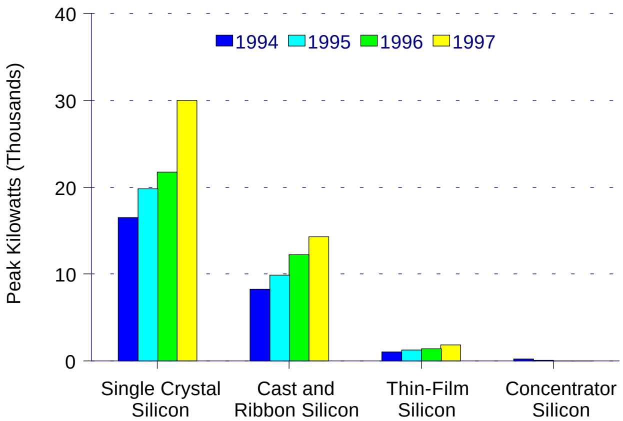
value. The average price of crystalline silicon modules in 1997 was $4.06 per peak watt, an increase of 3 percent from the 1996 price of $3.95 (Table 29).

Uses

The largest end-use application of PV cells and modules in 1997 was for electricity generation (combined grid-interactive and remote). This represented 36 percent of total shipments (Table 30). Of the 16.9 peak megawatts represented by this end use, 94 percent involved crystalline silicon cells and modules. Grid interactive and remote (i.e., stand-alone) power generation include applications for grid distribution and general remote uses, such as residential power and power for mobile homes. The second-largest PV end use in 1997 was in the communication sector, which accounted for 7.4 peak megawatts. An example of use in the commercial sector is the utilization of PV units to power fixed-based communications equipment, such as mountain-top signal-repeater stations. This sector represented 16 percent of total shipments. In 1997, transportation was the third-largest PV end-use application, representing 14 percent of total shipments.

In 1997, end uses related to water pumping and original equipment manufacturers accounted for 3.8 peak megawatts and 5.2 peak megawatts, respectively, and

Figure 11. Photovoltaic Cell and Module Shipments by Type, 1994-1997



Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

involved primarily the use of crystalline silicon cells and modules.

Sales for consumer goods accounted for 0.3 peak megawatts in 1997. PV cells and modules used for health and medical purposes, such as to power refrigerators, medical equipment, and water purifiers, totaled 1.3 peak megawatts in 1997, a 33-percent increase over the 1996 level. End uses reported as "Other" for 1997 totaled 4.7 peak megawatts.

Destinations

Market Sectors

The industrial sector was the largest market for PV cells and modules in 1997, accounting for 25 percent of total shipments (Table 30). This sector contains much of the nonutility electric generation capacity. The second-largest market sector was the residential sector, which purchased 24 percent of shipments. The commercial sector represented the third-largest market for PV shipments in 1997 with 18 percent. These cells and modules were shipped to provide power for establishments such as office buildings, retail establishments, private hospitals, and schools (publicly owned hospitals and schools are listed under the government sector).

PV cells and modules for the transportation sector, which were used to produce power on boats, in cars, in recreational vehicles, and to power transportation support systems, amounted to 3.6 megawatts. The transportation sector accounted for 8 percent of total shipments in 1997 compared with 11 percent in 1996.

Shipments to the utility sector, where cells and modules were used to produce power at utility-owned systems including central stations, decentralized systems, and experimental applications, amounted to 5.7 peak megawatts in 1997, a 19-percent increase from 1996. Combined with information from the analysis of PV's by end use, it is clear that there is considerable use of PV cells

Table 29. Photovoltaic Cell and Module Shipment Values by Type, 1996 and 1997

Type	1996 Value (Thousand Dollars)	1996 Average Price (Dollars per Peak Watt) Modules	1996 Average Price (Dollars per Peak Watt) Cells	1997 Value (Thousand Dollars)	1997 Average Price (Dollars per Peak Watt) Modules	1997 Average Price (Dollars per Peak Watt) Cells
Crystalline Silicon						
Single-Crystal	75,043	3.97	2.81	108,226	4.08	2.81
Cast and Ribbon	46,646	3.92	2.73	55,701	4.03	2.59
Subtotal	121,689	3.95	2.80	163,927	4.06	2.78
Thin-Film Silicon	W	W	W	W	W	W
Concentrator Silicon	W	W	W	W	W	W
Other[a]	0	--	--	0	--	--
Total	**131,066**	**4.09**	**2.80**	**175,089**	**4.16**	**2.78**

[a]Includes categories not identified by reporting companies.
W = Data withheld to avoid disclosure of proprietary company data.
-- = Does not apply.
Notes: Data do not include shipments of cells and modules for space/satellite applications. Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Table 30. Shipments of Photovoltaic Cells and Modules by Market Sector, End Use, and Type, 1996 and 1997
(Peak Kilowatts)

Sector and End Use	Crystalline Silicon[a]	Thin-Film Silicon	Concentrator Silicon	Other	1997 Total	1996 Total
Market Sector						
Industrial	11,244	504	0	0	11,748	8,300
Residential	10,691	300	2	0	10,993	8,475
Commercial	7,621	340	150	0	8,111	5,176
Transportation	3,378	196	0	0	3,574	3,995
Utility	5,331	320	0	0	5,651	4,753
Government[b]	3,772	135	2	0	3,909	3,126
Other[c]	2,276	91	0	0	2,367	1,639
Total	**44,314**	**1,886**	**154**	**0**	**46,354**	**35,464**
End Use						
Electricity Generation						
Grid Interactive	7,402	871	0	0	8,273	4,844
Remote	8,433	195	2	0	8,630	10,884
Communications	7,289	94	0	0	7,383	6,041
Consumer Goods	72	275	0	0	347	1,063
Transportation	6,645	60	0	0	6,705	5,196
Water Pumping	3,748	35	0	0	3,783	3,261
Cells/Modules to OEM[d]	4,984	261	0	0	5,245	2,410
Health	1,267	36	0	0	1,303	977
Other[e]	4,473	59	152	0	4,684	789
Total	**44,314**	**1,886**	**154**	**0**	**46,354**	**35,464**

[a]Includes single-crystal and cast and ribbon types.
[b]Includes Federal, State, and local governments, excluding military.
[c]Other includes shipments that are manufactured for private contractors for research and development projects.
[d]Original equipment manufacturers.
[e]Other uses include shipments of photovoltaic cells and modules for other uses, such as cooking food, desalinization, distilling, etc.
Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

and modules for electricity generation—even grid interactive uses—outside the utility sector.

Shipments of PV cells and modules used to produce power at installations of Federal, State, or local governments (excluding military) totaled 3.9 peak megawatts in 1997. This compares with 3.1 peak megawatts shipped to the government sector in 1996. The "Other" sector in 1997 consisted of 2.4 peak megawatts shipped to foreign governments or used for speciality purposes.

Exports

Export shipments totaled 33.8 peak megawatts in 1997 (Table 31), an increase of 51 percent from 1996 levels. Generally, export shipments since 1990 have increased because of the continued search for new PV markets outside the United States (Figure 10). A total of 17 companies reported exports of PV cells and modules in 1997, with exports accounting for 73 percent of total PV shipments. Of all types of cells and modules exported in 1997, 98 percent were crystalline silicon (Table 31). Destinations of PV exports by continent, region, and by country are shown in Table 32. Two countries, Germany and Japan, received the greatest share of exports, totaling 57 percent in 1997.

Systems

Of the 21 companies that reported shipments of PV systems in 1997, 12 reported shipments of 3,926 complete photovoltaic systems, an increase of 143 percent from 1996 (Table 33). A complete photovoltaic system is defined as a power supply unit that satisfies all the power requirements of an application. Such a system is generally made up of one or more modules, a power

Table 31. Export Shipments of Photovoltaic Cells and Modules by Type, 1996 and 1997
(Peak Kilowatts)

Item	Crystalline Silicon		Thin-Film Silicon		Concentrator Silicon		Total	
	1996	1997	1996	1997	1996	1997	1996	1997
Cells	8,312	10,837	8	0	0	0	**8,320**	**10,837**
Modules	13,690	22,247	437	707	2	2	**14,128**	**22,956**
Total	**22,002**	**33,084**	**445**	**707**	**2**	**2**	**22,448**	**33,793**

Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

conditioning unit to process the electricity into the form needed by the application, wires and other electrical connectors, and sometimes batteries for back-up power supply. Some complex, large-scale PV systems use concentrators to focus incident insolation onto small PV cells and tracking systems to track the sun. In this report, installation materials such as the support frame and concrete foundations are not considered as part of a system. The value of systems reported in Table 33 excludes excise taxes and charges for freight, transportation, and installation. The total value of complete systems shipped in 1997 was $4.1 million. Complete-system shipments in 1997 accounted for 200 peak kilowatts, or less than one percent of total module shipments.

Industry Status

Shipments totaling 46.4 peak megawatts were reported by 21 companies in 1997 (Table 34). Ten companies expect to introduce new crystalline-silicon module products, and 5 companies reported plans to introduce new thin-film products to the industry during 1998 (Table 35). One company reported plans to produce new PV concentrator products while another plans new non-module system components during 1998.

Employment in PV-related activities totaled 1,736 person-years in 1997 (Tables 26 and 34), an increase of 36 percent from the 1996 level of employment and slightly greater than the increase in shipments. The average employment per company was 82 person-years in 1997, compared with 51 person-years in 1996.

Many companies engaged in the manufacture and/or importation of PV cells and modules reported that they also are involved in other PV-related activities. There were 13 companies involved in cell manufacturing, 2 more than in 1996 (Table 36). There were 18 companies involved in module or system design, 14 were active in developing module prototypes, and 10 developed PV system prototypes. There were 15 companies that sold wholesale while 4 sold retail. Five companies installed PV cells or modules in 1997, 4 less than in 1996.

Table 32. Destination of U.S. Photovoltaic Cell and Module Export Shipments by Country, 1997

Destination	Peak Kilowatts	Percent of U.S. Exports
Africa		
Angola	1.6	*
Burkina Faso	0.1	*
Egypt	291.0	0.9
Morocco	285.4	0.8
Nigeria	1.6	*
South Africa	938.7	2.8
Uganda	0.1	*
Zimbabwe	134.5	0.4
Total	**1,653.0**	**4.9**
Asia and the Middle East		
China	0.1	*
Greece	0.4	*
Hong Kong	1,423.3	4.2
India	285.0	0.8
Japan	8,056.0	23.9
Oman	240.0	0.7
Philippines	8.7	*
Saudi Arabia	28.8	0.1
Singapore	1,106.4	3.3
Thailand	182.0	0.5
Total	**11,330.6**	**33.5**
Australia	**61.2**	**0.2**
Europe		
Belgium	1.6	*
England	103.0	0.3
Finland	527.0	1.6
France	136.1	0.4
Germany	11,162.0	33.0
Italy	62.0	0.2
Ireland	667.4	2.0
Norway	369.8	1.1
Spain	651.0	1.9
Sweden	347.1	1.0
Switzerland	31.0	0.1
Total	**14,057.9**	**41.6**
North America		
Canada	774.6	2.3
Dominican Republic	48.4	0.1
Mexico	1,318.7	3.9
Total	**2,141.7**	**6.3**
South America		
Argentina	476.3	1.4
Bolivia	2.2	*
Brazil	1,259.0	3.7
Chile	168.0	0.5
Columbia	349.4	1.0
Costa Rica	0.1	*
Ecuador	60.7	0.2
Nicaragua	0.1	*
Panama	30.0	0.1
Peru	608.6	1.8
Uruguay	1.0	*
Venezuela	1.0	*
Other Latin America	60.0	0.2
Total	**3,016.4**	**8.9**
Other	**1,532.2**	**4.6**
Total U.S. Exports	**33,793.0**	**100.0**

* = Less than 0.05 percent.

Note: "Other" represents shipments to countries not disaggregated by companies on Form EIA-63B. Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Table 33. Shipments of Complete Photovoltaic Module Systems, 1995-1997

Shipment Information	1995	1996	1997
Complete Photovoltaic Module Systems Shipped	1,077	1,615	3,926
Peak Kilowatts	937	647	202
Percent of Total Modules Shipments	R5	R3	1
Value of Systems (thousand dollars)	6,414	3,489	4,061

R = Revised.
Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Table 34. Employment in the Photovoltaic Manufacturing Industry, 1991-1997

Year	Number of Companies	Number of Person-Years
1991	23	1,588
1992	21	1,463
1993	19	1,431
1994	22	1,312
1995	24	1,578
1996	25	1,280
1997	21	1,736

Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Table 35. Companies Expecting To Introduce New Photovoltaic Products in 1998

New Product Type	Number of Companies
Crystalline Silicon	
Single-Crystal Silicon Modules	4
Cast Silicon Modules	2
Ribbon Silicon Modules	4
Thin Film	
Amorphous Silicon Modules	4
Other (Thin-Film)	1
Other (Flat Plate)	0
Concentrators	1
Nonmodule System Components	1

Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

Table 36. Number of Companies Involved in Photovoltaic-Related Activities, 1996 and 1997

Type of Activity	Number of Companies	
	1996	1997
Cell Manufacturing	11	13
Module or System Design	19	18
Prototype Module Development	15	14
Prototype Systems Development	14	10
Wholesale Distribution	19	15
Retail Distribution	10	4
Installation	9	5
Noncollector System Component Manufacturing	6	4

Source: Energy Information Administration, Form EIA-63B, "Annual Photovoltaic Module/Cell Manufacturers Survey."

3. Survey of Geothermal Heat Pump Shipments

Introduction

This chapter provides information on geothermal heat pump shipments, based on the Energy Information Administration's (EIA) Form EIA-902, "Annual Geothermal Heat Pump Manufacturers Survey." It begins with a general discussion of heat pumps, followed by a discussion of the survey results and some salient characteristics of the data, and ends with a technical discussion of heat pump operation.

Overview

"Heat pump" is a term applied to a machine that can transfer heat both to and from a source. Therefore, a heat pump can be used both for space heating in the winter and for cooling (air conditioning) in the summer. The most common type of heat pump for domestic use is the air-to-air (air source) system in which heat is taken from air (heat source) at one location and transferred to air (heat sink) at another location.

Another type of heat pump transfers heat from air to water and has been designed for domestic hot-water heating. Geothermal heat pumps are a special type of air-to-water heat pump that use the earth as a heat source or sink, depending on the season. Since the earth's temperature a few feet below the surface stays relatively constant (about 55 degrees Fahrenheit) year round, one can extract heat from the earth when the air temperature is below the earth's temperature (winter), and transfer heat to the earth when the air temperature is above the in-ground temperature (summer). Geothermal heat pumps are generally more expensive to install but more efficient (costing less to operate and maintain) than an air-to-air heat pump. The technical section at the end of this chapter further explains the operation and rating of heat pumps.

