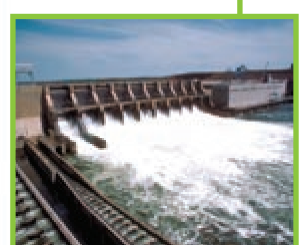
Power Technologies Energy Data Book

Third Edition



NREL National Renewable Energy Laboratory

Prepared for the Office of Energy Efficiency and Renewable Energy

April 2005 • NREL/TP-620-37930

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Power Technologies Energy Data Book

Third Edition

Compiled by J. Aabakken

Prepared under Task No(s). ASA4.6065

Technical Report

NREL/TP-620-37930
April 2005

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1.1 - Introduction

About the Power Technologies Energy Data Book (PTEDB), Third Edition

In 2002, the Energy Analysis Office of the National Renewable Energy Laboratory (NREL) developed the first version of the Power Technologies Energy Data Book for the Office of Power Technologies of the U.S. Department of Energy (DOE).

The main purpose of the data book is to compile – in one central document – a comprehensive set of data about power technologies from diverse sources. The need for policymakers and analysts to be well informed about power technologies suggests the need for a publication that includes a diverse, yet focused, set of data about power technologies.

This edition updates the same type of information that is in the previous edition. Most of the data in this publication is taken directly from the source materials, although it may be reformatted for presentation. Neither NREL nor DOE endorses the validity of these data.

This Third Edition of the Power Technologies Energy Data Book, and previous editions, are available on the Internet at http://www.nrel.gov/analysis/power_databook/, where the PTEDB may be downloaded as PDF files. Selected data also is available as Excel spreadsheets.

The Web site also features energy-conversion calculators and features links to the Transportation Energy Data Book and Buildings Energy Data Book. Readers are encouraged to suggest improvements to the PTEDB through the feedback form on the Web site.

Biopower

Technology Description

Biopower, also called biomass power, is the generation of electric power from biomass resources – now usually urban waste wood, crop and forest residues; and, in the future, crops grown specifically for energy production. Biopower reduces most emissions (including emissions of greenhouse gases-GHGs) compared with fossil fuel-based electricity. Because biomass absorbs CO_2 as it grows, the entire biopower cycle of growing, converting to electricity, and regrowing biomass can result in very low CO_2 emissions. Through the use of residues, biopower systems can even represent a net sink for GHG emissions by avoiding methane emissions that would result from landfilling of the unused biomass.

Representative Technologies for Conversion of Feedstock to Fuel for Power and Heat

• *Homogenization* is a process by which feedstock is made physically uniform for further processing or for combustion (includes chopping, grinding, baling, cubing, and pelletizing).

• *Gasification* (via pyrolysis, partial oxidation, or steam reforming) converts biomass to a fuel gas that can be substituted for natural gas in combustion turbines or reformed into H_2 for fuel cell applications.

• *Anaerobic digestion* produces biogas that can be used in standard or combined heat and power (CHP) applications. Agricultural digester systems use animal or agricultural waste. Landfill gas also is produced anaerobically.

• *Biofuels production for power and heat* provides liquid-based fuels such as methanol, ethanol, hydrogen, or biodiesel.

Representative Technologies for Conversion of Fuel to Power and Heat

• Direct combustion systems burn biomass fuel in a boiler to produce steam that is expanded in a Rankine Cycle prime mover to produce power.

• Cofiring substitutes biomass for coal or other fossil fuels in existing coal-fired boilers.

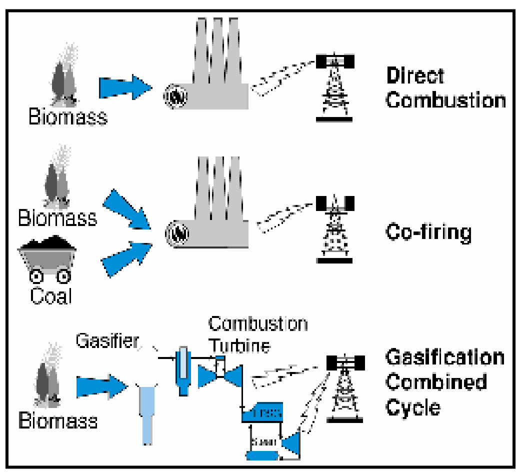
• Biomass or biomass-derived fuels (e.g. syngas, ethanol, biodiesel) also can be burned in combustion turbines (Brayton cycle) or engines (Otto or Diesel cycle) to produce power.

• When further processed, biomass-derived fuels can be used by fuels cells to produce electricity

System Concepts

• CHP applications involve recovery of heat for steam and/or hot water for district energy, industrial processes, and other applications.

• Nearly all current biopower generation is based on direct combustion in small, biomass-only plants with relatively low electric efficiency (20%), although total system efficiencies for CHP can approach 90%. Most biomass direct-combustion generation facilities utilize the basic Rankine cycle for electric-power generation, which is made up of the steam generator (boiler), turbine, condenser, and pump.



• For the near term, cofiring is the most cost-effective of the power-only technologies. Large coal steam plants have electric efficiencies near 33%. The highest levels of coal cofiring (15% on a heat-input basis) require separate feed preparation and injection systems.

• Biomass gasification combined cycle plants promise comparable or higher electric efficiencies (> 40%) using only biomass, because they involve gas turbines (Brayton cycle), which are more efficient than Rankine cycles. Other technologies being developed include integrated gasification/fuel cell and biorefinery concepts.

Technology Applications
• The existing biopower sector – nearly 1,000 plants – is mainly comprised of direct-combustion plants, with an additional small amount of cofiring (six operating plants). Plant size averages 20 MW_e, and the biomass-to-electricity conversion efficiency is about 20%. Grid-connected electrical capacity has increased from less than 200 MW_e in 1978 to more than 9700 MW_e in 2001. More than 75% of this power is generated in the forest products industry's CHP applications for process heat. Wood-fired systems account for close to 95% of this capacity. In addition, about 3,300 MW_e of municipal solid waste and landfill gas generating capacity exists. Recent studies estimate that on a life-cycle basis, existing biopower plants represent an annual net carbon sink of 4 MMTCe. Prices generally range from 8¢/kWh to 12¢/kWh.

Current Status
• CHP applications using a waste fuel are generally the most cost-effective biopower option. Growth is limited by availability of waste fuel and heat demand. • Biomass cofiring with coal ($50 - 250/kW of biomass capacity) is the most near-term option for large-scale use of biomass for power-only electricity generation. Cofiring also reduces sulfur dioxide and nitrogen oxide emissions. In addition, when cofiring crop and forest-product residues, GHG emissions are reduced by a greater percentage (e.g. 23% GHG emissions reduction with 15% cofiring). • Biomass gasification for large-scale (20 - 100MW_e) power production is being commercialized. It will be an important technology for cogeneration in the forest-products industries (which project a need for biomass and black liquor CHP technologies with a higher electric-thermal ratio), as well as for new baseload capacity. Gasification also is important as a potential platform for a biorefinery. • Small biopower and biodiesel systems have been used for many years in the developing world for electricity generation. However, these systems have not always been reliable and clean. DOE is developing systems for village-power applications and for developed-world distributed generation that are efficient, reliable, and clean. These systems range in size from 3kW to 5MW and completed field verification by 2003. • Approximately 15 million to 21 million gallons of biodiesel are produced annually in the United States. • Utility and industrial biopower generation totaled more than 60 billion kWh in 2001, representing about 75% of non-hydroelectric renewable generation. About two-thirds of this energy is derived from wood and wood wastes, while one-third of the biopower is from municipal solid waste and landfill gas. Industry consumes more than 2.1 quadrillion Btu of primary biomass energy. • Current companies include: Cargill-Dow; Foster Wheeler Energy Products of Idaho; Genecor International Future Energy Resources, Inc. (FERCO); PRM Energy Systems

Technology History
• In the latter part of the 19th century, wood was the primary fuel for residential, commercial, and transportation uses. By the 1950s, other fuels had supplanted wood. In 1973, wood use had dropped to 50 million tons per year. • At that point, the forest products and pulp and paper industries began to use wood with coal in new plants and switched to wood-fired steam power generation. • The Public Utility Regulatory Policies Act (PURPA) of 1978 stimulated the development of nonutility cogeneration and small-scale plants, leading to 70% self-sufficiency in the wood processing and pulp-and-paper sectors. • As incentives were withdrawn in the late 1980s, annual installations declined from just more than 600 MW in 1989, to 300-350MW in 1990. • There are now nearly 1,000 wood-fired plants in the United States, with about two-thirds of those providing power (and heat) for on-site uses only.