EIA Survey of Geothermal Heat Pumps

The Energy Information Administration's (EIA) new survey, Form EIA-902, "Annual Geothermal Heat Pump Manufacturers Survey," shows that manufacturers shipped almost 58,000 geothermal heat pumps in 1997 and over 213,000 during the period 1994 through 1997. The survey was completed by approximately 18 known domestic manufacturers of geothermal heat pumps. Data from the survey are collected under a confidentiality provision. As a result, only aggregated statistics are released. The Form EIA-902 tracks shipments of the three main types of geothermal heat pumps, as certified by the Air Conditioning and Refrigeration Institute (ARI), and a small volume of non-ARI rated heat pumps (Tables 37-40). The three ARI-rated classifications for geothermal heat pumps are as follows:

- ARI-320, Water-Source Heat Pumps (WSHP). These systems are installed in commercial buildings, where a central chiller or boiler supplies chilled or heated water, respectively, to heat pumps installed in series. The heat pumps reject building heat to chilled water during the cooling season and, during the heating season, take heat from boiler water;

- ARI-325, Ground Water-Source Heat Pumps (GWHP). The GWHP is an open-loop system in which ground water is drawn from an aquifer or other natural body of water into piping. At the heat pump, heat is drawn from or dumped into the water through a heat exchanger to the refrigerant in the heat pump. The heated or cooled water returns to its source; and

- ARI-330, Ground-Source Closed-Loop Heat Pumps (GSHP). A water or water/glycol (antifreeze) solution flows continuously through a closed loop of pipe buried underground. Ground heat is absorbed into or rejected from the solution flowing in the closed loop. At the heat pump, heat is drawn from or dumped to the closed loop solution via heat transfer through a heat exchanger, which passes heat to, or removes heat from, the refrigerant in the heat pump.

Manufacturers shipped nearly 58,000 heat pumps of all types in 1997 (Table 37) compared with about 52,000 in 1996—an increase of almost 13 percent. Of those shipped in 1997, over 28,000 were ARI-320 rated, 9,700 were

Table 37. Geothermal Heat Pump Shipments by Model Type 1994–1997
(Number of Units)

Model Type	1994	1995	1996	1997
ARI-320	26,757	26,787	24,832	28,260
ARI-325	5,924	8,615	7,603	9,724
ARI-330	16,023	18,185	18,094	18,611
Non-ARI Rated	757	838	991	1,327
Totals	**49,461**	**54,425**	**51,520**	**57,922**

Note: Data for ARI-320 units are subject to substantial revision. See Appendix B.
Source: Energy Information Administration, Form EIA-902 "Annual Geothermal Heat Pump Manufacturers Survey."

Table 38. Capacity of Geothermal Heat Pump Shipments by Model Type, 1994–1997
(Total Rated Capacity in Tons)

Model Type	1994	1995	1996	1997
ARI-320	73,879	72,304	78,391	92,116
ARI-325	29,003	39,672	28,705	37,049
ARI-330	63,101	74,253	64,114	73,137
Non-ARI Rated	2,879	3,935	5,091	6,662
Totals	**168,862**	**190,164**	**176,301**	**208,964**

Note: A capacity of one ton equals 12,000 Btu's. Data for ARI-320 units are subject to substantial revision. See Appendix B.
Source: Energy Information Administration, Form EIA-902 "Annual Geothermal Heat Pump Manufacturers Survey."

ARI-325 rated, 18,600 were ARI-330 rated, and approximately 1,300 were non-ARI-rated units.

The total rated capacity of heat pumps shipped in 1997 was almost 209,000 tons (Table 38). The average rated capacity of heat pumps shipped in 1997 was 3.6 tons compared to 3.4 tons in 1996. Average capacity increased for all ARI-rated geothermal heat pumps. ARI-320 units tend on average to be smaller at 3.3 tons per unit than ARI-325 or ARI-330 units at almost 4 tons per unit and non-ARI-rated units at 5 tons per unit. By comparison, a typical home central air conditioner has a rating of 3.0 tons. These results may indicate a niche market for larger geothermal heat pumps, where the savings in operating costs are greater than the higher initial investment for geothermal heat pumps.

The proportion of geothermal heat pumps shipped to each Census region in 1997 was as follows: the South (46 percent), the Midwest (23 percent), the Northeast (16 percent), the West 10 percent, and exports 4 percent (Table 39). The Northeast accounted for the greatest increase in units—up nearly 2,900 units in 1997 compared to 1996. In terms of the number of units and percentage of units, export shipments showed the greatest decline, falling 41 percent to just over 2,400 units in 1997. About 50 percent of total geothermal heat pumps were shipped to wholesalers (Table 40) of which nearly 40 percent were ARI-320 rated. Forty-four percent of geothermal heat pump shipments went to installers of which 58 percent were ARI-320 rated. Retail distributors represented less than 1 percent of heat pump shipments.

Consumer Awareness

Collaborative alliances among government organizations, the Geothermal Heat Pump Consortium, the International Ground Source Heat Pump Association, and the geothermal heat pump industry have expanded consumer awareness and acceptance of geothermal heat pumps. Such efforts have resulted in increased installation of geothermal heat pumps where electric utilities and electric service companies provide attractive financing, rebates, guaranteed utility rates, shared savings contracts, and/or equipment leasing arrangements.

How Heat Pumps Work

A heat pump is a device that operates on the concept of heat transfer from areas of lower temperature to areas of higher temperature—the reverse of normal heat flow. It

Table 39. Geothermal Heat Pump Shipments by Exports, Census Region, and Model Type, 1996 and 1997
(Number of Units)

1996

Exports and Census Region	Model Type				Total
	ARI-320	ARI-325	ARI-330	Non-ARI Rated	
Exports	3,103	302	624	61	4,090
Midwest	2,467	2,295	6,804	308	11,874
Northeast	2,572	1,001	2,774	70	6,417
South	14,138	3,834	6,880	450	25,302
West	2,552	171	1,012	102	3,837
Total	**24,832**	**7,603**	**18,094**	**991**	**51,520**

1997

Exports and Census Region	Model Type				Total
	ARI-320	ARI-325	ARI-330	Non-ARI Rated	
Exports	1,825	101	437	64	2,427
Midwest	3,413	2,717	6,780	492	13,402
Northeast	5,082	1,512	2,593	93	9,280
South	15,332	4,015	6,828	613	26,788
West	2,608	1,379	1,973	65	6,025
Total	28,260	9,724	18,611	**1,327**	**57,922**

Note: The Midwest Census region consists of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Wisconsin. The Northeast Census region consists of Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont. The South Census region consists of Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, and West Virginia. The West Census region consists of Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. Data for ARI-320 units are subject to substantial revision. See Appendix B.

Source: Energy Information Administration, Form EIA-902 "Annual Geothermal Heat Pump Manufacturers Survey."

employs a refrigeration cycle during which a refrigerant (known as the "working fluid") is compressed (as a liquid) then expanded (as a vapor) to absorb and release heat, respectively. Specifically, the heat pump absorbs from an outside medium (air, ground, groundwater) and then transfers ("pumps") the heat to a space to be heated during the winter season. By reversing the process, the heat pump extracts (absorbs) heat from the same space during the summer season, and then transfers it to the outside air. It also acts as a dehumidifier, removing moisture from the air and making it more comfortable.

Air Source Heat Pumps

An air-source heat pump—the most common type of heat pump—absorbs heat from the outside air and transfers the heat through the working fluid to the space to be heated. In the heating mode, however, air-source heat pumps lose efficiency and generally require a back-up heating system when the outside air approaches 32° F or less. In the cooling mode, the heat pump absorbs heat through the working fluid from the space to be cooled and rejects the heat to the outside air.

Geothermal (Groundwater) Heat Pumps

In a geothermal heat pump, the refrigerant exchanges heat with a fluid circulating through piping in contact with the earth. The fluid circulates in a variety of loop (pipe) configurations, depending on the temperature of the ground. Loops may be installed horizontally or vertically in the ground or submersed in a body of water (Figure 12). Although the fluid in most types of loop configurations circulates in a closed system, open loops (normally vertical systems) are sometimes used when a sufficient supply of water is available from wells.

The efficiency of a heat pump—measured by the electrical energy required for the working fluid to absorb and reject a certain amount of heat—is directly related to

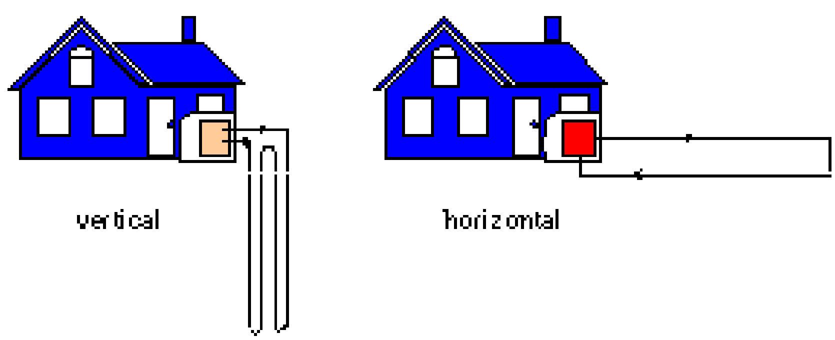
Table 40. Geothermal Heat Pump Shipments by Customer Type and Model Type, 1996 and 1997
(Number of Units)

Customer Type	ARI-320	ARI-325	ARI-330	Non-ARI Rated	Total
1996					
Exporter	W	W	W	57	2,276
Wholesale Distributor	10,929	2,980	7,346	189	21,444
Retail Distributor	W	W	7,267	273	8,336
Installer	12,256	3,285	2,755	466	18,762
End-User	124	W	W	W	689
Others	W	W	W	W	13
Total	**24,832**	**7,603**	**18,094**	**991**	**51,520**
1997					
Exporter	W	0	W	0	W
Wholesale Distributor	11,557	8,226	9,091	307	29,181
Retail Distributor	0	W	0	W	W
Installer	14,620	1,071	8,820	791	25,302
End-User	W	0	W	W	657
Others	1,555	W	W	W	1,727
Total	28,260	9,724	18,611	**1,327**	**57,922**

W = Data withheld to avoid disclosure of proprietary company data. Data for ARI-320 units are subject to substantial revision. See Appendix B.

Source: Energy Information Administration, Form EIA-902 "Annual Geothermal Heat Pump Manufacturers Survey."

Figure 12. Ground Coupled Heat Pumps-Loop Configurations



Note: For more in-depth information on geothermal heat pumps, visit the Geo-Heat Center's consumer information website at http://www.oit.edu.

Source: Geo-Heat Center.

the temperature differential between the ground and the fluid. In heat pump terminology, the difference between the temperature where the heat is absorbed (source) and the temperature where the heat is delivered (sink) is called the "lift." The larger the lift, the greater the power input required by the heat pump. This is the basis for the efficiency advantage of the geothermal heat pump over air-source heat pumps. Geothermal heat pumps are more efficient (a smaller "lift") than conventional heat pumps or air conditioners that use the outdoor air since the ground or ground water a few feet below the earth's surface remains relatively constant throughout the year. During the winter, heat is transferred from the relatively warm ground (approximately 55° F) than from the usually much colder atmosphere, while during the summer, excess waste heat is transferred to the cooler ground rather than to the normally much warmer atmosphere. Geothermal heat pumps generally have a higher capital cost, than air-to-air heat pumps, due to the cost of installing underground piping. However, depending on the location, geothermal heat pumps can reduce energy consumption (operating cost) and correspondingly, air emissions, by more than 20 percent compared to high-efficiency outside air heat pumps. Geothermal heat pumps also use the waste heat from air conditioning to provide free hot water heating in the summer.

Ratings of Heat Pumps

Heat pumps are rated according to their heating or cooling capacity and their operating efficiency. The capacity of a heat pump for either heating or cooling is commonly expressed in terms of British thermal units (Btu) per hour of heat delivery or removal. The heating or cooling capacity is sometimes stated in tons, where 1 ton is equivalent to a heat delivery or removal rate of 12,000 Btu per hour. Although an average home requires a unit of approximately 36,000 Btu (3 tons), the size of a house and the quality of insulation determine the necessary heat pump capacity. An under-sized unit will not keep the house comfortable during peak heating and cooling demand times and may run continuously, resulting in high operating costs. On the other hand, an over-sized unit is more costly to purchase and operate and during cooling seasons may not run long enough, causing conditions of high humidity.

The efficiency of a heat pump or performance rating (distinct from its capacity) is useful for comparing units of the same type. The ratings used for different types of equipment are not generally comparable. Heating performance is rated by the coefficient of performance (COP)—the rate of heat delivery relative to the total rate of energy input required to operate the heat pump. The average COP of a heat pump in heating mode may be in the range 2 to 3, meaning that heat delivered to a building is 2 to 3 times as great as the energy input required to operate the heat pump. The excess energy delivered (as heat) over the input (as electricity) is derived from the heat source—outdoor air for a conventional air source heat pump and ground or ground water for a geothermal unit).[15]

The COP of a heat pump is not the same in the heating and cooling modes but varies with conditions, in particular with the temperatures of the heat source and heat sink. This is important for heating, because the efficiency decreases as the temperature of the heat source decreases, i.e., the outdoor air in an air-to-air heat pump. When the outdoor air temperature falls to below about 32°F, the efficiency of an air-to-air heat pump is so low that auxiliary heating is required. The auxiliary heating system is usually resistance heat that supplements the heat pump, though an independent gas- or oil-fired furnace may be used. Electric resistance heat is very expensive and is best used as auxiliary heat or in climates where little heat is required. Hence, air-to-air heat pumps are not recommended where low winter temperatures are common and large amounts of auxiliary resistance heat are required. By comparison, geothermal heat pumps operate more efficiently by taking advantage of the fairly constant and warm temperature of the earth. Thus, they do not require auxiliary heating equipment.

The energy efficiency rating (EER) is commonly used to rate the efficiency of cooling performance. The EER in Btu per watthour is 3.412 (the Btu equivalent of a watthour) times the COP. A COP of 3 (i.e., 3.412 Btu per watthour x 3) equals an EER of 10.2 Btu per watthour. The EER can also be defined as the cooling capacity (size in Btu/hour) divided by the wattage of the unit (i.e., 36,000 Btu/hour/3,600 watts equals 10.0 Btu per watthour).

The newest term used by the air conditioning and heating industry to rate the efficiency of air conditioners and heat pumps is "Seasonal Energy Efficiency Rating" (SEER). While both the COP and EER values are valid only at specific test conditions used in the rating, the SEER is based on average or typical operating conditions.

Because of advances in technology and design, newer units have a SEER rating as high as 15 or 16. The Federal Government now requires new air conditioners and heat pumps to have a SEER of at least 10. Units that are 10 or more years old probably have a SEER of 10 or less. A new unit with a SEER of 12 will be one-third more efficient than an older unit with a SEER of 8.[16] In air-to-air heat pumps, when the outside air is below average temperatures (heat source) during the heating season or above average temperatures (heat sink) during the cooling season, the unit will not operate at the design SEER. Geothermal heat pumps that take advantage of the relatively constant temperature of the earth will be able to operate at the design SEER over wider temperature variations in the air.

[15] The heat in the outdoor air is derived from the sun, so that an air-to-air heat pump makes use of solar energy.

[16] To pump a specified amount of energy, in this example 24, two heat pumps with a SEER rating of 8 and 12 will require 3 and 2 units of input energy respectively, resulting in the heat pump with the SEER rating of 12 saving one-third the energy used by the less efficient unit.

Appendix A

EIA Renewable Energy Data Sources

The Energy Information Administration (EIA) develops renewable energy information from a wide variety of sources, cutting across different parts of the organization. This appendix provides a list of all sources which the EIA uses to obtain renewable energy information. While most data come from EIA data collection forms, some are derived from secondary sources. For EIA data collections, additional information is available in the EIA publication *Directory of Energy Data Collection Forms 1996*, DOE/EIA-0249(96), December 1996, or through the EIA home page.

EIA-63A/B, "Annual Solar Thermal Collector Manufacturers Survey" and "Annual Photovoltaic Module/Cell Manufacturers Survey"

Energy Sources: Solar energy.
Energy Functions: Disposition.
Frequency of Collection: Annually.
Respondent Categories: Solar thermal collector manufacturers and/or importers; photovoltaic module/cell manufacturers and/or importers;
Reporting Requirement: Mandatory.
Description: Forms EIA-63A/B are designed to gather for publication data on shipments of solar thermal collectors and photovoltaic modules. Data are collected by end use and market sector. Collector types include low-temperature, medium-temperature air, medium-temperature liquid, thermosiphon, flat plate, concentrator, integral collector storage, and evacuated tube and concentrators. Respondents are manufacturers, importers, and exporters of solar thermal collectors and photovoltaic modules. These forms were formerly known as CE-63A/B.

EIA-457A/H, "Residential Energy Consumption Survey"

Energy Sources: Coal and coal products; electricity; natural gas; petroleum and petroleum products; wood.
Energy Functions: Consumption costs and/or prices.
Frequency of Collection: Triennially.
Respondent Categories: Electric utilities; natural gas distributors (including importers/exporters); petroleum and petroleum product distributors; institutions (non-profit); individuals/households.
Reporting Requirement: Voluntary and mandatory.
Description: Forms EIA-457A through G are used to collect comprehensive national and regional data on both the consumption of and expenditures for energy in the residential sector of the economy. Data are used for analyzing and forecasting residential energy consumption. Housing, appliance, and demographic characteristics data are collected via personal interviews with households, and consumption and expenditure billing data are collected from the energy suppliers. End-use intensities are produced for space heating, water heating, air conditioning, refrigerators, and appliances. Rental agents are contacted by telephone to check on fuels used in rented apartments. Surveys were conducted in 1978, 1979, 1980, 1981, 1982, 1984, 1987, 1990, and 1993. Form EIA-457H is used to collect detailed lighting usage information for a subsample.

EIA-819M, "Monthly Oxygenate Telephone Report"

Energy Sources: Petroleum and petroleum products
Energy Functions: Production, Supply
Frequency of Collection: Monthly
Respondent Categories: Oxygenate producers, Petroleum and petroleum product distributors, Petroleum and petroleum product processors, Petroleum and petroleum product storers
Reporting Requirement: Mandatory
Legal Citation: Public Law 93-275 (FEAA), 13(b), 5(a), 5(b), 52
Description: Form EIA-819M is designed to obtain information on oxygenate production, imports, and end-of-month stocks. Data was previously collected using the EIA-819, Monthly Oxygenate Telephone Survey Data are reported by oxygenate type and PAD District. Respondents are a sample of: operators of facilities that produce oxygenates; operators of petroleum refineries;

operators of bulk terminals, bulk stations, blending plants, and other non-refinery facilities that store or blend oxygenates; and importers of oxygenates.

EIA-846 (A,B,C), "Manufacturing Energy Consumption Survey"

Energy Sources: Coal and coal products; electricity; natural gas; petroleum and petroleum products; wood.
Energy Functions: Consumption; disposition; financial; and/or management; production; research and development; other energy functions.
Frequency of Collection: Triennially.
Respondent Categories: Manufacturing.
Reporting Requirement: Mandatory.
Description: Forms EIA-846A through D are used to collect information on energy consumption, energy usage patterns, and fuel-switching capabilities of the manufacturing sector of the U.S. economy. The information from this survey is used to publish aggregate statistics on the consumption of energy for fuel and nonfuel purposes; fuel-switching capabilities; and certain energy-related issues such as energy prices, on-site electricity generation, and purchases of electricity from nonutilities. Since 1991, the survey has also collected information on end users of energy, participation in energy management programs, and penetration of new technology. Respondents are a sample of manufacturing establishments in Standard Industrial Classification categories 20 through 39.

EIA-860, "Annual Electric Generator Report"

Energy Sources: Electricity.
Energy Functions: Financial and/or management; production.
Frequency of Collection: Annually.
Respondent Categories: Electric utilities.
Reporting Requirement: Mandatory.
Description: Form EIA-860 is used to collect data on the status of electric generating plants and associated equipment in operation and those scheduled to be in operation in the United States within 10 years of filing of the report. These data are used to maintain and update EIA's electric power plant frame data base. Data are collected on power plant sites, and the design data of electric generators. Respondents include each electric utility that operates, or plans to operate, a power plant in the United States within 10 years of the report.

EIA-861, "Annual Electric Utility Report"

Energy Sources: Electricity.
Energy Functions: Disposition; financial and/or management; production.
Frequency of Collection: Annually.
Respondent Categories: Electric utilities.
Reporting Requirement: Mandatory.
Description: Form EIA-861 is a mandatory collection of data, filed annually by each electric utility in the United States, its territories, and Puerto Rico. The survey collects data on generation, wholesale purchases, and sales and revenue by class of consumer and State. These data are used to maintain and update the EIA's electric utility frame data base. This data base provides information to answer questions from the Executive Branch, Congress, other public agencies, and the general public. Respondents include each electric utility that is a corporation, person, agency, authority, or other legal entity or instrumentality that owns or operates facilities within the United States, its territories, or Puerto Rico for the generation, transmission, distribution, or sale of electric energy primarily for use by the public.

EIA-867, "Annual Nonutility Power Producer Report"

Energy Sources: Electricity.
Energy Functions: Production.
Frequency of Collection: Annually.
Respondent Categories: Nonutility power producers.
Reporting Requirement: Mandatory.
Description: Form EIA-867 is used to collect data annually from nonutility power producers who own or plan on installing electric generation equipment with a total capacity of one megawatt or more at an existing or proposed site. Electricity generation, installed capacity, and energy consumption data are collected. These data will be used to augment existing electric utility data and for electric power forecasts and analyses.

EIA-871A/F, "Commercial Buildings Energy Consumption Survey"

Energy Sources: Electricity; natural gas; natural gas products; petroleum and petroleum products; wood; other energy sources.
Energy Functions: Consumption; costs and/or prices.
Frequency of Collection: Triennially.

Respondent Categories: Commercial buildings; electric utilities; natural gas distributors (including importers / exporters); petroleum and petroleum product distributors; other (industry); Federal government institutions (nonprofit).

Reporting Requirement: Voluntary and mandatory.

Description: Forms EIA-871A through F are used to collect information for the Commercial Buildings Energy Consumption Survey (CBECS). The survey provides comprehensive national and regional information on the consumption of, and expenditures for, energy in the commercial sector of the economy. Data are used in EIA models and published in statistical and analytical reports. Physical characteristics information for commercial buildings is collected by personal interviews with building owners and managers using Form EIA-871A. Billing and consumption data for the buildings are collected by mail from individual energy suppliers by using Forms EIA-871C through F (depending upon the energy source). Supplemental information on construction improvements, maintenance, and repairs is collected for the Bureau of the Census by using Form EIA-871G. This survey was renamed the CBECS in 1989. Previously it was conducted under the name of Nonresidential Buildings Energy Consumption Survey.

EIA-902, "Annual Geothermal Heat Pump Manufacturers Survey"

Energy Sources: Geothermal.

Energy Functions: Disposition.

Frequency of Collection: Annually.

Respondent Categories: Geothermal heat pump manufacturers and importers.

Reporting Requirement: Mandatory.

Description: The Form EIA-902 collects information on shipments of geothermal heat pumps. The survey tracks shipments of the following three main types of geothermal heat pumps, as classified by the Air Conditioning & Refrigeration Institute (ARI), and the much smaller shipped volume of non-ARI rated systems. A brief description of the ARI-classified system is as follows:

> ARI 320—Water-Source Heat Pumps (WSHP)—These systems are installed in commercial buildings, where a central chiller or boiler supplies chilled or heated water, respectively, to heat pumps installed in series. The heat pumps reject building heat to chilled water during the cooling season and, during the heating season, take heat from boiler water.
>
> ARI 325—Ground Water-Source Heat Pumps (GWHP)—The GWHP is an open-loop system in which ground water is drawn from an aquifer or other natural body of water into piping. At the heat pump, heat is drawn from or dumped to the water through a heat exchanger to the refrigerant in the heat pump. The heated or cooled water returns to its source.
>
> ARI 330—Ground Source Closed-Loop Heat Pumps (GSHP)—A water or water / glycol (antifreeze) solution flows continuously through a closed loop of pipe buried underground. Ground heat is absorbed into or rejected from the solution flowing in the closed loop. At the heat pump, heat is drawn from or dumped to the closed loop solution via heat transfer through a heat exchanger, which passes heat to or removes heat from the refrigerant in the heat pump. Depending on the type of ground and land area, systems can either be installed horizontally or vertically.

Data are collected by model type, heat pump capacity, region of destination, customer type, and economic sector. Respondents are manufacturers and importers.

Appendix B

Renewable Data Limitations

This appendix provides information about the quality of renewable energy data presented in this report. Information pertinent to renewable energy source data quality, in general, is presented first, followed by discussion of electric and non-electric data sources by fuel type.

Renewable energy projects pose special challenges when attempting to collect complete information on them. One challenge is the dispersed nature of many renewable energy forms, such as a photovoltaic (PV) system for generating electricity that may operate in a "standalone" fashion in a remote location. If the facility is not connected to an electricity grid, there is no Federal regulatory requirement to report its operating information. Tracking down hundreds or thousands of such facilities, each with a small power output, can be extremely challenging.

Another challenge involves tracking renewable energy supplies. Conventional energy supplies, such as petroleum, are easily tracked because the distribution networks (usually pipelines) are limited and well-defined. This permits one to make reasonable assumptions about fuel consumption, assuming stocks can be reasonably estimated.[17] The same cannot be said for many renewable energy supplies. Often a large number of energy consumers must be surveyed in order to make reasonable inferences about renewable energy consumption. Wood, for example, is gathered by tens of thousands of entities—millions if residential use is considered—for fuel uses not reportable for regulatory purposes. Thus, obtaining accurate data on wood energy consumption would entail conducting large end use consumption surveys.

Finally, some renewable energy sources are byproducts (such as pulping liquor) of non-energy processes. To track such uses, information must be solicited from respondents not generally in the energy supply chain.

Electricity[18]

As noted in Chapter 1, 69 percent of renewable energy consumption measured by EIA is used to produce electric power. It is, therefore, important to examine the coverage quality of EIA renewable electricity data. EIA renewable electricity generation is derived from two principal sources: Form EIA-759, "Monthly Power Plant Report," and Form EIA-867, "Annual Nonutility Power Producer Report." Form EIA-759 is sent to all utilities, while the EIA-867 is required of all nonutility generating facilities exceeding 1 megawatt capacity. (This includes facilities which meet Federal Energy Regulatory Commission [FERC] standards as a "qualifying facility" [QF], as well as independent power producers [IPPs]). Therefore, off-grid electric applications are not captured here (although they may be covered in EIA's Manufacturing Energy Consumption Survey[19]).

Because electric utilities are easily identified, seldom change business status, and have mandatory regulatory reporting requirements, complete coverage of utility-generated electricity is virtually assured. In contrast, nonutilities (i.e., QFs and IPPs) are required only to file regulatory reports at the time of their intention to become a grid electricity-producing facility. Over time, QF ownerships and locations change frequently. These factors, combined with the large number of QF applications, make tracking these facilities difficult. Accordingly, EIA has developed a threshold below which nonutility units are not surveyed. Form EIA-867 is a mandatory survey of all existing and planned nonutility electric generating facilities in the United States with a total generator nameplate capacity of 1 megawatt or more.

An analysis of the Form EIA-867 universe indicates that the survey's capacity under coverage varies between 3

[17] Even if stock data are only approximate, conventional energy stocks are normally a small percentage of production.

[18] Information in this section is based on the report, "Renewable Energy Frame Review Updated Report: Survey Sampling Frame and Electricity Discrepancy Estimates," by Decision Analysis Corporation of Virginia (Vienna, Virginia, August 1993).

[19] Because the MECS is based on the Bureau of the Census' Annual Survey of Manufacturers, EIA does not know the identity of MECS respondents.

and 10 percent, depending on the fuel source (Table B1). Capacity and unit coverage are the most difficult for wind, where numerous small units exist. EIA has analyzed the differences between capacities reported for identical renewable units on Form EIA-867 and alternative sources. Capacity discrepancies were found to result from these factors:

- Obsolete information
- Facility versus generator reporting: A non-EIA source may cite capacity figures for an entire facility, not taking into account individual generators that use conventional fuels or a mixture of conventional and renewable fuels
- Capacity definition differences: Form EIA-867 requests respondents to report nameplate electric capacity. However, alternative capacity measures are being reported on non-EIA data sources
- Numerical rounding practices: This has the greatest effect on small units.

In a follow-up study of capacity discrepancies, the EIA-867 was over four times more likely to have the correct value than the alternative source, which covered units of all sizes.

Industrial (Nonutility) Generation

Until this issue of this report, nonutility generation for the current year was based on preliminary estimates of nonutility generation, with final data appearing in the following year's issue. An examination of 1996 data reveals that the preliminary estimate overstated the year-to-year increase in generation by a substantial amount (Table B2). In this report, final 1997 data comes from the Form EIA-867, "Annual Nonutility Power Producer Report," eliminating the source of error associated with preliminary data.

Table B2. Preliminary and Final Nonutility Renewable Generation Data Comparison
(Billion Kilowatthours)

Source	1996 Preliminary	1996 Final
Biomass	62,107	57,937
Geothermal	11,015	10,198
Hydroelectric	16,712	16,555
Wind	3,507	3,400
Solar	908	903

Sources: **1996 Preliminary:** Energy Information Administration, *Annual Energy Review 1996*, DOE/EIA-0384(96) (Washington, DC, July 1997); **1996 Final:** Table 4 of this report.