Technology Future

The levelized cost of electricity (in constant 1997$/kWh) for biomass direct-fired and gasification configurations are projected to be:

	2000	2010	2020
Direct-fired	7.5	7.0	5.8
Gasification	6.7	6.1	5.4

Source: *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997.

- R&D directions include:

Gasification – This technology requires extensive field verification in order to be adopted by the relatively conservative utility and forest-products industries, especially to demonstrate integrated operation of biomass gasifier with advanced-power generation (turbines and/or fuel cells). Integration of gasification into a biorefinery platform is a key new research area.

Small Modular Systems – Small-scale systems for distributed or minigrid (for premium or village power) applications will be increasingly in demand.

Cofiring – The DOE biopower program is moving away from research on cofiring, as this technology has reached a mature status. However, continued industry research and field verifications are needed to address specific technical and nontechnical barriers to cofiring. Future technology development will benefit from finding ways to better prepare, inject, and control biomass combustion in a coal-fired boiler. Improved methods for combining coal and biomass fuels will maximize efficiency and minimize emissions. Systems are expected to include biomass cofiring up to 5% of natural gas combined-cycle capacity.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term*. DOE/PI-0002. November 2003.

Biomass

Market Data

Cumulative Generating Capability, by Type (MW)

Source: Energy Information Administration (EIA), EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Tables 8.11a and 8.11c, and world data from United Nations Development Program, World Energy Assessment, 2000, Table 7.25.

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
U.S. Electric Power Sector												
Municipal Solid Waste[1]	N/A	151	1,852	2,733	2,600	2,528	2,636	2,614	2,789	2,993	2,949	2,989
Wood and Other Biomass[2]	78	200	964	1,451	1,425	1,452	1,438	1,484	1,486	1,487	1,410	1,389
U.S. Cogenerators[3]												
Municipal Solid Waste[1]			659	786	998	1,062	1,058	1,046	1,094	834	842	894
Wood and Other Biomass[2]			4,585	5,298	5,382	5,472	5,364	5,311	4,655	4,394	4,399	4,527
U.S. Total												
Municipal Solid Waste[1]	NA	151	2,511	3,519	3,598	3,590	3,694	3,660	3,883	3,827	3,845	3,883
Wood and Other Biomass[2]	78	200	5,549	6,750	6,808	6,924	6,802	6,795	6,141	5,882	5,844	5,916
Biomass Total	78	351	8,061	10,269	10,405	10,515	10,495	10,454	10,024	9,709	9,689	9,799
Rest of World Total[4]							29,505					
World Total							40,000					

[1] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass.

[2] Wood, black liquor, and other wood waste.

[3] Data include electric power sector and end-use sector (industrial and commercial) generators.

[4] Number derived from subtracting U.S. total from the world total. Figures may not add due to rounding.

U.S. Annual Installed Generating Capability, by Type (MW)

Source: Renewable Electric Plant Information System (REPiS), Version 7, NREL, 2003.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003[1]
Agricultural Waste[2]	22.6	20.1	0	4.0	0	21.6	0	0	0	0	0	0
Biogas[3]	0.1	58.6	51.3	17.5	74.8	92.7	87.3	107.6	43.8	66.8	30.2	23.1
Municipal Solid Waste[4]	50.0	117.2	260.3	94.5	0	0	0	22.0	0	0	0	30.0
Wood Residues[5]	260.4	254.8	299.4	66.5	91.6	40.0	90.3	13.0	0	11.3	38.8	0
Total	333.0	450.7	611.0	182.5	166.4	154.3	177.6	142.6	43.8	78.1	69.0	53.1

U.S. Cumulative Generating Capability, by Type[6] (MW)

Source: Renewable Electric Plant Information System (REPiS), Version 7, NREL, 2003.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003[1]
Agricultural Waste[2]	40	92	165	351	351	373	373	373	373	373	373	373
Biogas[3]	18	117	361	526	601	694	781	889	933	999	1,030	1,053
Municipal Solid Waste[4]	263	697	2,172	2,948	2,948	2,948	2,948	2,970	2,970	2,970	2,970	3,000
Wood Residues[5]	3,576	4,935	6,305	7,212	7,303	7,343	7,434	7,447	7,447	7,458	7,497	7,497
Total	3,897	5,840	9,003	11,037	11,203	11,358	11,535	11,678	11,722	11,800	11,869	11,922

Note: The data in this table does not match data in the previous table due to different coverage ratios in EIA and REPIS databases.

[1] 2003 data not complete as REPiS database is updated through 2002.

[2] Agricultural residues, cannery wastes, nut hulls, fruit pits, nut shells

[3] Biogas, alcohol (includes butahol, ethanol, and methanol), bagasse, hydrogen, landfill gas, livestock manure, wood gas (from wood gasifier)

[4] Municipal solid waste (includes industrial and medical), hazardous waste, scrap tires, wastewater sludge, refused-derived fuel

[5] Timber and logging residues (includes tree bark, wood chips, saw dust, pulping liquor, peat, tree pitch, wood or wood waste)

[6] There are an additional 65.45 MW of Ag Waste, 5.445 MW of Bio Gas, and 483.31 MW of Wood Residues that are not accounted for here because they have no specific online date.

Generation from Cumulative Capacity, by Type (Million kWh)

Source: EIA, *Annual Energy Review 2003*, Tables 8.2a and 8.2c, and world data from United Nations Development Program, World Energy Assessment, 2000, Table 7.25.

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
U.S. Electric Power Sector												
Municipal Solid Waste[1]	158	640	10,245	16,326	16,078	16,397	16,963	17,112	17,592	17,221	17,359	16,922
Wood and Other Biomass[2]	275	743	5,327	5,885	6,493	6,468	6,644	7,254	7,301	6,571	7,265	7,216
U.S. Cogenerators[3]												
Municipal Solid Waste[1]			2,904	4,079	4,834	5,312	5,485	5,460	5,540	4,543	5,498	5,889
Wood and Other Biomass[2]			26,939	30,636	30,307	30,480	29,694	29,787	30,294	28,629	31,400	29,735
U.S. Total												
Municipal Solid Waste[1]	158	640	13,149	20,405	20,911	21,709	22,448	22,572	23,131	21,765	22,857	22,811
Wood and Other Biomass[2]	275	743	32,266	36,521	36,800	36,948	36,338	37,041	37,595	35,200	38,665	36,951
Biomass Total	433	1,383	45,415	56,926	57,712	58,658	58,786	59,613	60,726	56,964	61,522	59,762
Rest of World Total[4]							101,214					
World Total							160,000					

1 Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass.

2 Wood, black liquor, and other wood waste.

3 Data include electric power sector and end-use sector (industrial and commercial) generators.

4 Number derived from subtracting U.S. total from the world total. Figures may not add due to rounding.

U.S. Annual Energy Consumption for Electricity Generation (Trillion Btu)

Source: EIA, *Annual Energy Review 2003*, Tables 8.4b and 8.4c

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Electric-Power Sector	4.5	14.4	285.9	388.0	397.3	408.3	412.0	415.5	420.7	430.4	494.1	488.3
Commercial Sector[1]			16.7	22.3	32.1	34.3	32.7	33.5	26.5	22.6	28.5	31.7
Industrial Sector[1]			351.0	385.3	407.1	380.7	362.0	373.0	378.8	379.6	481.5	437.0
Total Biomass	4.5	14.4	653.5	795.6	836.5	823.3	806.8	822.0	825.9	832.6	1,004.1	957.0

Data include wood (wood, black liquor, and other wood waste) and waste (municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass).
[1] Data includes combined-heat-and-power (CHP) and electricity-only plants.

Technology Performance

Source: *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997 (this document is currently being updated by DOE and the values most likely will change).