Non-Electric Renewable Energy Consumption

Overview

The primary application for renewable energy other than making electricity is creating heat for industrial processes, buildings, or water. Most non-electric

Table B1. Evaluation of EIA's Undercoverage of Nonutility Electricity Data

Fuel	Source	Number of Facilities[a]	Capacity (megawatts)
Biomass	EIA-867[b] (≥ 1 MW)	471	14,090
	"Electricity Discrepancy Estimates"[c]	759	15,037
Geothermal	EIA-867	48	1,551
	"Electricity Discrepancy Estimates"	57	1,590
Wind	EIA-867	82	1,803
	"Electricity Discrepancy Estimates"	739	1,992
Solar	EIA-867	11	365
	"Electricity Discrepancy Estimates"	152	374

[a]Excludes some EIA-867 facilities that could not be matched with facilities contained in non-EIA data sources.
[b]Based upon the 1991 survey year. Excludes *some* EIA-867 facilities that could not be matched with facilities contained in non-EIA data sources. The 1991 EIA-867 survey did not indicate what nonutility facilities under 5 megawatts are renewable.
[c]"Renewable Energy Frame Review Updated Report: Survey Sampling Frame and Electricity Discrepancy Estimates," by Decision Analysis Corporation of Virginia, August 2, 1993.
Source: Energy Information Administration, Form EIA-867, "Annual Nonutility Power Producer Report."

consumption data are gathered on two EIA consumption surveys: the Manufacturing Energy Consumption Survey (MECS), and the Residential Energy Consumption Survey (RECS). MECS is based on the U.S. Bureau of the Census' Census of Manufacturing. As far as renewable energy is concerned, MECS provides consumption estimates of total industrial energy and various categories of biomass, including wood. RECS is based on an area probability sample of households selected by EIA. For renewable energy, it provides estimates of residential wood energy consumption.

There are three other non-electric applications for renewable energy: solar heating, alcohol transportation fuels, and geothermal energy. Solar energy for non-electric applications is derived from the EIA Solar Collector Manufacturing Survey, Form EIA-63A/B (formerly CE-63A/B). The survey does not collect energy "consumption" data, but rather production statistics on various types of solar and photovoltaic energy units. EIA applies additional assumptions regarding their application to estimate the amount of heat energy derived from installed solar/PV panels. Alcohol fuel consumption information is provided by the Form EIA-819M, "Monthly Oxygenate Telephone Report." Geothermal non-electric energy information is taken from data provided by the Oregon Institute of Technology, Geo-Heat Center.

Biomass

Wood is the principal component of biomass energy. Information on non-electric wood energy consumption is derived from the MECS and RECS surveys.

Although some questions about MECS coverage have been raised, no formal analysis of current data exists to support this concern. According to 1983 U.S. Forest Service statistics on wood harvested for fuelwood, the Pulp and Paper Industry subgroup of the Forest Products Industry group consumed only 42 percent of total sector wood energy, not including black liquor (a byproduct fuel). MECS surveys the smaller-populated Pulp and Paper Industry intensively but only randomly samples the larger-populated remainder of the Forest Products Industry. For a variety of reasons, it is difficult to trace wood energy supply to wood consumed for energy. RECS covers wood consumption only for the primary residence of those surveyed; thus, wood consumption by second homes is omitted. This causes residential wood energy consumption to be understated by about 5 percent, if not adjusted. Beginning this year, EIA is adjusting RECS wood consumption estimates for second home use.

Cross-checks of Form EIA-819M information on alcohol fuels with data from the Bureau of Alcohol, Tobacco, and Firearms and the U.S. Department of Transportation have not revealed any major deficiencies in the Form EIA-819M data.

Geothermal

EIA does not collect data on non-electric applications of geothermal energy such as crop drying and ground-water heat pumps. A study prepared for the U.S. Department of Energy by the Oregon Institute of Technology, Geo-Heat Center, indicates that non-electric uses of geothermal energy amounted to nearly 16.2 trillion Btu in 1997 (Table B3). Sixty-four percent of this energy was provided by geothermal heat pumps.

Table B3. Geothermal Direct Use of Energy and Heat Pumps
(Quadrillion Btu)

	Direct Use	Heat Pumps	Total
1990	0.0048	0.0054	0.0102
1991	0.0050	0.0060	0.0110
1992	0.0051	0.0067	0.0118
1993	0.0053	0.0072	0.0125
1994	0.0054	0.0078	0.0132
1995	0.0056	0.0085	0.0141
1996	0.0057	0.0095	0.0152
1997	0.0059	0.0103	0.0162

Source: John Lund, Oregon Institute of Technology, Geo-Heat Center (Klamath Falls, Oregon, March 1998), unpublished data.

Wind, Solar, and Photovoltaics

EIA does not collect information on direct energy uses of wind (e.g., water-pumping). No comprehensive source of such information is known.

The data collected on Forms EIA-63A and EIA-63B are subject to various limitations: (1) coverage (the list of respondents may not be complete or, on the other hand, there may be double counting); (2) nonresponse (some of those surveyed may not respond, or they may not provide all the information requested); and (3) adjustments (errors may be made in estimating values for missing data).

EIA collects solar data only on terrestrial systems; it does not collect data on satellite and military applications. The total value of U.S. photovoltaic shipments in 1997 according to the Forms EIA-63A and EIA-63B was $175 million. Based on anecdotal information for 1998, shipments ranging from about $150 million to $160 million went for satellite applications. Military applications cannot be estimated due to classified information and budgetary accounting. These figures do not include possible inventories held by distributors, retailers, and installers.

The universe of solar / PV survey respondents is a census of those U.S.-based companies involved in manufacturing and / or importing solar collectors and photovoltaic cells and modules. Care has been taken to establish the survey frames accurately. The frames of potential respondents are compiled from previous surveys and from information in the public domain. However, because the solar collector and photovoltaic cell and module industries are subject to sporadic entry and exit of manufacturers and importers, the frame may exclude some small companies that have recently entered or reentered the industry. From 1993 through 1997, EIA received reports from all known potential respondents.

Geothermal Heat Pump Manufacturing Activity

In 1997, the EIA began collecting information on geothermal heat pumps using its new survey the Form EIA-902, "Annual Geothermal Heat Pump Manufacturers Survey." The principal data collected are the number and type of heat pumps and their capacity ratings.

The data collected on Form EIA-902 are subject to various sources of error. These sources are: (1) coverage (the list of respondents may not be complete or, on the other hand, there may be double counting); (2) nonresponse (all that are surveyed may not respond or may not provide all information requested); (3) respondents (respondents may commit errors in reporting the data); (4) processing (the data collection agency may omit or incorrectly transcribe a submission); (5) concept (the data collection elements may not measure the items they were intended to measure); and (6) estimation (errors may be made in estimating values for missing data). Because the survey is a census survey, the estimates shown in this report are not subject to sampling error. Although it is not possible to present estimates of nonsampling error, precautionary steps were taken at each stage of the survey design to minimize the possible occurrence of these errors.

Follow-up contacts with EIA-902 respondents suggest that the most important data quality issue is whether manufacturers are reporting ARI-320 units accurately, because these units can be used in multiple applications. ARI-320 units may be connected either to a "boiler / cooling tower" configuration or ground / ground water. Ground / ground water connections are geothermal applications, while boiler / cooling tower configurations are traditional water-to-water heat exchange uses. Some respondents apparently interpreted any water-to-water connection as geothermal and therefore reported all ARI-320 shipments as being units used in geothermal applications. The potential error is very large, possibly exceeding 50 percent of the ARI-320 estimate. Also, most manufacturers do not have records indicating the application type for individual ARI-320 units shipped. Therefore, manufacturer data reported on the EIA-902 for ARI-320 units are estimates and not counts.

Another data quality issue involves the distinction between ARI-325 and ARI-330 units. Many ARI-325 units are dual-rated to qualify as ARI-330 units, also. Which rating is appropriate depends upon the installed application, another factor not known when the manufacturer ships the unit. Therefore, while the sum of ARI-325 and ARI-330 units may be regarded as an accurate total, manufacturers estimate the number in each category based upon heuristic information.

EIA will be addressing these data quality issues in two steps. For the upcoming survey being sent out in 1999, the EIA-902 instructions and form will be clarified to emphasize the type of ARI-320 applications manufacturers should report as geothermal. Subsequently, EIA will propose modifications to the year 2000 survey to address the above issues.

Appendix C

Geothermal Heat Pump Survey Methodology

The Energy Information Administration (EIA) uses the Form EIA-902, "Annual Geothermal Heat Pump Manufacturers Survey," to collect annual information about the U.S. geothermal heat pump industry. Using this survey, the EIA obtains data from all U.S.-based geothermal heat pump manufacturers. Respondents to the survey are required to report data, by average rated capacity on: (1) shipments by calendar year; (2) shipments by destination; (3) shipments by type of customer; and (4) shipments by economic sector. The survey form and instructions are contained herein.

Survey Universe and Frame

The universe of the EIA-902 respondents is a census of U.S.-based companies involved in manufacturing geothermal heat pumps. Sources of potential respondents are compiled from previous surveys, professional and trade associations, and information in the public domain. However, because the geothermal heat pump industry is subject to sporadic entry and exit of manufacturers, the frame could exclude some small companies that recently entered (or re-entered) the industry.

Survey Procedures

The survey forms were sent out via first class mail to ensure their receipt only by the proper respondent organization. If the U.S. Postal Service was unable to deliver a survey form, the corrected address was obtained where possible. All known companies manufacturing geothermal heat pumps were contacted during this survey.

Approximately half of the respondents replied to the form within the specified initial deadlines. Those that did not were mailed another form specifying a new deadline. Those that had not responded by the second deadline were telephoned to encourage submission of the forms, and those calls resulted in the submission of the remaining forms.

Data Editing, Analyzing, and Processing

Responses to the surveys were first edited manually to verify the accuracy of the reporting and to ensure reliability of the data. Wherever manual editing procedures indicated discrepancies or omissions, telephone calls were made to confirm or clarify the data. Data from manually edited forms were then entered into the database and edited a second time via an automated procedure. After the second edit, a copy of each entry was reviewed by an analyst familiar with the survey, the geothermal heat pump industry, and its companies.

Response Rates

The response rate for the EIA-902 survey was 100 percent. The status of the companies that were mailed the Form EIA-902 is:

- Active Companies: Eighteen (18) companies are known to have shipped geothermal heat pumps during 1997.

- Out of Business: Twenty (20) companies reported being out of the geothermal heat pump industry during 1997.

Nondisclosure of Data

To protect the confidentiality of individual respondents' data, a policy was implemented to ensure that the reporting of survey data in this publication would not associate those data with a particular company. This is in compliance with EIA Standard No. 88-05-06 "Nondisclosure of Company Identifiable Data in Aggregate Cells." In tables where the nonzero value of a cell is composed of data from fewer than three companies, or if a single company dominates a table-cell value so that the publication of the value would lead to identification of a company's data, the EIA classifies the cell value as "sensitive" and the cell value is withheld ("W") from publication. Within a table having a sensitive cell value, selected values in other cells of the table are also withheld, as necessary, so that the sensitive cell value cannot be computed using the values in published cells.

A sensitive table-cell value can be reported, if permission is first obtained from each company (whose data contribute to the sensitivity) to publish the value. This is the only exception to the application of EIA Standard No. 88-05-06 in this report.

Survey Accuracy

A discussion of potential limitations on the accuracy of the data collected on the Form EIA-902 is contained in Appendix B.

U.S. Department of Energy
Energy Information Administration
FORM EIA-902 (1997)

FORM EIA-902
ANNUAL GEOTHERMAL HEAT PUMP MANUFACTURERS SURVEY
1997

Form Approved
OMB No. 1901-0303,
Expires 8/31/2000

GENERAL INFORMATION AND INSTRUCTIONS

I. PURPOSE

Form EIA-902 is used to collect data about the manufacture and distribution of geothermal heat pumps and the status of the industry. The information collected will be used by public and private analysts interested in geothermal heat pumps and related energy issues.

II. WHO MUST SUBMIT

This report is mandatory and is being required pursuant to the authority granted to the Department of Energy (DOE) by the Federal Energy Information Administration Act of 1974 (Public Law 93-275). Form EIA-902 is to be submitted by all companies within the 50 States, District of Columbia, Puerto Rico, the Virgin Islands, Guam, and the other U.S. territories and possessions which manufactured and shipped any geothermal heat pumps during the period 1994-1996. The form requests information on any geothermal heat pumps shipped in calendar years 1994, 1995, and 1996, and detailed information about shipments made in 1996.

III. WHERE TO SUBMIT COMPLETED FORMS

Return the completed Form EIA-902 to:

U.S. Department of Energy (EI-522)
Energy Information Administration, BG-094
1000 Independence Ave., SW
Washington, D.C. 20277-7091

Completed forms may also be faxed to Peter Holihan, the Form EIA-902 Manager, at (202) 426-1308. Requests for further information and/or additional forms may be mailed to the above address, telephoned to Mr. Holihan at (202) 426-1147, or sent by E-mail to JHolihan@eia.doe.gov

IV. WHEN TO SUBMIT

Completed EIA-902 forms are due by October 20, 1997.

V. SANCTIONS

The timely submission of Form EIA-902 by those required to report is mandatory under Section 13(b) of the Federal Energy Administration Act of 1974 (FEAA) (Public Law 93-275), as amended. Failure to respond may result in a civil penalty of not more than $2,500 for each violation, or a fine of not more than $5,000 for each willful violation. The government may bring a civil action to prohibit reporting violations which may result in a temporary restraining order or a preliminary or permanent injunction without bond. In such civil action, the court may also issue mandatory injunctions commanding any person to comply with these reporting requirements.

VI. PROVISIONS REGARDING CONFIDENTIALITY OF INFORMATION

The Office of Legal Counsel of the Department of Justice concluded on March 20, 1991, that the Federal Energy Administration Act requires the Energy Information Administration to provide company-specific data to the Department of Justice, or to any other Federal agency when requested for official use, which may include enforcement of Federal law. The information contained on this form may also be made available, upon request, to another component of the Department of Energy (DOE), to any Committee of Congress, the General Accounting Office, or other Congressional agencies authorized by law to receive such information. A court of competent jurisdiction may obtain this information in response to an order.

The information contained on this form will be kept confidential and not disclosed to the public to the extent that it satisfies the criteria for exemption under the Freedom of Information Act (FOIA), 5 U.S.C. §552, the DOE regulations, 10 C.F.R. §1004.11, implementing the FOIA, and the Trade Secrets Act, 18 U.S.C. §1905.

GENERAL INSTRUCTIONS

Upon receipt of a request for this information under the FOIA, the DOE shall make a final determination whether the information is exempt from disclosure in accordance with the procedures and criteria provided in the regulations. To assist in this determination, respondents should demonstrate to the DOE that, for example, their information contains trade secrets or commercial or financial information whose release would be likely to cause substantial harm to their company's competitive position. A letter accompanying the submission that explains (on an element-by-element basis) the reasons why the information would likely cause the respondent substantial competitive harm if released to the public would aid in this determination. A new justification does not need to be provided each time information is submitted on the form, if the company has previously submitted a justification for that information and the justification has not changed.