Efficiency		1980	1990	1995[1]	2000	2005	2010	2015[2]	2020
Capacity Factor (%)	Direct-fired			80.0	80.0	80.0	80.0	80.0	80.0
	Cofired			85.0	85.0	85.0	85.0	85.0	85.0
	Gasification			80.0	80.0	80.0	80.0	80.0	80.0
Efficiency (%)	Direct-fired			23.0	27.7	27.7	27.7	30.8	33.9
	Cofired			32.7	32.5	32.5	32.5	32.5	32.5
	Gasification			36.0	36.0	37.0	37.0	39.3	41.5
Net Heat Rate (kJ/kWh)	Direct-fired			15,280	13,000	13,000	13,000	11,810	10,620
	Cofired			11,015	11,066	11,066	11,066	11,066	11,066
	Gasification			10,000	10,000	9,730	9,730	9,200	8,670

Cost		1980	1990	1995[1]	2000	2005	2010	2015	2020
Total Capital Cost ($/kW)	Direct-fired			1,965	1,745	1,510	1,346	1,231	1,115
	Cofired[3]			272	256	241	230	224	217
	Gasification			2,102	1,892	1,650	1,464	1,361	1,258
Feed Cost ($/GJ)	Direct-fired			2.50	2.50	2.50	2.50	2.50	2.50
	Cofired[3]			-0.73	-0.73	-0.73	-0.73	-0.73	-0.73
	Gasification			2.50	2.50	2.50	2.50	2.50	2.50
Fixed Operating Cost ($/kW-yr)	Direct-fired			73.0	60.0	60.0	60.0	54.5	49.0
	Cofired[3]			10.4	10.1	9.8	9.6	9.5	9.3
	Gasification			68.7	43.4	43.4	43.4	43.4	43.4
		1980	1990	1995[1]	2000	2005	2010	2015	2020
Variable Operating Costs ($/kWh)	Direct-fired			0.009	0.007	0.007	0.007	0.006	0.006
	Cofired[3]			-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
	Gasification			0.004	0.004	0.004	0.004	0.004	0.004
Total Operating Costs ($/kWh)	Direct-fired			0.055	0.047	0.047	0.047	0.043	0.039
	Cofired[3]			-0.008	-0.008	-0.008	-0.009	-0.009	-0.009
	Gasification			0.040	0.036	0.036	0.036	0.034	0.033
Levelized Cost of Energy ($/kWh)	Direct-fired			0.087	0.075		0.070		0.058
	Cofired[3]			N/A	N/A	N/A	N/A	N/A	N/A
	Gasification			0.073	0.067		0.061		0.054

[1] Data is for 1997, the base year of the Renewable Energy Technology Characterizations analysis.

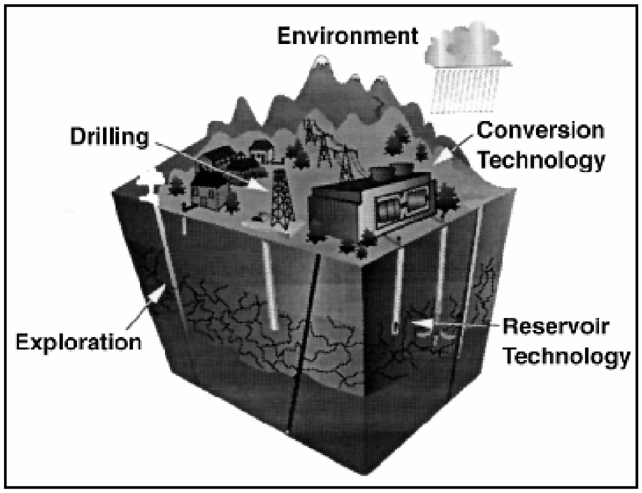
[2] Number derived by interpolation.

[3] Note cofired cost characteristics represent only the biomass portion of costs for capital and incremental costs above conventional costs for Operations & Maintenance (O&M), and assume $9.14/dry tonne biomass and $39.09/tonne coal, a heat input from biomass at 19,104 kJ/kg, and that variable O&M includes an SO2 credit valued at $110/tonne SO2. No cofiring COE is reported in the *RETC*.

Geothermal Energy

Technology Description

Geothermal energy is thermal energy from within the Earth. Hot water and steam are used to produce electricity or applied directly for space heating and industrial processes. There is potential to use geothermal energy to recover minerals and metals present in the geothermal brine.



System Concepts

- Geophysical, geochemical, and geological exploration locate permeable hot reservoirs to drill.
- Wells are drilled into the reservoirs.
- Well fields and distribution systems allow the hot geothermal fluids to move to the point of use, and are injected back to the earth.
- Steam turbines using natural steam or hot water flashed to steam, and binary turbines produce mechanical power that is converted to electricity.
- Direct applications utilize the thermal energy directly, for heating, without conversion to another form of energy.

Representative Technologies

- Dry-steam plants, which use geothermal steam to spin turbines.
- Flash-steam plants, which pump deep, high-pressure hot water into lower-pressure tanks and use the resulting flashed steam to drive turbines.
- Binary-cycle plants, which use moderately hot geothermal water to heat a secondary fluid with a much lower boiling point than water. This causes the secondary fluid to flash to vapor, which then drives the turbines.
- Exploration technologies for the identification of fractures and geothermal reservoirs; drilling to access the resource; geoscience and reservoir testing and modeling to optimize production and predict useful reservoir lifetime.

Technology Applications

- Mile-or-more-deep wells can be drilled into underground reservoirs to tap steam and very hot water that drive turbines and electricity generators. Because of economies of scale, geothermal power plants supply power directly to the grid, typically operating as baseload plants.
- Another use is direct applications to use the heat from geothermal fluids without conversion to electricity. In the United States, most geothermal reservoirs are located in the western states, Alaska, and Hawaii; but some eastern states have geothermal resources that are used for direct applications. Hot water near the Earth's surface can be piped directly into facilities and used to heat buildings, grow plants in greenhouses, dehydrate onions and garlic, heat water for fish farming, and pasteurize milk. Some cities pipe the hot water under roads and sidewalks to melt snow. District heating systems use networks of piped hot water to heat many buildings in a community.
- The recovery of minerals and metals from geothermal brine can add value to geothermal-power projects.

Current Status
• Hydrothermal reservoirs provide the heat for about 2,400 MW of operating generating capacity in the United States at 18 resource sites. Another 700 MW of capacity at The Geysers was shut down. • Three types of power plants are operating today: dry steam, flash steam, and binary. • Worldwide installed capacity stands at about 8,000 MW. • The United States has a resource base capable of supplying heat for 40 GW of electrical capacity at costs competitive with conventional systems. With improved technology, this resource base could expand to 100 GW of electricity at 3 to 5¢/kWh. • Hydrothermal reservoirs are being used to produce electricity with an online availability of 97%; advanced energy conversion technologies are being implemented to improve plant thermal efficiency. • Direct applications capacity is about 600 MW_t in the United States. • Direct-use applications are successful, but require colocation of a quality heat source and need. • More than 20 states use the direct use of geothermal energy, including Georgia and New York. About 300 MW of geothermal energy is being developed in California, Nevada, and Idaho. • Current leading geothermal technology companies include the following: Calpine Corporation Caithness Energy Cal Energy Company (a subsidiary of Mid American Energy Holding Company) Ormat International, Inc.
Technology History
• The use of geothermal energy as a source of hot water for spas dates back thousands of years. • In 1892, the world's first district heating system was built in Boise, Idaho, as water was piped from hot springs to town buildings. Within a few years, the system was serving 200 homes and 40 downtown businesses. Today, the Boise district heating system continues to flourish. Although no one imitated this system for nearly 70 years, there are now 17 district heating systems in the United States and dozens more around the world. • The United States' first geothermal power plant went into operation in 1922 at The Geysers in California. The plant was 250 kW, but fell into disuse. • In 1960, the country's first large-scale geothermal electricity-generating plant began operation. Pacific Gas and Electric operated the plant, located at The Geysers. The resource at The Geysers is dry steam. The first turbine produces 11 megawatts (MW) of net power and operated successfully for more than 30 years. • In 1979, the first electrical development of a water-dominated geothermal resource occurred at the East Mesa field in the Imperial Valley in California. • In 1980, UNOCAL built the country's first flash plant, generating 10 MW at Brawley, California. • In 1981, with a supporting loan from DOE, Ormat International Inc. successfully demonstrated binary technology in the Imperial Valley of California. This project established the technical feasibility of larger-scale commercial binary power plants. The project was so successful that Ormat repaid the loan within a year. • By the mid 1980s, electricity was being generated by geothermal power in four western states: California, Hawaii, Utah, and Nevada. • In the 1990s, the U.S. geothermal industry focused its attention on building power plants overseas, with major projects in Indonesia and the Philippines. • In 1997, a pipeline began delivering treated municipal wastewater and lake water to The Geysers steamfield in California, increasing the operating capacity by 70 MW. • In 2000, DOE initiated its GeoPowering the West program to encourage development of geothermal resources in the western United States by reducing nontechnical barriers. • The DOE Geothermal Program sponsored research that won two R&D awards in 2003, advancing this renewable energy.