SPECIFIC INSTRUCTIONS

Item

1.01 (a-e) Make corrections to the company name or address in the spaces provided.

2.0 Enter the number of geothermal heat pumps and the total rated capacity in tons of those pumps for each heat pump type listed that was manufactured and shipped in each of the years 1994, 1995, and 1996. The totals should be the sums of the various heat pump types and their capacities for each report year.

3.0 Enter the number of geothermal heat pumps by type shipped in 1996 to each destination listed. Destinations include exported as well as the 50 States, the District of Columbia, Puerto Rico, and the U. S. Virgin Islands. Include shipments within the State of manufacture.

4.0 Enter the number of geothermal heat pumps shipped to each type of customer in 1996. If a customer could be included in more than one of the customer categories listed, include the number of pumps shipped to that customer in the first appropriate category in the list. For example, if a customer is both an exporter and a wholesale distributor, shipments to that customer would be classified as shipments to an "exporter." Another example is a customer that is both a retail distributor and an installer. Shipments to that customer would be reported under the "retail distributor" category because that category appears in the list before the "installer" category.

5.0 For each economic sector enter the average rated capacity (size in tons) of geothermal heat pumps by type shipped in 1996. The economic sectors are defined below. (Detailed descriptions are in the Definitions section of the instructions):

Residential—Geothermal heat pump applications related to any building used for residential occupancy that has a system for heating or cooling, or both. This includes single-family homes, multifamily dwellings, and mobile. Institutional housing, such as school dormitories, hospitals, and military barracks should be included in the "Commercial" category.

Commercial—Geothermal heat pump applications for use in businesses where services (rather than products) are provided, such as wholesale and retail trade or health and educational services. Institutional housing such as school dormitories, hospitals, and military barracks are included in the commercial sector. Federal, State, and local government should <u>not</u> be included in commercial, but should be reported in the "Government" category.

Industrial—Geothermal heat pump applications for use in business where products (rather than services) are provided, such as the manufacture and processing of goods and basic materials. Also included are mining, construction, agriculture, fisheries, and forestry. Electric utilities should <u>not</u> be included in the industrial sector, but should be reported in the "Electric Utility" category.

SPECIFIC INSTRUCTIONS (Continued)

Item

5.0 (continued)

Government –Geothermal heat pump applications for use with local, State, or Federal government buildings.

Electric utility–Geothermal heat pump applications used at any electric utility. Nonutility power producers should not be included in the electric utility sector.

Other–Shipments of heat pumps to customers that can not be included in one of the economic sectors listed above. Please include a brief description of the customer type.

6.1 Enter any comments or remarks in the space provided.

6.2 Check either " yes" or "no" to indicate whether you want the name and address of your company to appear in an Energy Information Administration (EIA) report publishing the data collected by this survey. Persons who read the report may refer to the Appendix to determine who are geothermal heat pump manufacturers.

6.3 Check either " yes" or "no" to indicate whether you want to receive a copy of the EIA report publishing the data collected by this survey.

7.0 Enter the name, title, signature, date and telephone number of a company representative who may be contacted for additional information regarding this submission.

DEFINITIONS

1. **ARI certified:** certification by the Air-Conditioning and Refrigeration Institute (ARI) that a pump has been tested using procedures stipulated in ARI standards and that it meets the manufacturer's certified published performance rating.

   ARI Standards 320, 325, and 330 refer to a rating system for testing performance of a water source heat pump when installed under three different conditions. For this reason, a single pump could be certified under all three ratings, and could potentially be installed under different circumstances.

   Geothermal heat pumps refer to systems where the unit uses the earth or natural body of water as a heat sink. There are typically three types of geothermal systems:

1) A water source heat pump rated under standard ARI-320 is typically installed in a commercial application where several heat pumps are installed in series, with a central chiller or boiler supplying the heating or cooling of the fluid.

2) A ground water source system is a standard ARI-325 installation, and is an open-loop system that uses a natural body of water for the exchange of heat. An open-loop heat pump system is a heat pump system that directly utilizes water from a well or water body, pumps it through a pipe for use as a heat exchanger and returns it back to the environment.

3A) A ground source system is a standard ARI-330 installation, and is a closed-loop system that uses water or a water/glycol solution to exchange heat. The system employs extensive tubing which is buried fairly deep the ground. A closed-loop heat pump system is a geothermal heat pump system that uses water/anti-freeze in a buried pipe loop as a heat exchanger. The water/anti-freeze in the loop never leaves the system. Loop piping can be installed vertically or horizontally in the earth, a lake, a channel or the ocean.

3B) A direct expansion system is a geothermal heat pump system that uses refrigerant in a buried pipe loop as a heat exchanger. The refrigerant in the loop never leaves the system. A direct expansion system is also ground source system with a closed-loop which uses refrigerant throughout the system rather than a water/glycol solution to exchange heat.

2. **Commercial sector:** The commercial sector, as defined economically, consists of all business facilities and organizations that are engaged in other than those classified as industrial (manufacturing, agriculture, forestry, fisheries, mining, and construction), government, or electric utilities. Commercial establishments include hotels, motels, restaurants, wholesale businesses, retail stores, laundries, and other enterprises; religious and nonprofit organizations; transportation facilities such as bus stations, airports, and train stations; health, social, and educational institutions. Institutional housing, such as school dormitories, hospitals, and military barracks are included in the commercial sector. Federal, State, and local governments are not included in the commercial sector for this survey, but should be reported in the government sector.

3. **Electric utility sector:** The electric utility sector includes a corporation, person, agency, authority, or other legal entity or instrumentality that owns, and/or operates facilities for the generation, transmission, distribution, or sale of electric energy. Nonutility electric power producers are not included in the electric utility sector and should be included in the industrial sector.

4. **Geothermal heat pump:** Also referred to as ground-source, earth-coupled, or ground-water heat pumps. A pump which uses the earth as a heat sink during warm weather and as a heat source during colder weather. A pump is rated to ARI standards but may not be certified by ARI.

5. **Government sector:** The government sector includes all local, State, and Federal government buildings. This includes military barracks.

6. **Heat sink:** A substance into which heat is injected or is absorbed. Substances can be gas, liquid or solid like air, water and earth.

7. **Heat source:** A substance from which heat is received or radiates. Substances can be a gas, liquid or solid like air, water and earth.

DEFINITIONS (continued)

8. **Industrial sector:** The industrial sector comprises manufacturing industries, which make up the largest part of the sector, along with mining, construction, agriculture, fisheries, and forestry. Establishments in this sector range from steel mills, to small farms, to companies assembling electronic components. Electric utilities should not be included in the industrial sector but should be reported in the electric utility sector.

9. **Residential sector:** The residential sector consists of all private residences, whether occupied or vacant, owned or rented, including single-family homes, multifamily housing units, and mobile homes. Secondary homes, such as summer homes, are also included. Institutional housing, such as school dormitories, hospitals, and military barracks are included in the commercial sector.

10. **Ton:** A measure of the amount of Btu's (British thermal units) needed to melt one ton of ice in a 24-hour period. One ton equals 12,000 Btu's/hour available to heat and/or cool space.

Energy Information Administration
U.S. Department of Energy

Form Approved
OMB No. 1901-0303
Expiration Date: 8/31/2000

ANNUAL GEOTHERMAL HEAT PUMP MANUFACTURERS SURVEY
FORM EIA-902

This report is authorized under Federal Energy Administration Act of 1974 (Public Law 93-275). Your response is mandatory and confidential. For the provisions regarding the confidentiality of information submitted on this form, see Part VI of the instructions. Respondents are not required to file or reply to any Federal collection of information unless it has a valid OMB control number. Public reporting burden for this collection of information is estimated to average 4 hours per response including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to the Energy Information Administration, Statistics and Methods Group, EI-70, 1000 Independence Ave., S.W., Washington, D.C. 20585-0670, and the Office of Information and Regulatory Affairs, Office of Management and Budget, Washington, D.C. 20503.

The report period for Question 2 is calendar years 1994-1996.
Questions 3 - 5 are for calendar year 1996 shipments **only**.

For instructions and definitions, please refer to the General Information and Instructions included with this form.

If you have any additional questions, please call Peter Holihan, the Survey Manager, at (202) 426-1147.

1.0 RESPONDENT INFORMATION

Use (a) through (e) below only if the label is incorrect.

ADDRESS LABEL HERE

(a) Company Name: ____________________

(b) Street Address: ____________________

(c) City : ____________________

(d) State: ____________________

(e) Zip: ____________________

2.0 SHIPMENTS IN CALENDAR YEARS 1994-1996 - Please enter the total number of units and the total rated capacity for each type of geothermal heat pump unit shipped for the years 1994, 1995, and 1996.

		1994		1995		1996	
Code	Type of Geothermal Heat Pump (GHP)	Number of GHPs (1)	Total Rated Capacity (in tons) (2)	Number of GHPs (3)	Total Rated Capacity (in tons) (4)	Number of GHPs (5)	Total Rated Capacity (in tons) (6)
1	ARI-320 **for GHP only**						
2	ARI-325						
3	ARI-330						
4	Other Non-ARI Rated						
5	TOTALS						

3.0 SHIPMENTS IN 1996 BY DESTINATION - Enter the number of geothermal heat pumps your company shipped in 1996 to the destinations (i.e., exported, by State, the District of Columbia, Puerto Rico, and the Virgin Islands) listed below. Include in the shipments geothermal heat pumps shipped within the state of manufacture. If any geothermal heat pumps were exported, please indicate the number exported under Code 00.

		NUMBER OF GEOTHERMAL HEAT PUMPS SHIPPED IN 1996			
Code	Destination	ARI-320 (1)	ARI-325 (2)	ARI-330 (3)	Other Non-ARI Rated GHPs (4)
00	Exported				
01	Alabama				
02	Alaska				
03	Arizona				
04	Arkansas				
05	California				
06	Colorado				
07	Connecticut				
08	Delaware				
09	District of Columbia				
10	Florida				
11	Georgia				
12	Hawaii				
13	Idaho				
14	Illinois				
15	Indiana				
16	Iowa				
17	Kansas				
18	Kentucky				
19	Louisiana				
20	Maine				
21	Maryland				
22	Massachusetts				
23	Michigan				
24	Minnesota				
25	Mississippi				
26	Missouri				
27	Montana				
28	Nebraska				
29	Nevada				
30	New Hampshire				

3.0 SHIPMENTS IN 1996 BY DESTINATION (continued)

		NUMBER OF GEOTHERMAL HEAT PUMPS SHIPPED IN 1996			
Code	Destination	ARI-320 (1)	ARI-325 (2)	ARI-330 (3)	Other Non-ARI Rated GHPs (4)
31	New Jersey				
32	New Mexico				
33	New York				
34	North Carolina				
35	North Dakota				
36	Ohio				
37	Oklahoma				
38	Oregon				
39	Pennsylvania				
40	Puerto Rico				
41	Rhode Island				
42	South Carolina				
43	South Dakota				
44	Tennessee				
45	Texas				
46	Utah				
47	Vermont				
48	Virgin Islands (U.S.)				
49	Virginia				
50	Washington				
51	West Virginia				
52	Wisconsin				
53	Wyoming				
99	TOTALS				

4.0 1996 SHIPMENTS BY TYPE OF CUSTOMER - Enter the number of geothermal heat pumps shipped in 1996 by customer type. If a customer could be included in more than one category (e.g., a retail distributor who is also an installer), report the units shipped to that customer in the first appropriate category listed (i.e., retail distributor for the example listed).

		NUMBER OF GEOTHERMAL HEAT PUMPS SHIPPED IN 1996			
Code	Customer Type	ARI-320 (1)	ARI-325 (2)	ARI-330 (3)	Other Non-ARI Rated GHPs (4)
1	Exporter				
2	Wholesale Distributor				
3	Retail Distributor				
4	Installer				
5	End-User				
6	Others (describe)				
7	TOTALS				

5.0 1996 SHIPMENTS BY ECONOMIC SECTOR - Enter the average rated capacity (i.e., size in tons) of each type of geothermal heat pump shipped in 1996 to each economic sector.

		AVERAGE RATED CAPACITY (size in tons)			
Code	Economic Sector	ARI-320 (1)	ARI-325 (2)	ARI-330 (3)	Other Non-ARI Rated GHPs (4)
1	Residential				
2	Commercial (excluding government)				
3	Industrial (excluding electric utilities)				
4	Government (local, State, and Federal)				
5	Electric utility				
6	Other (describe)				

6.0 ADDITIONAL INFORMATION

6.1 Enter any additional comments or remarks here: ______________________________

____

6.2 Do you want the name and address of your company to appear in the Energy Information Administration report publishing data collected in this survey? Yes________ No_________

6.3 Do you want to receive a copy of the report publishing the survey data? Yes________ No_________

7.0 CONTACT PERSON

7.1 Name: ______________________ 7.2 Title: ______________________

7.3 Signature: ______________________ 7.4 Date: __________ 7.5 Phone Number: ____________

Completed forms should be mailed to: U.S. Department of Energy (EI-522), Energy Information Administration, BG-094, 1000 Independence Ave. SW, Washington, D.C. 20277-7091

Completed forms may also be faxed to: ATTN: Peter Holihan at 202-426-1308.

Appendix D

Selected List of Internet Addresses: Renewable Energy Information by Resource

The list of addresses that follow are current as of Summer 1998. This list is abbreviated due to the great increase in internet sites as well as the growing presence of links to associated web sites over the past few years. Therefore, this list should provide at least a useful start in a search for renewable energy information.