Technology Future

The levelized cost of electricity (in constant 1997$/kWh) for the two major future geothermal energy configurations are projected to be:

	2000	2010	2020
Hydrothermal Flash	3.0	2.4	2.1
Hydrothermal Binary	3.6	2.9	2.7

Source: *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997.

- New approaches to utilization will be developed, which increase the domestic resource base by a factor of 10.
- Improved methodologies will be developed for predicting reservoir performance and lifetime.
- Advances will be made in finding and characterizing underground permeability and developing low-cost, innovative drilling technologies.
- Further R&D will reduce capital and operating costs and improve the efficiency of geothermal conversion systems.
- Heat recovery methods will be developed that allow the use of geothermal areas that are deeper, less permeable, or dryer than those currently considered as resources.
- Production will continue at existing geothermal plants, totaling 2.2GW. Ten gigawatts of energy may be sourced from geothermal power by 2015, providing sufficient heat and electricity for 7 million homes. By 2020, 20 GW of installed capacity from hydrothermal plants and 20 GW from enhanced geothermal systems may exist. One hundred gigawatts of future construction potential exists for this sector. Direct heat will replace existing systems in 19 western states' markets.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term*. DOE/PI-0002. November 2003.

Geothermal

Market Data

Cumulative Installed Capacity

Source: U.S. electricity data from EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.11a; world totals from *Renewable Energy World*/July-August 2000, page 123, Table 1; 1998 world totals from *UNDP World Energy Assessment 2000*, Tables 7.20 and 7.25; 1997 world electricity and U.S. and world direct-use heat data from Stefansson and Fridleifsson 1998, "Geothermal Energy: European and World-wide Perspective."

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Electricity (MW_e)												
U.S.	909	1,580	2,666	2,968	2,893	2,893	2,893	2,846	2,793	2,216	2,252	2,252
Rest of World	1,191	3,184	3,166	3,829		5,128	5,346		5,181			
World Total	2,100	4,764	5,832	6,797		8,021	8,239		7,974			
Direct-Use Heat (MW_{th})												
U.S.						1,905						
Rest of World						7,799						
World Total	1,950	7,072	8,064	8,664		9,704	11,000		17,175			

Cumulative Installed Capacity

Source: International Geothermal Association, http://iga.igg.cnr.it/index.php

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Electricity (MW_e)												
U.S.			2,775	2,817					2,228			2,020
Rest of World			3,057	4,016					5,746			6,382
World Total			5,832	6,833					7,974			8,402
Direct-Use Heat (MW_{th})												
U.S.				1,874					3,766			4,350
Rest of World				6,730					11,379			
World Total				8,604					15,145			

Annual Installed Electric Capacity (MW_e) — Source: Renewable Energy Project Information System (REPiS), Version 7, NREL, 2003.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003*
U.S.	251.0	352.9	48.6		36.0				59.9			

Cumulative Installed Electric Capacity (MW_e) — *Source: Renewable Energy Project Information System (REPiS), Version 7, NREL, 2003.*

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003*
U.S.	802	1,698	2,540	2,684	2,720	2,720	2,720	2,720	2,779	2,779	2,779	2,779

* 2003 data not complete as REPiS database is updated through 2002.

Installed Capacity and Power Generation/Energy Production from Installed Capacity — Source: Lund and Freeston, *World-Wide Direct Uses of Geothermal Energy 2000*, Lund and Boyd, Geothermal Direct-Use in the United States Update: 1995-1999, J. Lund, *World Status of Geothermal Energy Use Overview 1995-1999* http://www.geothermie.de/europaundweltweit/Lund/wsoge_index.htm, Sifford and Blommquist, *Geothermal Electric Power Production in the United States: A Survey and Update for 1995-1999*, and G. Huttrer, *The Status of World Geothermal Power Generation 1995-2000.* Proceedings of the World Geothermal Congress 2000 http://geothermal.stanford.edu/wgc2000/SessionList.htm, Kyushu-Tohoku, Japan, May 28-June10, 2000.

Cumulative Installed Capacity

	1980	1985	1990	1995	1996	1997	1998	1999	2000
Electricity (MW_e)									
U.S.				2,369	2,343	2,314	2,284	2,293	2,228
Rest of World				4,464					5,746
World Total	3,887	4,764	5,832	6,833					7,974
Direct-Use Heat* (MW_{th})									
U.S.									4,200
Rest of World									12,975
World Total	1,950	7,072	8,064	8,664				16,209	17,175

Annual Generation/Energy Production from Cumulative Installed Capacity

	1980	1985	1990	1995	1996	1997	1998	1999	2000
Electricity (Billion kWh_e)									
U.S.				14.4	15.1	14.6	14.7	15.0	15.5

Rest of World				33.8
World Total				49.3
Direct-Use Heat* (TJ)				
U.S.		13,890	20,302	21,700
Rest of World		98,551	141,707	
World Total	86,249	112,441	162,009	185,139

* Direct-use heat includes geothermal heat pumps as well as traditional uses. Geothermal heat pumps account for 1854 MW_{th} (14,617 TJ) in 1995 and 6849 MW_{th} (23,214 TJ) in 1999 of the world totals and 3600 MW_{th} (8,800 TJ) in 2000 of the U.S. total. Conversion of GWh to TJ is done at 1TJ = 0.2778 GWh.

Annual Generation from Cumulative Installed Capacity

Source: U.S. electricity data from EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.2a; world electricity totals from *Renewable Energy World*/July-August 2000, page 126, Table 2; 1997 world electricity and U.S. and world direct-use heat data from Stefansson and Fridleifsson 1998, "Geothermal Energy: European and World-wide Perspective." 1998 world totals from UNDP World Energy Assessment 2000, Table 7.25; 1995, 2000, and 2003 direct-use heat and 1999 electricity world total from International Geothermal Association, http://iga.igg.cnr.it/index.php.

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Electricity (Billion kWh_e)												
U.S.	5.1	9.3	15.4	13.4	14.3	14.7	14.8	14.8	14.1	13.7	14.5	13.1
Rest of World	8.9	7.7	3.6	6.6		29.0	31.2		35.2			
World Total	14	17	19	20		43.8	46	49	49.3			
Direct-Use Heat (billion kWhth)												
U.S.				3.9		4.0			5.6			6.2
Rest of World				27.4		31.1			47.3			
World Total				31.2		35.1	40		53.0			

Annual Geothermal Energy Consumption for Electric Generation (Trillion Btu)

Source: EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.4a.

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
U.S.	110	198	326	280	300	309	311	312	296	289	305	276
Rest of World												
World Total												

Annual U.S. Geothermal Heat Pump Shipments, by type (units)

Source: EIA, *Renewable Energy Annual 2003*, DOE/EIA-0603(2003) (Washington, D.C., December 2004), Table 37.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001*	2002	2003
ARI-320				4,696	4,697	7,772	10,510	7,910	7,808	N/A	6,445	10,306
ARI-325/330				26,800	25,697	28,335	26,042	31,631	26,219	N/A	26,802	25,211
Other non-ARI Rated				838	991	1,327	1,714	2,138	1,554	N/A	3,892	922
Totals				32,334	31,385	37,434	38,266	41,679	35,581	N/A	37,139	36,439

* No survey was conducted for 2001.

Capacity of U.S. Heat Pump Shipments (Rated Tons)

Source: EIA, *Renewable Energy Annual 2003*, DOE/EIA-0603(2003) (Washington, D.C., December 2004), Table 38.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	20012	2002	2003
ARI-320				13,120	15,060	24,708	35,776	27,970	26,469	N/A	16,756	29,238
ARI-325/330				113,925	92,819	110,186	98,912	153,947	130,132	N/A	96,541	89,731
Other non-ARI Rated				3,935	5,091	6,662	6,758	9,735	7,590	N/A	12,000	5,469
Totals				130,980	112,970	141,556	141,446	191,652	164,191	N/A	125,297	124,438

1 One Rated Ton of Capacity equals 12,000 Btu's.

2 No survey was conducted for 2001.

Annual U.S. Geothermal Heat Pump Shipments by Customer Type and Model Type (units)

Source: EIA, *Renewable Energy Annual 2003*, DOE/EIA-0603(2003) (Washington, D.C., December 2004), Table 40, REA 2002 Table 40, REA 2001 Table 40, REA 2000 Table 38, REA 1999 Table 38, and REA 1998 Table 40.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001*	2002	2003
Exporter					2,276	226	109	6,172	784	N/A	1,165	945
Wholesale Distributor					21,444	29,181	14,377	9,193	9,804	N/A	20,888	16,167
Retail Distributor					8,336	829	3,222	2,555	2,272	N/A	552	1,145
Installer					18,762	25,302	18,429	24,917	20,491	N/A	10,999	10,784
End-User					689	657	994	66	63	N/A	207	1,103
Others					13	1,727	1,135	6,259	2,167	N/A	3,328	6,295
Total					51,520	57,922	38,266	49,162	35,581	N/A	37,139	36,439

Annual U.S. Geothermal Heat Pump Shipments by Export & Census Region (units)

Source: EIA, *Renewable Energy Annual 2003*, DOE/EIA-0603(2003) (Washington, D.C., December 2004), Table 39, REA 2002 Table 39, REA 2001 Table 39, REA 2000 Table 37, REA 1999 Table 37, and REA 1998 Table 39.

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001***	**2002**	**2003**
Export					4,090	2,427	481	6,303	1,220	N/A	3,271	2,764
Midwest					11,874	13,402	12,240	13,112	10,749	N/A	12,982	12,042
Northeast					6,417	9,280	5,403	6,044	4,138	N/A	3,903	5,924
South					25,302	26,788	16,195	20,935	17,403	N/A	13,660	12,543
West					3,837	6,025	3,947	2,768	2,071	N/A	3,323	3,166
Total					51,520	57,922	38,266	49,162	35,581	N/A	37,139	36,439

Technology Performance

Source: *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997 (this document is currently being updated by DOE and the values most likely will change).

		1980	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Efficiency									
Capacity Factor (%)	Flashed Steam			89	92	93	95	96	96
	Binary			89	92	93	95	96	96
	Hot Dry Rock			80	81	82	83	84	85
Cost		**1980**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Capital Cost ($/kW)	Flashed Steam			1,444	1,372	1,250	1,194	1,147	1,100
	Binary			2,112	1,994	1,875	1,754	1,696	1,637
	Hot Dry Rock			5,519	5,176	4,756	4,312	3,794	3,276
Fixed O&M ($/kW-yr)	Flashed Steam			96.4	87.1	74.8	66.3	62.25	58.2
	Binary			87.4	78.5	66.8	59.5	55.95	52.4
	Hot Dry Rock			219	207	191	179	171	163

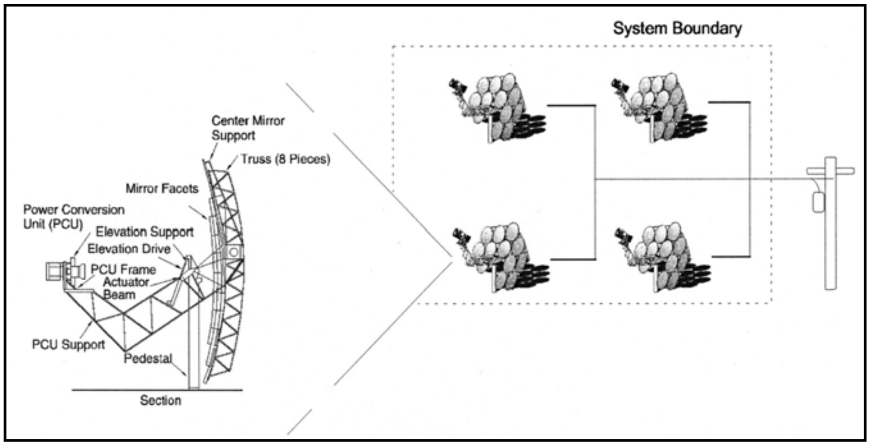
Concentrating Solar Power

Technology Description

Concentrating Solar Power (CSP) systems concentrate solar energy 50 to 5,000 times to produce high-temperature thermal energy, which is used to produce electricity for distributed- or bulk-generation power applications.

System Concepts

- In CSP systems, highly reflective sun-tracking mirrors produce temperatures of 400ºC to 800ºC in the working fluid of a receiver; this heat is used in conventional heat engines (steam or gas turbines or Stirling engines) to produce electricity at system solar-to-electric efficiencies of up to 30%. Systems using advanced photovoltaics (PV) cells may achieve efficiencies greater than 33%.



Representative Technologies

- A parabolic trough system focuses solar energy on a linear oil-filled receiver, which collects heat to generate steam and power a steam turbine. When the sun is not shining, steam can be generated with fossil fuel to meet utility needs. Plant sizes can range from 10 MWe to 100 MWe.
- A power tower system uses many large heliostats to focus the solar energy onto a tower-mounted central receiver filled with a molten-salt working fluid that produces steam. The hot salt can be stored efficiently to allow power production to match utility demand even when the sun is not shining. Plant size can range from 30 MWe to 200 MWe.
- A dish/engine system (see diagram above) uses a dish-shaped reflector to power a small Stirling or Brayton engine/generator or a high-concentrator PV module mounted at the focus of the dish. Dishes are 2 to 25 kW in size, can be used individually or in small groups, and are easily hybridized with fossil fuel.

Technology Applications

- Concentrating solar power systems can be sized for village power (10 kilowatts) or grid-connected applications (up to 100 megawatts). Some systems use thermal storage during cloudy periods or at night. Others can be combined with natural gas such that the resulting hybrid power plants can provide higher-value, dispatchable power.

- To date, the primary use of CSP systems has been for bulk power supply to the southwestern grid. However, these systems were installed under very attractive power purchase rates that are not generally available today. With one of the best direct normal insolation resources anywhere on Earth, the southwestern states are still positioned to reap large and, as yet, largely uncaptured economic benefits from this important natural resource. California, Nevada, Arizona, and New Mexico are each exploring policies that will nurture the development of their solar-based industries.

- In addition to the concentrating solar power projects under way in this country, a number of projects are being developed in India, Egypt, Morocco, and Mexico. In addition, independent power producers are in the early stages of design and development for potential parabolic trough and/or power tower projects in Greece (Crete) and Spain. Given successful deployment of systems in one or more of these initial markets, several domestic project opportunities are expected to follow.
- Distributed-systems deployment opportunities are emerging for dish-engine systems. Many states are adopting green power requirements in the form of "portfolio standards" and renewable energy mandates. While the potential markets in the United States are large, the size of developing worldwide markets is immense. The International Energy Agency (IEA) projects an increased demand for electrical power worldwide more than doubling installed capacity. More than half of this is in developing countries; and a large part is in areas with good solar resources, limited fossil fuel supplies, and no power distribution network. The potential payoff for dish/engine system developers is the opening of these immense global markets for the export of power generation systems.

Current Status

- CSP technology is generally still too expensive to compete in widespread domestic markets without significant subsidies. Consequently, RD&D goals are to reduce costs of CSP systems to 5¢/kWh to 8¢/kWh with moderate production levels within five years, and below 5c/kWh at high production levels in the long term.
- Nine parabolic trough plants, with a total rated capacity of 354 MWe, were installed in California between 1985 and 1991. Their continuing operation has demonstrated their ability to achieve commercial costs of about 12¢/kWh to 14¢/kWh. O&M costs at these plants have declined by 40% due to technological improvements, saving the commercial plant operators $50 million.
- Solar Two, a 10-MWe pilot power tower with three hours of storage, also installed in California, provided technical information needed to scale up to a 30-100 MW commercial plant, the first of which is now being planned in Spain.
- A number of prototype dish/Stirling systems are currently operating in Nevada, Arizona, Colorado, and Spain. High levels of performance have been established; durability remains to be proven, although some systems have operated for more than 10,000 hours.
- The CSP industry includes 25 companies who design, sell, own, and/or operate energy systems and power plants based on the concentration of solar energy. CSP companies include energy utilities, independent power producers or project developers, equipment manufacturers, specialized development firms, and consultants. While some firms only offer CSP products, many offer related energy products and services. Four of the 25 are "Fortune 500 Companies." Current companies include:

Duke Solar Energy, LLC
Nexant (a Bechtel Technology & Consulting Company)
The Boeing Company
KJC Operating Company
SunRay Corporation
Arizona Public Service Corporation
Spencer Management Associates
Kearney & Associates
Nagel Pump
Clever Fellows Innovative Consortium
Array Technologies
Concentrating Technologies
Ed Tek Inc.
Stirling Energy Systems
Science Applications International Corp.
STM Corporation
WGAssociates
Morse & Associates
United Innovations Inc.
Reflective Energies
Industrial Solar Technologies
Spectralab
Salt River Project
Energy Laboratories Inc.
Amonix

Technology History

Organized, large-scale development of solar collectors began in the United States in the mid-1970s under the Energy Research and Development Administration (ERDA) and continued with the establishment of the U.S. Department of Energy (DOE) in 1978.