General: Renewables

Department of Energy (DOE), Energy Efficiency and Renewable Energy Homepage
http://eren.doe.gov

For information on DOE Renewable Energy Regional Offices
http://www.eren.doe.gov/rso.html

Energy Information Administration Homepage
http://www.eia.doe.gov

North Carolina Solar Center, Renewable Energy State Incentives Database (co-sponsored by DOE)
http://www.ncsc.ncsu.edu

Center for Renewable Energy and Sustainable Technology
http://www.crest.org./renewables/index.html

International Energy Agency
IEA CADDET International Information on Renewable Energy
http://www.caddet.co.uk/re/

National Renewable Energy Laboratory
NREL Publication Index
http://www.nrel.gov/cgi-bin/pubspage.cgi

National Association of Regulatory Utility Commissioners (NARUC) Homepage
http://www.naruc.org/

California Energy Commission
http://www.energy.ca.gov/index.html

Biomass: Wood

Regional Wood Energy Development Programme in Asia
http://www.rwedp.org/

WSU Energy Program Library Title List: Wood Fuels
http://www.energy.wsu.edu/ep/library/catalog/eng/slinks/s002476.htm

Supply of Short Rotation Woody Crop Biomass to the Watts Bar Power Facility This is a brief description of studies that exemplify the methods and approaches that have been developed:
http://www.esd.ornl.gov/iab/iab5-7.htm
and for standing woody biomass (TREEDYN3*):
http://www.gsf.de/UFIS/ufis/modell60/grs957.html

Chemical Nature of Biomass from Semi-Arid Forest Tree Species S5.01-02 Natural Variations in Wood Quality / P5.01-00 Properties and Utilization of Tropical Woods Theme: ...
http://www.metla.fi/conf/iufro95abs/d5pap22.htm

PCSD Agriculture: Biomass PCSD BRIEFING BOOK Sustainable Agriculture BIOMASS ENERGY INITIATIVES PROJECT HISTORY
http://bertha.chattanooga.net/sustain/pcsd_briefing_book/agriculture_biomass.html
http://www.gsf.de/UFIS/ufis/schlag_groessen/schlagwort419.html

Biomass: Biofuels

Biofuels (Federal Government) Resources on the Internet
http://www.nal.usda.gov/ttic/biofuels/nonusda.htm

BioPower Information Network
http://www.eren.doe.gov/biopower/

American Bioenergy Association
http://www.biomass.org/

Bioenergy Information Network Database Annex Search the ORNL Bioenergy Feedstock Development Program Bibliography
http://dsimd.dsrd.ornl.gov/htmldocs/biofuels/biofuels.htp

Energy Information on Internet: BIOFUELS INFORMATION NETWORK ECN_logo Energie Informatie via Internet BIOFUELS INFORMATION NETWORK Title Organization: Biofuels System ...
http://blister.ecn.nl/eii/homepgnl/eii_013.html

Renewable Energy: Biomass and Biofuels Renewable Energy: Biomass and Biofuels
http://lacebark.ntu.edu.au/j_mitroy/sid101/energyfacts/re-bioms.html

Atmospheric Science Curriculum Bookmarks Alternative Fuels Biofuels Information
http://krusty.eecs.umich.edu/people/jreed/weather/ravenbkms.html

Alternative Fuels Data Center
http://www.afdc.doe.gov

Sustainable Energy Energy Agricultural Energy Agricultural Energy Assistance Program, California ALTERNATIVE ENERGY California Energy Commission: Alternative/Renewable Technologies EPA.
http://www.netins.net/showcase/s_energy/energy.htm

National Renewable Energy Laboratories- Biofuels Information Center; The Biofuels Information Center, managed by the National Renewable Energy Laboratory
http://www.biofuels.nrel.gov/

Short-Rotation Woody Crops (SRWC) Operations Working Group
http://www.esd.ornl.gov/bfdp/srwcwgrp/menu.html

Municipal Solid Waste

Characterizations of Municipal Solid Waste in the United States 1995 Update
http://rredc.nrel.gov/biomass/epa/msw95/msw95_index.html

ENVIRONMENTAL STUDIES 17. TOXIC AND SOLID WASTE Most waste produced by preindustrial societies is biodegradable. In industrial societies, much waste is nondegradable ...
http://www.fcn.org/fcn/ecosystem/wast_po.html

The Solid Waste Association of North America
http://www.swana.org/

Municipal Solid Waste Factbook.
http://www.epa.gov/epaoswer/non-hw/muncpl/factbook.htm

Guide to the Preparation of Regional Solid Waste Management Plans by Regional Districts (Part I), British Columbia, Canada
http://www.env.gov.bc.ca/epd/cpr/guidelns/gprswmp1.html

Waste-to-Energy

Waste-to-Energy in the United States: A Social and Economic Assessment
http://www.esd.ornl.gov/iab/iab8-6.htm

Integrated Waste Services Association
http://www.wte.org/index.html

European Energy-from-Waste Coalition
http://www.eewc.org/19.htm

U.K. World Resource Foundation Homepage: sustainable waste management
http://www.wrfound.org.uk/

Geothermal

GeoLinks
http://www.inter-pc.com/user/josh/es/project/geolinks.html

Geothermal Heat Pumps
http://www.apogee.net/res/rehpgov.htm

Geothermal Products Inc. - Energy Star Programs
http://www.geoproducts.com/estar.html

Geothermal Heat Pump Links
http://www.ilec.org/heatlink.html

Geothermal Technologies Program - Other Resources
http://www.eren.doe.gov/geothermal/resource.html

Geothermal Technologies Program - Publications
http://www.eren.doe.gov/geothermal/public.html

International Geothermal Association - US DOE Sites
http://www.demon.co.uk/geosci/wrusadoe.html

US DOE/Geothermal Energy Technical Site
http://geothermal.id.doe.gov

Geo-Heat Center, Oregon Institute of Technology, Geothermal Information and Technology Transfer
http://www.oit.osshe.edu/~geoheat/

International Geothermal Association
http://www.demon.co.uk/geosci/igahome.html

IEA: International Energy Agency
http://www.iea.org/stats/defs/sources/geo.htm

U.S. Geothermal Direct Use Projects and Resource Areas
http://www.oit.osshe.edu/~geoheat/dusys.htm

Geothermal Theory: Introduction
Summary: How Geothermal Systems Form. Geothermal Occurances Today.
http://www.crest.org/renewables/re-kiosk/geothermal/theory/index.shtml

Geothermal Energy in California
http://www.energy.ca.gov/development/geothermal/index.html

Geothermal Workshop
Summary: The New Zealand Geothermal Workshop is a three-day conference held annually in early November. The Workshop provides an international forum where engineers and earth scientists discuss aspects of geothermal development.
http://www.auckland.ac.nz/gei/workshop.htm

Geothermal Links
Summary: GEOTHERMAL LABORATORY GEOTHERMAL LINKS.
Internation Geothermal Association Nappa Valley/Geysers/Geothermal Area Sites/Geyser Resources/ Coso's Geothermal Field/Water Resources of California/Geothermal Resources/ Council World Geothermal Resources/ Maps.
http://www.geology.smu.edu/~bonner/geothermlinks.html

Geothermal Theory: Geothermal Use Today
Summary: Geothermal power plants now provide more than 2,500 megawatts of clean electricity to the United States, equivalent to three large nuclear power plants. According to the U.S. Energy Information Administration, geothermal has the potential to provide the United States with 12,000 megawatts of electricity by the year 2010.
http://www.crest.org/renewables/re-kiosk/geothermal/theory/usetoday.shtml

Geothermal Theory, Geothermal Reservoirs: Fractured Rock (2)
Summary: In most high-temperature reservoirs, much of the porosity and permeability exist in natural rock fractures, although they may be artificially induced. In other reservoirs, the space between sand grains in the rock provides ample porosity and permeability.
http://www.crest.org/renewables/re-kiosk/geothermal/theory/fracturedrock2.html

Wind

Danish Wind Turbine Manufacturers Association
http://www.windpower.dk/core.htm

Wind Info Resources on the Net
http://www.afm.dtu.dk/wind/bookmark.html

British Wind Energy Association
http://www.bwea.com/

Wind Energy Utilization in the Federal Republic of Germany -
http://www.dewi.de/statistics.html

RICO Wind Energy & Atmospheric Physics
http://www.risoe.dk/vea-wind/

03/27/95 Talking Points - 25th Annual Conference U. S. Wind Energy Industry Opening Session Monday, March 27, 1995 8:30 a.m. PRESS AVAILABILITY 25th ANNUAL CONFERENCE U.S.
...http://apollo.osti.gov/html/secretry/tp950327.html

American Wind Energy Association. This comprehensive, up-to-date reference includes contact as well as product information. .
http://www.igc.apc.org/awea/aweapage.html

Alternative Energy Institute Homepage:
http://www.wtamu.edu/academic/gradres/aei/

Windpower Monthly
http://www.wpm.co.nz/

U.S. Dept. of Energy, Energy Efficiency and Renewable Energy Network (EREN), Wind Energy Program
http://www.eren.doe.gov/RE/wind.html

National Renewable Energy Laboratory's National Wind Technology Center
http://nwtc.nrel.gov/

Wind Power Development
http://www.telosnet.com/wind

Solar Energy

Solar Energy Industry
http://www.seia.org

International Solar Energy Society
http://wire.ises.org

Solar Thermal

DOE's Solar Thermal Electric Program
http://www.eren.doe.gov/ste/

ASME Solar Energy Division
http://www.asme.org/divisions/solar/index.html

FREQUENTLY ASKED QUESTIONS - SOLAR POWER
http://www.greenpeace.org.uk//solar//faq2.html

Solar Energy
http://solstice.crest.org/renewables/re-kiosk/solar/index.shtml

Solar Thermal Case Studies A solar thermal water heating system provides St. Rose Hospital in San Antonio, TX.
http://solstice.crest.org/renewables/re-kiosk/solar/solar-thermal/case-studies/commercial.shtml

EREN - Solar Thermal Utilization Energy Efficiency and Renewable Energy Network
http://apollo.osti.gov/html/eren/1409.html

EREN - Solar Thermal Power Systems
http://www.doe.gov/html/eren/1407.html

The National Solar Thermal Test Facility (NSTTF) is operated by Sandia National Laboratories for the U.S. Department of Energy. It...
http://www.sandia.gov/Renewable_Energy/solarthermal/nsttf.html

National Solar Thermal Test Facility Questions Frequently Asked by NSTTF Visitors About Solar Energy How do Central Receiver power plants produce electricity from the heat of...
http://www.sandia.gov/Renewable_Energy/solarthermal/question.html

Solar Radiation and Solar Thermal Systems
Date: Saturday, 20-Jul-96 00:46:40 GMT Last-Modified: Wednesday, 11-Oct-95 14:27:55 GMT Content-type: text/html Content-length: 8514 MS 54 Selected Papers on Solar Radiation and ...
http://www.spie.org/web/abstracts/oepress/MS54.html

National Solar Thermal Test Facility Sandia National Laboratories Advantages of Using Molten Salt A variety of fluids was tested to transport the sun's heat, including water, air, ...
http://www.sandia.gov/Renewable_Energy/solarthermal/salt.html

National Solar Thermal Test Facility Sandia National Laboratories Desirable Features of Power Towers for Utilities Because of their practical energy storage, solar power ...
http://www.sandia.gov/Renewable_Energy/solarthermal/feature.html

National Solar Thermal Test Facility Sandia National Laboratories Engine Test Facility, Test Cell 1 and 2
http://www.sandia.gov/Renewable_Energy/solarthermal/engine1.html

The Sun's Joules: Solar Thermal, page 634/937, Solar1 and Solar2
http://www.crest.org/renewables/SJ/solar-thermal/634.html

Solar Photovoltaic

National Center For Photovoltaics
http://www.nrel.gov/ncpv

PV WEB SITES
http://www.pvpower.com/pvsites.html

Photovoltaic Energy -- Electricity from the Sunlight
http://www.doe.gov/phv/phvhome.html

Photovoltaic Module - PV Module Businesses in the World
http://www.mtt.com/theSource/renewableEnergy/businesses/byP/pvM/pvM.html

NREL Photovoltaics Program - What is PV?
http://www.nrel.gov/pv/whatispv.html

Siemens Solar Online
http://www.siemenssolar.com

Power Technology Division PHOTOVOLTAIC GENERATION PHOTOVOLTAIC BRANCH
http://powerweb.lerc.nasa.gov/pv/home.html

Advancing Photovoltaic Technology at NREL's Outdoor Test Facility logo
http://www.nrel.gov/lab/pao/otf.html

Million Solar Roofs Program
http://www.millionsolarroofs.org

PV at Electric Utilities
http://www.ttcorp.com/upvg

PV Systems Assistance Center
http://www.sandia.gov/pv

National Center For Photovoltaics
http://www.nrel.gov/ncpv

Appendix E

State Energy Agencies

The following lists the State Energy Office (or equivalent) and the Public Utility Commission (or equivalent) for each State.[20]

Alabama

State Energy Office
Martha McInnis, Division Chief
Department of Economic and Community Affairs
Science Technology and Energy Division
P.O. Box 5690
Montgomery, AL 36103-5690
(334) 242-5292
Fax: (334) 242-0552

Public Service Commission
Walter L. Thomas, Jr., Secretary
100 North Union Street
Room 850
P.O. Box 991
Montgomery, AL 36104
(334) 242-5218
Fax: (304) 242-0509

Alaska

State Energy Office
Robert Brean
Alaska Housing Finance Corporation
520 East 34th Avenue
Anchorage, AK 99503
(907) 338-6100
Fax: (907) 338-1747

Alaska Public Utilities Commission
Robert A. Lohr, Executive Director
1016 West 6th Avenue, Suite 400
Anchorage, AK 99501
(907) 276-6222
Fax: (907) 276-0160
E-Mail: apuc@apuc.ak.net

American Samoa

State Energy Office
Reupena Tagaloa, Director
ASPA / Territorial Energy Office
Samoa Energy House, Tafuna
P.O. Box PPB
Pago Pago, AS 96799
011 (684) 699-1101
Fax: 011 (684) 699-2835

Arizona

State Energy Office
Amanda Ormond, Director
Arizona Department of Commerce
3800 North Central Avenue, Suite 1200
Phoenix, AZ 85012
(602) 280-1402
Fax: (602) 280-1445

Corporation Commission
James Matthews, Executive Secretary
Arizona Corporation Commission
1200 W. Washington
Phoenix, AZ 85007-2996
(602) 542-3931
Fax: (602) 542-3977

Arkansas

State Energy Office
Morris Jenkins, Director
Arkansas Energy Office
One State Capitol Mall
Little Rock, AR 72201
(501) 682-7377
Fax: (501) 682-2703

[20] This information was excerpted from, Energy Information Administration, *Energy Information Directory, 1998,* DOE / EIA-0205(98) (September 1998).