Troughs:

- Parabolic trough collectors capable of generating temperatures greater than 500ºC (932 F) were initially developed for industrial process heat (IPH) applications. Acurex, SunTec, and Solar Kinetics were the key parabolic trough manufacturers in the United States during this period.
- Parabolic trough development also was taking place in Europe and culminated with the construction of the IEA Small Solar Power Systems (SSPS) Project/Distributed Collector System in Tabernas, Spain, in 1981. This facility consisted of two parabolic trough solar fields – one using a single-axis tracking Acurex collector and one the double-axis tracking parabolic trough collectors developed by M.A.N. of Munich, Germany.
- In 1982, Luz International Limited (Luz) developed a parabolic trough collector for IPH applications that was based largely on the experience that had been gained by DOE/Sandia and the SSPS projects.
- Southern California Edison (SCE) signed a power purchase agreement with Luz for the Solar Electric Generating System (SEGS) I and II plants, which came online in 1985. Luz later signed a number of Standard Offer (SO) power purchase contracts under the Public Utility Regulatory Policies Act (PURPA), leading to the development of the SEGS III through SEGS IX projects. Initially, the plants were limited by PURPA to 30 MW in size; later this limit was raised to 80 MW. In 1991, Luz filed for bankruptcy when it was unable to secure construction financing for its 10th plant (SEGS X).
- The 354 MWe of SEGS trough systems are still being operated today. Experience gained through their operation will allow the next generation of trough technology to be installed and operated much more cost-effectively.

Power Towers:

- A number of experimental power tower systems and components have been field-tested around the world in the past 15 years, demonstrating the engineering feasibility and economic potential of the technology.
- Since the early 1980s, power towers have been fielded in Russia, Italy, Spain, Japan, and the United States.
- In early power towers, the thermal energy collected at the receiver was used to generate steam directly to drive a turbine generator.
- The U.S.-sponsored Solar Two was designed to demonstrate the dispatchability provided by molten-salt storage and to provide the experience necessary to lessen the perception of risk from these large systems.
- U.S. industry is currently pursuing a subsidized power tower project opportunity in Spain. This project, dubbed "Solar Tres," represents a 4x scale-up of the Solar 2 design.

Dish/Engine Systems:

- Dish/engine technology is the oldest of the solar technologies, dating back to the 1800s when a number of companies demonstrated solar-powered steam Rankine and Stirling-based systems.
- Development of modern technology began in the late 1970s and early 1980s. This technology used directly illuminated, tubular solar receivers, a kinematic Stirling engine developed for automotive applications, and silver/glass mirror dishes. Systems, nominally rated at 25 kWe, achieved solar-to-electric conversion efficiencies of around 30 percent. Eight prototype systems were deployed and operated on a daily basis from 1986 through 1988.
- In the early 1990s, Cummins Engine Company attempted to commercialize dish/Stirling systems

based on free-piston Stirling engine technology. Efforts included a 5 to 10 kWe dish/Stirling system for remote power applications, and a 25 kWe dish/engine system for utility applications. However, largely because of a corporate decision to focus on its core diesel-engine business, Cummins canceled their solar development in 1996. Technical difficulties with Cummins' free-piston Stirling engines were never resolved.

- Current dish/engine efforts are being continued by three U.S. industry teams - Science Applications International Corp. (SAIC) teamed with STM Corp., Boeing with Stirling Energy Systems, and WG Associates with Sunfire Corporation. SAIC and Boeing together have five 25kW systems under test and evaluation at utility, industry, and university sites in Arizona, California, and Nevada. WGA has two 10kW systems under test in New Mexico, with a third off-grid system being developed in 2002 on an Indian reservation for water-pumping applications.

Technology Future

The levelized cost of electricity (in constant 1997$/kWh) for the three CSP configurations are projected to be:

	2000	2010	2020
Trough	9.5	5.4	4.4
Power Tower	9.5	4.8	3.6
Dish/Engine	17.9	6.1	5.5

Source: *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997 for Dish/Engine, and Program values for Trough and Power Tower.

- RD&D efforts are targeted to improve performance and lifetime, reduce manufacturing costs with improved designs, provide advanced designs for long-term competitiveness, and address barriers to market entry.
- RD&D goals are to reduce the cost of CSP systems to 5 to 8¢/kWh within five years at moderate production levels. Long-run goals are to reduce costs below 4¢/kWh at high production levels.
- Improved manufacturing technologies are needed to reduce the cost of key components, especially for first-plant applications where economies of scale are not yet available.
- Demonstration of Stirling engine performance and reliability in the field are critical to the success of dish/engine systems.
- DOE expects Dish/Stirling systems to be available by 2005, after deployment and testing of 1 MW (40 systems) during the next two years.
- Key DOE program activities are targeted to support the next commercial opportunities for these technologies, demonstrate improved performance and reliability of components and systems, reduce energy costs, and develop advanced systems and applications.
- The successful conclusion of Solar Two sparked worldwide interest in power towers. As Solar Two completed operations, an international consortium led by U.S. industry including Bechtel and Boeing (with technical support from Sandia National Laboratories), formed to pursue power tower plants worldwide, especially in Spain (where special solar premiums make the technology cost-effective), but also in Egypt, Morocco, and Italy. Their first commercial power tower plant is planned to be four times the size of Solar Two (about 40 MW equivalent, utilizing storage to power a 15MW turbine up to 24 hours per day).
- The World Bank's Solar Initiative is pursuing CSP technologies for less-developed countries. The World Bank considers CSP as a primary candidate for Global Environment Facility funding, which could total $1B to $2B for projects during the next two years.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003.

Concentrating Solar Power

Market Data

U.S. Installations (electric only)

Source: Renewable Energy Project Information System (REPiS), Version 7, NREL, 2003, and *Renewable Energy Technology Characterizations,* EPRI TR-109496.

Cumulative (MW)	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002
U.S.	0	24	274	354	364	364	364	364	354	354	354
Power Tower	0	10	0	0	10	10	10	10	0	0	0
Trough	0	14	274	354	354	354	354	354	354	354	354
Dish/Engine	0	0	0	0	0	0	0.125	0.125	0.125	0.125	0.125

Annual Generation from Cumulative Installed Capacity (Billion kWh)

Source: EIA, Annual Energy Outlook 1998-2004 Table A17, Renewable Resources in the Electric Supply, 1993 Table 4.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002
U.S.			1*	0.82	0.90	0.89	0.89	0.87	0.49	0.54	0.54

* Includes both solar thermal and less than 0.02 billion kilowatthours grid-connected photovoltaic generation.

Annual U.S. Solar Thermal Shipments (Thousand Square Feet)

Source: EIA - *Annual Energy Review 2003* Table 10.3 and *Renewable Energy Annual 2003* Table 11.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total 1	19,398	N/A	11,409	7,666	7,616	8,138	7,756	8,583	8,354	11,189	11,663	11,444
Imports	235	N/A	1,562	2,037	1,930	2,102	2,206	2,352	2,201	3,502	3,068	2,986
Exports	1,115	N/A	245	530	454	379	360	537	496	840	659	518

1 Total shipments as reported by respondents include all domestic and export shipments and may include imports that subsequently were shipped to domestic or to foreign customers.
No data are available for 1985.

Technology Performance

Efficiency		1980	1990	1995	2000	2005	2010	2015	2020
Capacity Factor (%)	Power Tower			20.0	43.0	44.0	65.0	71.0	77.0
	Trough			34.0	33.3	41.7	51.2	51.2	51.2
	Dish			12.4	50.0	50.0	50.0	50.0	50.0
Solar to Electric Eff. (%)	Power Tower			8.5	15.0	16.2	17.0	18.5	20.0
	Trough			10.7	13.1	13.9	14.8	14.8	15.6
	Dish/Engine								

Source: *Renewable Energy Technology Characterizations,* EPRI TR-109496, 1997 (this document is currently being updated by DOE, and the values most likely will change), and TC revisions made by Hank Price of NREL for Trough technologies and Scott Jones of Sandia National Laboratory for Power Towers in 2001.

Cost*		1980	1990	1995	2000	2005	2010	2015	2020
Total ($/kWp)	Power Tower				1,747	1,294	965	918	871
	Trough			4,033	2,103	1,633	1,277	1,185	1,072
	Dish/Engine			12,576	5,191	2,831	1,365	1,281	1,197
Total ($/kWnameplate)	Power Tower				3,145	2,329	2,605	2,475	2,345
	Trough			4,033	3,154	2,988	2,766	2,568	2,323
	Dish/Engine			12,576	5,691	3,231	1,690	1,579	1,467
O&M ($/kWh)	Power Tower			0.171	0.018	0.006	0.005	0.004	0.004
	Trough			0.025	0.017	0.013	0.009	0.007	0.007
	Dish/Engine			0.210	0.037	0.023	0.011	0.011	0.011
Levelized Cost of Energy	Power Tower				0.101	0.066	0.051	0.044	0.038
($/kWh)	Trough			0.160	0.101	0.077	0.057	0.052	0.047
	Dish/Engine				0.179		0.061	0.058	0.055

* Cost data for trough and power tower technologies are from 2001 revisions (in 2001$). Dish/Engine data for $/kWp excludes costs of hybrid system and $/kWnameplate includes hybrid costs (in 1997$).

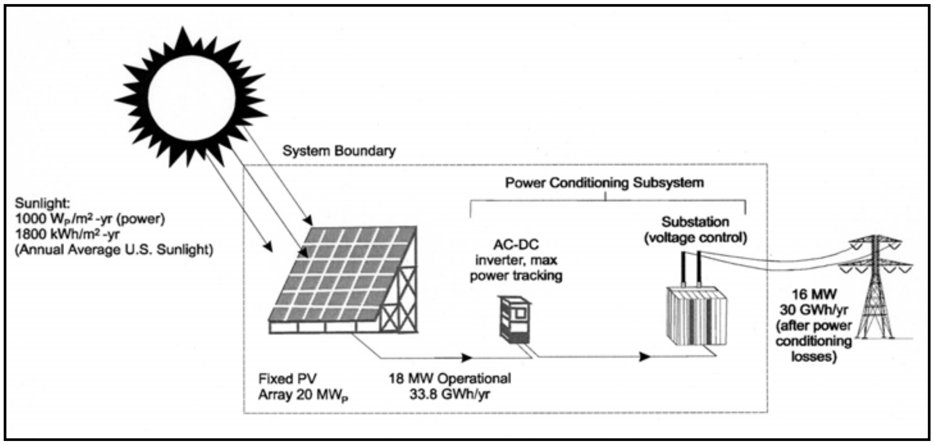
Photovoltaics

Technology Description

Photovoltaic (PV) arrays convert sunlight to electricity without moving parts and without producing fuel wastes, air pollution, or greenhouse gases (GHGs). Using solar PV for electricity and eventually transportation (from hydrogen production) will help reduce CO_2 worldwide.

System Concepts

- Flat-plate PV arrays use global sunlight; concentrators use direct sunlight. Modules are mounted on a stationary array or on single- or dual-axis sun trackers. Arrays can be ground-mounted or on all types of buildings and structures (e.g., see semi-transparent solar canopy, right). PV dc output can be conditioned into grid-quality ac electricity, or dc can be used to charge batteries or to split water to produce H_2.



Representative Technologies

- Flat-plate cells are either constructed from crystalline silicon cells, or from thin films using amorphous silicon. Other materials such as copper indium diselinide (CIS) and cadmium telluride also hold promise as thin-film materials. The vast majority of systems installed today are in flat-plate configurations where multiple cells are mounted together to form a module. These systems are generally fixed in a single position, but can be mounted on structures that tilt toward the sun on a seasonal basis, or on structures that roll east to west over the course of the day.
- Photovoltaic concentrator systems use optical concentrators to focus direct sunlight onto solar cells for conversion to electricity. A complete concentrating system includes concentrator modules, support and tracking structures, a power-processing center, and land. PV concentrator module components include solar cells, an electrically isolating and thermally conducting housing for mounting and interconnecting the cells, and optical concentrators. The solar cells in today's concentrators are predominantly silicon, although gallium arsenide-based (GaAs) solar cells may be used in the future because of their high-conversion efficiencies. The housing places the solar cells at the focus of the optical concentrator elements and provides means for dissipating excess heat generated in the solar cells. The optical concentrators are generally Fresnel lenses but also can be reflectors.

Technology Applications

- PV systems can be installed as either grid supply technologies or as customer-sited alternatives to retail electricity. As suppliers of bulk grid power, PV modules would typically be installed in large array fields ranging in total peak output from a few megawatts on up. Very few of these systems have been installed to-date. A greater focus of the recent marketplace is on customer-sited systems, which may be installed to meet a variety of customer needs. These installations may be residential-size systems of just one kilowatt, or commercial-size systems of several hundred kilowatts. In either case, PV systems meet customer needs for alternatives to purchased power, reliable power, protection from price escalation, desire for green power, etc. Interest is growing in the use of PV systems as part of the building structure or façade ("building integrated"). Such systems use PV modules designed to look like shingles, windows, or other common building elements.

- PV systems are expected to be used in the United States for residential and commercial buildings; distributed utility systems for grid support; peak power shaving, and intermediate daytime load following; with electric storage and improved transmission, for dispatchable electricity; and H_2 production for portable fuel.
- Other applications for PV systems include electricity for remote locations, especially for billions of people worldwide who do not have electricity. Typically, these applications will be in hybrid minigrid or battery-charging configurations.
- Almost all locations in the United States and worldwide have enough sunlight for PV (e.g., U.S. sunlight varies by only about 25% from an average in Kansas).
- Land area is not a problem for PV. Not only can PV be more easily sited in a distributed fashion than almost all alternatives (e.g., on roofs or above parking lots), a PV-generating station 140 km-by-140 km sited at an average solar location in the United States could generate all of the electricity needed in the country (2.5×10^6 GWh/year), assuming a system efficiency of 10% and an area packing factor of 50% (to avoid self-shading). This area (0.3% of U.S.) is less than one-third of the area used for military purposes in the United States.

Current Status

- The cost of PV-generated electricity has dropped 15- to 20-fold; and grid-connected PV systems currently sell for about \$5–\$8/W_p (20 to 32¢/kWh), including support structures, power conditioning, and land. They are highly reliable and last 20 years or longer.
- Crystalline silicon is widely used and the most commercially mature photovoltaic material. Thin-film PV modules currently in production include three based on amorphous silicon, cadmium telluride, and CIS alloys.
- About 288 MW of PV were sold in 2000 (more than \$2 billion worth) and 510 MW of PV were sold in 2002; total installed PV is more than 2 GW. The U.S. world market share is about 20%. Annual market growth for PV has been about 25% as a result of reduced prices and successful global marketing. Specifically, sales grew 36% in 2001 and 31% in 2002. Hundreds of applications are cost-effective for off-grid needs. Almost two-thirds of U.S.-manufactured PV is exported. However, the fastest growing segment of the market is grid-connected PV, such as roof-mounted arrays on homes and commercial buildings in the United States. California is subsidizing PV systems because it is considered cost-effective to reduce their dependence on natural gas, especially for peak daytime loads for air-conditioning, which matches PV output.
- Highest efficiency for wafers of single-crystal or polycrystalline silicon is 25%, and for commercial modules is 13%–17%. Silicon modules currently cost about \$2/W_p to manufacture.
- In the past few years, *world record* solar cell sunlight-to-electricity conversion efficiencies were set by federally funded universities, national laboratories, or industry in copper indium gallium diselenide (19% cells and 13% modules) and cadmium telluride (16% cells, 11% modules). Cell and module efficiencies for these technologies have increased more than 50% in the past decade. Efficiencies for commercial thin-film modules are 5%–11%, with the best cells offering 12-19% efficiency. A new generation of thin-film PV modules is going through the high-risk transition to first-time and large-scale manufacturing. If successful, market share could increase rapidly.
- Highest efficiencies for single-crystal Si and multijunction gallium arsenide (GaAs)-alloy cells for concentrators are 25%–34%; and for commercial modules are 15%–17%. Prototype systems are being tested in the U.S. desert SW.
- Current leading PV companies in 2000 and associated production of cells/modules are listed below:

Top PV Producers (2002)