Public Service Commission
Jerrell Clark, Director
Arkansas Public Service Commission
1000 Center Street
P.O. Box 400
Little Rock, AR 72203-0400
(501) 682-1794
Fax: (501) 682-2572

California

State Energy Commission
William J. Keese, Chairman
California Energy Commission
1516 9th Street
Sacramento, CA 95814
(916) 654-5000
Fax: (916) 654-4420

California Public Utilities Commission
Wesley M. Franklin, Executive Director
505 Van Ness Avenue, Room 5222
San Francisco, CA 94102
(415) 703-3808
Fax: (415) 703-1758

Colorado

State Energy Office
Wade Buchanan, Director
Colorado Office of Energy Conservation
1675 Broadway, Suite 1300
Denver, CO 80202-4613
(303) 620-4292
Fax: (303) 620-4288

Public Utilities Commission
R. Brent Alderfer, Commissioner
Logan Tower OL2, Logan Street
Denver, CO 80203
(303) 894-2070
Fax: (303) 894-2065

Connecticut

State Energy Office
Allan Johanson
Policy Development and Planning Division
Energy Unit
P.O. Box 341441, MS-52ENR
Hartford, CT 06134-1441
(860) 418-1441
Fax: (860) 418-6297

Department of Public Utility Control
Steven D. Cadwallader, Chief of Research
and Policy Analysis
10 Franklin Square
New Britain, CT 06051
(860) 827-2629
Fax: (860) 827-2613

Delaware

State Energy Office
Charlie T. Smisson, Jr., Energy Program
Administrator
Division of Facilities Management
410 Federal Street, Suite #2
O'Neill Building
Dover, DE 19903
(302) 739-5644
Fax: (302) 739-6148
URL: CSMISSON@STATE.DE.US

Delaware Public Service Commission
Bruce H. Burcat, Executive Director
1560 South Dupont Highway
Dover, DE 19901
(302) 739-4247
Fax: (302) 739-4849

District of Columbia

City Energy Office
Charles J. Clinton, Director
District of Columbia Energy Office
2000 14th Street, N.W., Suite 300E
Washington, DC 20009
(202) 673-6750
Fax: (202) 673-6725

Public Service Commission
Marlene L. Johnson, Esq., Chairperson
717 14th Street, N.W.
Washington, DC 20005
(202) 626-5100
Fax: (202) 393-1389

Florida

State Energy Office
William J. Tait, Director
Department of Community Affairs
2555 Shumard Oak Boulevard
Tallahassee, FL 32399-2100
(850) 488-2475
Fax: (850) 488-7688

Public Service Commission
William D. Talbott, Executive Director
2540 Shumard Oak Boulevard
Tallahassee, FL 32399-0850
(850) 413-6055
Fax: (850) 413-6052

Georgia

State Energy Office
Paul Burks
Georgia Environmental Facilities Authority
100 Peachtree Street, N.W.
2090 Equitable Building
Atlanta, GA 30303
(404) 656-0938
Fax: (404) 656-6416
Fax: (404) 656-7970 (Division of Energy)

Public Service Commission
B. B. Knowles, Director of Utilities
47 Trinity Avenue
Atlanta, GA 30334
(404) 656-4501
Fax: (404) 463-6532

Guam

State Energy Office
Fred P. Camacho, Director
Guam Energy Office
1504 East Sunset Boulevard
Tiyan, GU 96913
(671) 477-0557
Fax: (671) 477-0589

Hawaii

State Energy Office
Maurice H. Kaya, Administrator
Energy, Resources, and Technology
Division
Department of Business, Economic
Development and Tourism
P.O. Box 2359
Honolulu, HI 96804
(808) 587-3812
Fax: (808) 586-2536

Public Utilities Commission
Chairman
465 S. King Street, #103
Honolulu, HI 96813
(808) 586-2020
Fax: (808) 586-2066

Idaho

State Energy Office
Karl Dreher, Director
Idaho Department of Water Resources
1301 North Orchard Street
Boise, ID 83706
(208) 327-7900
Fax: (208) 327-7866

Public Utilities Commission
Stephanie Miller, Administrator
Utilities Division
P.O. Box 83720
Boise, ID 83720-0074
(208) 334-0366
Fax: (208) 334-3762

Illinois

Department of Commerce and Community Affairs
Mitch Beaver, Deputy Director
Bureau of Energy and Recycling
325 W. Adams Street, #300
Springfield, IL 62704-1892
(217) 785-2800
Fax: (217) 785-2618

Commerce Commission
Donna M. Caton, Chief Clerk
527 E. Capitol Avenue
Box 19280
Springfield, IL 62794-9280
(217) 782-7434
Fax: (217) 524-0673

Indiana

Indiana Department of Commerce
Cheryl L. DeVol-Glowinski, Director
Energy Policy Division
One North Capitol, Suite 700
Indianapolis, IN 46204-2288
(317) 232-8939
Fax: (317) 232-8995

Utility Regulatory Commission
302 West Washington Street
Suite E-306
Indianapolis, IN 46204
(317) 232-2701
Fax: (317) 232-6758

Iowa

State Energy Office
Larry Bean, Administrator
Iowa Department of Natural Resources
Energy and Geological Resources Division
502 E. 9th Street
Des Moines, IA 50319
(515) 281-4308
Fax: (515) 281-6794

Sharon A. Tahtinen, Chief
Energy Bureau
Iowa Department of Natural Resources
502 E. 9th Street
Des Moines, IA 50319
(515) 281-7066
Fax: (515) 281-6794

Iowa Utilities Board
Raymond K. Vawter, Executive Secretary
Lucas State Office Building
Des Moines, IA 50319
(515) 281-5256
Fax: (515) 281-5329

Kansas

State Energy Office
Jim Ploger, Energy Program Manager
Energy Programs
Kansas Corporation Commission
1500 S.W. Arrowhead Road
Topeka, KS 66604-4027
(785) 271-3349
Fax: (785) 271-3268

Corporation Commission
John Wine, Chairman
Kansas Corporation Commission
1500 S.W. Arrowhead Road
Topeka, KS 66604
(785) 271-3100
Fax: (785) 271-3354

Kentucky

State Energy Office
John M. Stapleton, Director
Kentucky Division of Energy
663 Teton Trail
Frankfort, KY 40601
(502) 564-7192
Fax: (502) 564-7484

Public Service Commission
Helen Helton, Executive Director
730 Schenkel Lane, Box 615
Frankfort, KY 40602
(502) 564-3940
Fax: (502) 564-3460

Louisiana

State Energy Office
Paula Ridgeway
Louisiana Department of Natural Resources
P.O. Box 44156
Baton Rouge, LA 70804-4156
(504) 342-1399
Fax: (504) 342-1397

Public Service Commission
Lawrence C. St. Blanc, Secretary
Suite 1630, One American Place
Baton Rouge, LA 70825
(504) 342-4427
Fax: (504) 342-4087

Mail letters to:
P.O. Box 91154
Baton Rouge, LA 70821-9154

Maine

State Energy Office
Brian K. Dancause, Supervisor
Energy Conservation Division
Department of Economic and Community Development
59 State House Station
Augusta, ME 04333
(207) 287-2656
Fax: (207) 287-5701

Public Utilities Commission
Christoper P. Simpson, Administrative Director
18 State House Station
242 State Street
Augusta, ME 04333
(207) 287-3831
Fax: (207) 287-1039

Maryland

State Energy Office
Frederick H. Hoover, Jr., Director
Maryland Energy Administration
45 Calvert Street, 4th Floor

Annapolis, MD 21401
(410) 260-7511
Fax: (410) 974-2250

Public Service Commission
Daniel P. Gahagan
6 St. Paul Centre
Baltimore, MD 21202-6806
(410) 767-8067
Fax: (410) 333-6495

Massachusetts

State Energy Office
David L. O'Connor, Commissioner
Massachusetts Division of Energy Resources
Leverett Saltonstall Building
100 Cambridge Street, Room 1500
Boston, MA 02202
(617) 727-4732
Fax: (617) 727-0030
E-Mail: energy@state.ma.us
URL: http://www.magnet.state.ma.us/doer

Department of Telecommunications and Energy
100 Cambridge Street, 12th Floor
Boston, MA 02202
(617) 305-3500
Fax: (617) 723-8812
URL: http://www.magnet.state.ma.us/dpu/

Michigan

Public Service Commission
John Strand, Chairman
Michigan Public Service Commission
P.O. Box 30221
6545 Mercantile Way
Lansing, MI 48909
(517) 334-6370
Fax: (517) 882-5002

Minnesota

State Energy Office
Krista L. Sanda, Commissioner
Department of Public Service
121 7th Place East, Suite 200
St. Paul, MN 55101-2145
(651) 296-7107
Fax: (651) 297-1959

Public Utilities Commission
Rick Lancaster, Executive Secretary
121 Seventh Place East, Suite 350
St. Paul, MN 55101-2147
(651) 296-7124
Fax: (651) 297-7073

Mississippi

State Energy Office
Chester B. Smith, Director
Mississippi Department of Economic and Community Development
Energy Division
P.O. Box 850
Jackson, MS 39205-0850
(601) 359-6600
Fax: (601) 359-6642

Mississippi Public Utilities Staff
Robert G. Waites, Director
Room 1738, Walter Sillers State Office Building
P.O. Box 1174
Jackson, MS 39215-1174
(601) 961-5493
Fax: (601) 961-5804

Missouri

State Energy Office
Division of Energy
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, MO 65102
(573) 751-4000
Fax: (573) 751-6860

Public Service Commission
Gordon Persinger
Executive Secretary
P.O. Box 360
Jefferson City, MO 65102
(573) 751-3234
Fax: (573) 526-7341

Montana

State Energy Office
Van Jamison, Administrator
Department of Environmental Quality
Planning, Prevention and Assistance Division
1520 East Sixth Avenue
Helena, MT 59620-0901
(406) 444-6812
Fax: (406) 444-1804

Public Service Commission
Kathy Anderson, Commission Secretary
1701 Prospect Avenue
Helena, MT 59620
(406) 444-6170
Fax: (406) 444-7618

Nebraska

State Energy Office
Robert Harris, Director
Nebraska Energy Office
The Atrium, 1st Floor
1200 N Street, Suite 110
Lincoln, NE 68509
(402) 471-2867
Fax: (402) 471-3064

Public Service Commission
M. G. Hand, Chief Engineer
300 The Atrium
1200 N Street, P. O. Box 94927
Lincoln, NE 68509-4927
(402) 471-3101
Fax: (402) 471-0254

Nevada

State Energy Office
DeeAnn Parsons, Chief
Nevada State Energy Office
1050 East William, Suite 435
Carson City, NV 89710
(702) 687-4910
Fax: (702) 687-4914

Public Service Commission
William H. Vance, Secretary
727 Fairview Drive
Carson City, NV 89710
(702) 687-6007
Fax: (702) 687-6110

New Hampshire

State Energy Office
Deborah Schachter, Director
Office of Energy and Community Service
57 Regional Drive
Concord, NH 03301-8519
(603) 271-2711
Fax: (603) 271-2615

Public Utilities Commission
Thomas B. Getz, Executive Director
8 Old Suncook Road
Concord, NH 03301-7319
(603) 271-2431
Fax: (603) 271-3878

New Jersey

New Jersey Board of Public Utilities
Herbert Tate, President
2 Gateway Center, 8th Floor
Newark, NJ 07102
(973) 648-2503
Fax: (973) 648-4195

Robert Chilton, Director
Division of Gas, Electric and Energy
2 Gateway Center, 9th Floor
Newark, NJ 07102
(973) 648-3621
Fax: (973) 648-2467

New Mexico

State Energy Office
Dianne Caron, Director
Energy Conservation & Management Division
Energy, Minerals & Natural Resources
Department
2040 South Pacheco
Santa Fe, NM 87505
(505) 827-4323
Fax: (505) 827-5870

Public Utility Commission
Dave Warren, Executive Director
224 E. Palace
Santa Fe, NM 87501
(505) 827-6940
Fax: (505) 827-6973

New York

Department of Public Service
John C. Crary, Secretary
3 Empire State Plaza
Albany, NY 12223-1350
(518) 474-6530
Fax: (518) 486-6081
E-Mail: web@dps.state.ny.us

North Carolina

State Energy Office
T. C. Adams, III, Director
North Carolina Department of Commerce
Energy Division
430 North Salisbury Street
P.O. Box 25249
Raleigh, NC 27611
(919) 733-1889
Fax: (919) 733-2953

Public Utilities Commission
Robert P. Gruber, Executive Director
Public Staff, P.O. Box 29520
Raleigh, NC 27626-0520
(919) 733-2435
Fax: (919) 733-9565

North Dakota

State Energy Office
Kim Christianson
Energy Program Manager
Office of Intergovernmental Assistance
State Capitol Building
600 E. Boulevard Avenue, 14th Floor
Bismarck, ND 58505-0170
(701) 328-2094
Fax: (701) 328-2308

Public Service Commission
Jon H. Mielke, Executive Secretary
State Capitol
Bismarck, ND 58505
(701) 328-2400
Fax: (701) 328-2410

Ohio

State Energy Office
Donald Jakeway, Director
Ohio Department of Development
Community Development Division
Office of Energy Efficiency
77 S. High Street, 26th Floor
Columbus, OH 43266-0413
(614) 466-6797
Fax: (614) 466-1864

State Oil and Gas Agency
Thomas G. Tugend, Acting Chief
Department of Natural Resources
Division of Oil and Gas
Fountain Square B-3
Columbus, OH 43224
(614) 265-6922
Fax: (614) 268-4316

Public Utilities Commission
Gary Vigorito, Director
Administration and Commission Secretary
180 E. Broad Street
Columbus, OH 43266-0573
(614) 466-4294
Fax: (614) 644-9546

Oklahoma

Secretary of Energy
Mike Smith
125 N.W. Sixth Street
Oklahoma City, OK 73105
(405) 235-4204
Fax: (405) 522-3492

State Alternative Fuels Office
Jeanie Robards, Administrator
Alternative Fuels Program
Department of Central Services
3301 North Santa Fe
Oklahoma City, OK 73118
(405) 521-4687
Fax: (405) 525-2682

State Energy Office
Brenda Williams
Oklahoma Department of Commerce
Division of Community Affairs and Development
P.O. Box 26980
Oklahoma City, OK 73126-0980
(405) 815-5351
Fax: (405) 815-5344

Oklahoma Corporation Commission
Ernest G. Johnson, Director
Public Utility Division
500 Jim Thorpe Office Building
2101 North Lincoln Boulevard
Oklahoma City, OK 73105
(405) 521-3908
Fax: (405) 522-3371

Larry A. Schroeder, Deputy Director
(405) 521-2518

Oregon

State Energy Office
John Savage, Director
Oregon Department of Energy
625 Marion Street NE
Salem, OR 97310-0831
(503) 378-4040
Fax: (503) 373-7806

Public Utility Commission
Ron Eachus, Commissioner
550 Capitol Street, N.E.
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Glossary

Alternating Current: An electric current that reverses its direction at regularly recurring intervals, usually 50 or 60 times per second.

Amorphous Silicon: An alloy of silica and hydrogen, with a disordered, noncrystalline internal atomic arrangement, that can be deposited in thin-layers (a few micrometers in thickness) by a number of deposition methods to produce thin-film photovoltaic cells on glass, metal, or plastic substrates.

Annualized Growth Rates: Calculated as follows:

$$(x_n / x_1)^{1/n} \quad ,$$

where x is the value under consideration and n is the number of periods.

Aquifer: A subsurface rock unit from which water can be produced.

ARI: Air-Conditioning and Refrigeration Institute

Availability Factor: A percentage representing the number of hours a generating unit is available to produce power (regardless of the amount of power) in a given period, compared to the number of hours in the period.

Biodiesel: A renewable fuel synthesized from soy beans, other oil crops, or animal tallow which can substitute for petroleum diesel fuel.

Biomass: Organic nonfossil material of biological origin constituting a renewable energy source.

Black Liquor: A byproduct of the paper production process that can be used as a source of energy.

Capacity Factor: The ratio of the electrical energy produced by a generating unit for the period of time considered to the electrical energy that could have been produced at continuous full-power operation during the same period.

Capacity, Gross: The full-load continuous rating of a generator, prime mover, or other electric equipment under specified conditions as designated by the manufacturer. It is usually indicated on a nameplate attached to the equipment.

Capital Cost: The cost of field development and plant construction and the equipment required for the generation of electricity.

Cast Silicon: Crystalline silicon obtained by pouring pure molten silicon into a vertical mold and adjusting the temperature gradient along the mold volume during cooling to obtain slow, vertically-advancing crystallization of the silicon. The polycrystalline ingot thus formed is composed of large, relatively parallel, interlocking crystals. The cast ingots are sawed into wafers for further fabrication into photovoltaic cells. Cast-silicon wafers and ribbon-silicon sheets fabricated into cells are usually referred to as polycrystalline photovoltaic cells.

Climate Change (Greenhouse Effect): The increasing mean global surface temperature of the Earth caused by gases in the atmosphere (including carbon dioxide, methane, nitrous oxide, ozone, and chlorofluorocarbons). The greenhouse effect allows solar radiation to penetrate the Earth's atmosphere but absorbs the infrared radiation returning to space.

Cogeneration: The production of electrical energy and another form of useful energy (such as heat or steam) through the sequential use of energy.

Combined Cycle: An electric generating technology in which electricity is produced from otherwise lost waste heat exiting from one or more gas (combustion) turbines. The exiting heat is routed to a conventional boiler or to a heat recovery steam generator for utilization by a steam turbine in the production of electricity. Such designs increase the efficiency of the electric generating unit.

Concentrator: A reflective or refractive device that focuses incident insolation onto an area smaller than the reflective or refractive surface, resulting in increased insolation at the point of focus.

Cull Wood: Wood logs, chips, or wood products that are burned.

Direct Current: An electric current that flows in a constant direction. The magnitude of the current does not vary or has a slight variation.

Electric Utility Restructuring: With some notable exceptions, the electric power industry historically has been composed primarily of investor-owned utilities. These utilities have been predominantly vertically integrated monopolies (combining electricity generation, transmission, and distribution), whose prices have been regulated by State and Federal government agencies. Restructuring the industry entails the introduction of competition into at least the generation phase of electricity production, with a corresponding decrease in regulatory control. Restructuring may also modify or eliminate other traditional aspects of investor-owned utilities, including their exclusive franchise to serve a given geographical area, assured rates of return, and vertical integration of the production process.

Emission: The release or discharge of a substance into the environment; generally refers to the release of gases or particulates into the air.

Evacuated Tube: In a solar thermal collector, an absorber tube, which is contained in an evacuated glass cylinder, through which collector fluids flows.

Exempt Wholesale Generator (EWG): A nonutility electricity generator that is not a qualifying facility under the Public Utility Regulatory Policies Act of 1978.

Externalities: Benefits or costs, generated as a byproduct of an economic activity, that do not accrue to the parties involved in the activity. Environmental externalities are benefits or costs that manifest themselves through changes in the physical or biological environment.

Flat Plate Pumped: A medium-temperature solar thermal collector that typically consists of a metal frame, glazing, absorbers (usually metal), and insulation and that uses a pump liquid as the heat-transfer medium: predominant use is in water heating applications.

Flow Control: The laws, regulations, and economic incentives or disincentives used by waste managers to direct waste generated in a specific geographic area to a designated landfill, recycling, or waste-to-energy facility.

Fuel Cells: One or more cells capable of generating an electrical current by converting the chemical energy of a fuel directly into electrical energy. Fuel cells differ from conventional electrical cells in that the active materials such as fuel and oxygen are not contained within the cell but are supplied from outside.

Fuelwood: Wood and wood products, possibly including coppices, scrubs, branches, etc., bought or gathered, and used by direct combustion.

Fumarole: A vent from which steam or gases issue; a geyser or spring that emits gases.

Generation (Electricity): The process of producing electric energy from other forms of energy; also, the amount of electric energy produced, expressed in watthours (Wh).

Geopressured: A type of geothermal resource occurring in deep basins in which the fluid is under very high pressure.

Geothermal Energy: As used at electric utilities, hot water or steam extracted from geothermal reservoirs in the Earth's crust that is supplied to steam turbines at electric utilities that drive generators to produce electricity.

Geothermal Plant: A plant in which a turbine is driven either from hot water or by natural steam that derives its energy from heat found in rocks or fluids at various depths beneath the surface of the earth. The fluids are extracted by drilling and/or pumping.

Geyser: A special type of thermal spring that periodically ejects water with great force.

Giga: One billion.

Green Pricing: In the case of renewable electricity, green pricing represents a market solution to the various problems associated with regulatory valuation of the nonmarket benefits of renewables. Green pricing programs allow electricity customers to express their willingness to pay for renewable energy development through direct payments on their monthly utility bills.

Grid: The layout of an electrical distribution system.

Groundwater: Water occurring in the subsurface zone where all spaces are filled with water under pressure greater than that of the atmosphere.

Heat Pump: A year-round heating and air-conditioning system employing a refrigeration cycle. In a refrigeration cycle, a refrigerant is compressed (as a liquid) and expanded (as a vapor) to absorb and reject heat. The heat pump transfers heat to a space to be heated during the winter period and by reversing the operation extracts (absorbs) heat from the same space to be cooled during the summer period. The refrigerant within the heat pump in the heating mode absorbs the heat to be supplied to the space to be heated from an outside medium (air, ground or ground water) and in the cooling mode absorbs heat from the space to be cooled to be rejected to the outside medium.

Heat Pump (Air Source): An air-source heat pump is the most common type of heat pump. The heat pump absorbs heat from the outside air and transfers the heat to the space to be heated in the heating mode. In the cooling mode the heat pump absorbs heat from the space to be cooled and rejects the heat to the outside air. In the heating mode when the outside air approaches 32° F or less, air-source heat pumps loose efficiency and generally require a back-up (resistance) heating system.

Heat Pump (Geothermal): A heat pump in which the refrigerant exchanges heat (in a heat exchanger) with a fluid circulating through an earth connection medium (ground or ground water). The fluid is contained in a variety of loop (pipe) configurations depending on the temperature of the ground and the ground area available. Loops may be installed horizontally or vertically in the ground or submersed in a body of water.

Heat Pump (efficiency): The efficiency of a heat pump, that is, the electrical energy to operate it, is directly related to temperatures between which it operates. Geothermal heat pumps are more efficient than conventional heat pumps or air conditioners that use the outdoor air since the ground or ground water a few feet below the earth's surface remains relatively constant throughout the year. It is more efficient in the winter to draw heat from the relatively warm ground than from the atmosphere where the air temperature is much colder, and in summer transfer waste heat to the relatively cool ground than to hotter air. Geothermal heat pumps are generally more expensive ($2,000-$5,000) to install than outside air heat pumps. However, depending on the location geothermal heat pumps can reduce energy consumption (operating cost) and correspondingly, emissions by more than 20 percent compared to high-efficiency outside air heat pumps. Geothermal heat pumps also use the waste heat from air conditioning to provide free hot water heating in the summer

High-Temperature Collector: A solar thermal collector designed to operate at a temperature of 180 degrees Fahrenheit or higher.

Hot Dry Rock: Heat energy residing in impermeable, crystalline rock. Hydraulic fracturing may be used to create permeability to enable circulation of water and removal of the heat.

Hub Height: In a horizontal-axis wind turbine, the distance from the turbine platform to the rotor shaft.

Hydraulic Fracturing: Fracturing of rock at depth with fluid pressure. Hydraulic fracturing at depth may be accomplished by pumping water into a well at very high pressures. Under natural conditions, vapor pressure may rise high enough to cause fracturing in a process known as hydrothermal brecciation.

Independent Power Producer (IPP): A wholesale electricity producer (other than a qualifying facility under the Public Utility Regulatory Policies Act of 1978), that is unaffiliated with franchised utilities in the area in which the IPP is selling power and that lacks significant marketing power. Unlike traditional utilities, IPPs do not possess transmission facilities that are essential to their customers and do not sell power in any retail service territory where they have a franchise.

Internal Collector Storage (ICS): A solar thermal collector in which incident solar radiation is absorbed by the storage medium.

Kilowatt (kW): One thousand watts of electricity (See Watt).

Kilowatthour (kWh): One thousand watthours.

Levelized Cost: The present value of the total cost of building and operating a generating plant over its economic life, converted to equal annual payments. Costs are levelized in real dollars (i.e., adjusted to remove the impact of inflation).

Liquid Collector: A medium-temperature solar thermal collector, employed predominantly in water heating, which uses pumped liquid as the heat-transfer medium.

Low-Temperature Collectors: Metallic or nonmetallic solar thermal collectors that generally operate at temperatures below 110 degrees Fahrenheit and use pumped liquid or air as the heat transfer medium. They usually contain no glazing and no insulation,and they are often made of plastic or rubber, although some are made of metal.

Magma: Naturally occurring molten rock, generated within the earth and capable of intrusion and extrusion, from which igneous rocks are thought to have been derived through solidification and related processes. It may or may not contain suspended solids (such as crystals and rock fragments) and / or gas phases.

Marginal Cost: The change in cost associated with a unit change in quantity supplied or produced.

Medium-Temperature Collectors: Solar thermal collectors designed to operate in the temperature range of 140 degrees to 180 degrees Fahrenheit, but that can also operate at a temperature as low as 110 degrees Fahrenheit. The collector typically consists of a metal frame, metal absorption panels with integral flow channels (attached tubing for liquid collectors or integral ducting for air collectors), and glazing and insulation on the sides and back.

Megawatt (MW): One million watts of electricity (See Watt).

Merchant Facilities: High-risk, high-profit facilities that operate, at least partially, at the whims of the market, as opposed to those facilities that are constructed with close cooperation of municipalities and have significant amounts of waste supply guaranteed.

Net Photovoltaic Cell Shipment: The difference between photovoltaic cell shipments and photovoltaic cell purchases.

Net Photovoltaic Module Shipment: The difference between photovoltaic module shipments and photovoltaic module purchases.

Nonutility Generation: Electric generation by end-users, independent power producers, or small power producers under the Public Utility Regulatory Policies Act, to supply electric power for industrial, commercial, and military operations, or sales to electric utilities.

Operation and Maintenance (O&M) Cost: Operating expenses are associated with operating a facility (i.e., supervising and engineering expenses). Maintenance expenses are that portion of expenses consisting of labor, materials, and other direct and indirect expenses incurred for preserving the operating efficiency or physical condition of utility plants that are used for power production, transmission, and distribution of energy.

Parabolic Dish: A high-temperature (above 180 degrees Fahrenheit) solar thermal concentrator, generally bowl-shaped, with two-axis tracking.

Parabolic Trough: A high-temperature (above 180 degrees Fahrenheit) solar thermal concentrator with the capacity for tracking the sun using one axis of rotation.

Passive Solar: A system in which solar energy alone is used for the transfer of thermal energy. Pumps, blowers, or other heat transfer devices that use energy other than solar are not used.

Peak Watt: A manufacturer's unit indicating the amount of power a photovoltaic cell or module will produce at standard test conditions (normally 1,000 watts per square meter and 25 degrees Celsius).

Photovoltaic Cell: An electronic device consisting of layers of semiconductor materials fabricated to form a junction (adjacent layers of materials with different electronic characteristics) and electrical contacts and being capable of converting incident light directly into electricity (direct current).

Photovoltaic Module: An integrated assembly of interconnected photovoltaic cells designed to deliver a selected level of working voltage and current at its output terminals, packaged for protection against environment degradation, and suited for incorporation in photovoltaic power systems.

Public Utility Regulatory Policies Act of 1978 (PURPA): One part of the National Energy Act, PURPA contains measures designed to encourage the conservation of energy, more efficient use of resources, and equitable rates. Principal among these were suggested retail rate reforms and new incentives for production of electricity by cogenerators and users of renewable resources.

Pulpwood: Roundwood, whole-tree chips, or wood residues.

Quadrillion Btu: Equivalent to 10 to the 15th power Btu.

Qualifying Facility (QF): A cogeneration or small power production facility that meets certain ownership, operating, and efficiency criteria established by the Federal Energy Regulatory Commission (FERC) pursuant to the Public Utility Regulatory Policies Act of 1978

(PURPA). (See the Code of Federal Regulations, Title 18, Part 292.)

Refuse-Derived Fuel (RDF): Fuel processed from municipal solid waste that can be in shredded, fluff, or densified pellet forms.

Renewable Energy Source: An energy source that is regenerative or virtually inexhaustible. Typical examples are wind, geothermal, and water power.

Ribbon Silicon: Single-crystal silicon derived by means of fabricating processes that produce sheets or ribbons of single-crystal silicon. These processes include edge-defined film-fed growth, dendritic web growth, and ribbon-to-ribbon growth.

Roundwood: Logs, bolts, and other round timber generated from the harvesting of trees.

Silicon: A semiconductor material made from silica, purified for photovoltaic applications.

Single Crystal Silicon (Czochralski): An extremely pure form of crystalline silicon produced by the Czochralski method of dipping a single crystal seed into a pool of molten silicon under high vacuum conditions and slowly withdrawing a solidifying single crystal boule rod of silicon. The boule is sawed into thin wafers and fabricated into single-crystal photovoltaic cells.

Solar Energy: The radiant energy of the sun, which can be converted into other forms of energy, such as heat or electricity.

Solar Thermal Collector: A device designed to receive solar radiation and convert it into thermal energy. Normally, a solar thermal collector includes a frame, glazing, and an absorber, together with the appropriate insulation. The heat collected by the solar thermal collector may be used immediately or stored for later use.

Solar Thermal Collector, Special: An evacuated tube collector or a concentrating (focusing) collector. Special collectors operate in the temperature (low concentration for pool heating) to several hundred degrees Fahrenheit (high concentration for air conditioning and specialized industrial processes).

Thermosiphon System: A solar collector system for water heating in which circulation of the collection fluid through the storage loop is provided solely by the temperature and density difference between the hot and cold fluids.

Tipping Fee: Price charged to deliver municipal solid waste to a landfill, waste-to-energy facility, or recycling facility.

Transmission System (Electric): An interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and points at which it is transformed for delivery over the distribution system lines to consumers, or is delivered to other electric systems.

Turbine: A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.

Vapor-Dominated Geothermal System: A conceptual model of a hydrothermal system where steam pervades the rock and is the pressure-controlling fluid phase.

Watt (Electric): The electrical unit of power. The rate of energy transfer equivalent to 1 ampere of electric current flowing under a pressure of 1 volt at unity power factor.

Watt (Thermal): A unit of power in the metric system, expressed in terms of energy per second, equal to the work done at a rate of 1 joule per second.

Watthour (Wh): The electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an electric circuit steadily for 1 hour.

Wheeling: The use of the transmission facilities of one system to transmit power and energy by agreement of and for, another system with a corresponding wheeling charge, e.g., the transmission of electricity for compensation over a system that is received from one system and delivered to another system).

Wood Pellets: Fuel manufactured from finely ground wood fiber and used in pellet stoves.