	U.S. Production MW	World Production MW
Sharp	-	198.0
Shell Solar	52.0	73.0

Kyocera	-	72.0
BP Solar	13.4	70.2
RWE (ASE)	4.0	44.0
Mitsubishi	-	42.0
Isofoton	-	35.2
Sanyo	-	35.0
Q-Cells	-	28.0
Photowatt	-	20.0
AstroPower	17.0	17.0
USSC	7.0	
Global Solar	3.0	-
First Solar	3.0	-
Evergreen Solar	2.8	-
Other*	2.0	-
Total	104.22	632.4
World Total	-	744.1

Source: US: PV News, Vol. 23, No. 3, Page 2; World: PV News, Vol. 23, No. 4, Page 2

Technology History

- French physicist Edmond Becquerel first described the photovoltaic (PV) effect in 1839, but it remained a curiosity of science for the next three quarters of a century. At only 19, Becquerel found that certain materials would produce small amounts of electric current when exposed to light. The effect was first studied in solids, such as selenium, by Heinrich Hertz in the 1870s. Soon afterward, selenium PV cells were converting light to electricity at more than 1 percent efficiency. As a result, selenium was quickly adopted in the emerging field of photography for use in light-measuring devices.
- Major steps toward commercializing PV were taken in the 1940s and early 1950s, when the Czochralski process was developed for producing highly pure crystalline silicon. In 1954, scientists at Bell Laboratories depended on the Czochralski process to develop the first crystalline silicon photovoltaic cell, which had an efficiency of 4%. Although a few attempts were made in the 1950s to use silicon cells in commercial products, it was the new space program that gave the technology its first major application. In 1958, the U.S. Vanguard space satellite carried a small array of PV cells to power its radio. The cells worked so well that PV technology has been part of the space program ever since.
- Even today, PV plays an important role in space, supplying nearly all power for satellites. The commercial integrated circuit technology also contributed to the development of PV cells. Transistors and PV cells are made from similar materials and operate on similar physical mechanisms. As a result, advances in transistor research provided a steady flow of new information about PV cell technology. (Today, however, this technology transfer process often works in reverse, as advances in PV research and development are sometimes adopted by the integrated circuit industry.)
- Despite these advances, PV devices in 1970 were still too expensive for most "down-to-Earth" uses. But, in the mid-1970s, rising energy costs, sparked by a world oil crisis, renewed interest in making PV technology more affordable. Since then, the federal government, industry, and research organizations have invested billions of dollars in research, development, and production. A thriving industry now exists to meet the rapidly growing demand for photovoltaic products.

Technology Future			
The levelized cost of electricity (in constant 1997$/kWh) for PV are projected to be:			
	2000	2010	2020
Utility-owned Residential (crystalline Si)	29.7	17.0	10.2
Utility-Scale Thin-Film	29.0	8.1	6.2
Concentrator	24.4	9.4	6.5

Source: *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997.
(Note that this document is currently being updated by DOE, and the values most likely will change).

- Crystalline Silicon - Most PV systems installed to-date have used crystalline silicon cells. That technology is relatively mature. In the future, cost-effectiveness will be achieved through incremental efficiency improvements, enhanced yields, and advanced lower-cost manufacturing techniques.
- Even though some thin-film modules are now commercially available, their real commercial impact is only expected to become significant during the next three to 10 years. Beyond that, their general use should occur in the 2005-2015 time frame, depending on investment levels for technology development and manufacture.
- Thin films using amorphous silicon, which are a growing segment of the U.S. market, have several advantages over crystalline silicon. It can be manufactured at lower cost, is more responsive to indoor light, and can be manufactured on flexible or low-cost substrates. Improved semiconductor deposition rates will reduce manufacturing costs in the future. Other thin-film materials will become increasingly important in the future. In fact, the first commercial modules using indium gallium diselinide thin-film devices were produced in 2000. Improved manufacturing techniques and deposition processes will reduce costs and help improve efficiency.
- Substantial commercial interest exists in scaling-up production of thin films. As thin films are produced in larger quantity, and as they achieve expected performance gains, they will become more economical for the whole range of applications.
- Multijunction cells with efficiencies of 38% at very high concentrations are being developed.
- Manufacturing research and supporting technology development hold important keys to future cost reductions. Large-scale manufacturing processes will allow major cost reductions in cells and modules. Advanced power electronics and non-islanding inverters will lessen barriers to customer adoption and utility interface.
- A unique multijunction GaAs-alloy cell developed at NREL was spun off to the space power industry, leading to a record cell (34%) and a shared R&D100 Award for NREL/Spectrolab in 2001. This device configuration is expected to dominate future space power for commercial and military satellites.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003

Photovoltaics

Market Data

PV Cell/Module Production (Shipments)

Source: *PV News,* Vol. 15, No. 2, Feb. 1996; Vol. 16, No. 2, Feb. 1997; Vol. 20, No. 2, Feb. 2001, Vol. 22, No. 5, May 2003 and Volume 23, No. 4, April 2004. Paul Maycock, www.pvenergy.com

Annual (MW)	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
U.S.	3	8	15	35	39	51	54	61	75	100	121	103
Japan	1	10	17	16	21	35	49	80	129	171	251	364
Europe	0	3	10	20	19	30	34	40	61	87	135	193
Rest of World	0	1	5	6	10	9	19	21	23	33	54	84
World Total	4	23	47	78	89	126	155	201	288	391	560	744

Cumulative (MW)	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
U.S.	5	45	101	219	258	309	363	424	499	599	720	823
Japan	1	26	95	185	206	241	290	370	499	670	921	1,285
Europe	1	13	47	136	155	185	219	259	320	407	542	735
Rest of World	0	3	20	45	55	65	83	104	127	160	214	298
World Total	7	87	263	585	674	800	954	1,156	1,444	1,835	2,395	3,139

U.S. % of World Sales	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Annual	71%	34%	32%	44%	44%	41%	35%	30%	26%	26%	22%	14%
Cumulative	75%	52%	39%	37%	38%	39%	38%	37%	35%	33%	30%	26%

Annual Capacity (Shipments retained, MW)*

Source: *Strategies Unlimited*

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
U.S.	1.4	4.2	5.1	8.4	9.2	10.5	13.6	18.4	21.3
Total World	3	15	39	68	79	110	131	170	246

*Excludes indoor consumer (watches/calculators).

Cumulative Capacity (Shipments retained, MW)* — Source: *Strategies Unlimited*

	1980	1985	1990	1995	1996	1997	1998	1999	2000
U.S.	3	23	43	76	85	96	109	128	149
Total World	6	61	199	474	552	663	794	964	1,210

*Excludes indoor consumer (watches/calculators).

U.S. Shipments (MW) — Source: *EIA, Annual Energy Review 2003,* DOE/EIA-0384(2003) (Washington, D.C., September 2004), Tables 10.5 and 10.6, and EIA, *Renewable Energy Annual 2003*, DOE/EIA-0603(2003) (Washington, D.C., December 2004) Table 26.

Annual Shipments	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total		5.8	13.8	31.1	35.5	46.4	50.6	76.8	88.2	97.7	112.1	109.4
Imports		0.3	1.4	1.3	1.9	1.9	1.9	4.8	8.8	10.2	7.3	9.7
Exports		1.7	7.5	19.9	22.4	33.8	35.5	55.6	68.4	61.4	66.8	60.7
Domestic Total On-Grid*		0.4	0.2	1.7	1.8	2.2	4.2	6.9	4.9	10.1	13.7	NA
Domestic Total Off-Grid*		3.7	6.1	9.5	11.2	10.3	10.8	14.4	15.0	26.2	31.6	NA
Cumulative Shipments (since 1982)	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Total		35.2	84.7	193.3	228.8	275.2	325.7	402.5	490.7	588.4	700.5	809.8
Imports		1.0	5.6	14.3	16.2	18	19.9	24.7	33.5	43.7	51.0	60.8
Exports		5.7	32.9	104	126.5	160.3	195.8	251.3	319.7	381.0	447.8	508.5
Domestic Total On-Grid*		2.9	4.7	8.2	10.0	12.2	16.5	23.3	28.2	38.3	52.0	NA
Domestic Total Off-Grid*		26.6	47.2	81.1	92.3	102.7	113.5	127.9	142.8	169.0	200.6	NA

* Domestic Totals include imports and exclude exports.

NA = Not Available; 2003 data not available at time of publication

U.S. Shipments (MW) — Source: *Renewable Energy World*, July-August 2003, Volume 6, Number 4, and *PV News*, Vol. 23, No. 5, May 2004

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total				34.8	38.9	51.0	53.7	60.8	75.0	100.3	120.6	103.0
Imports								2.0	4.0	5.0	9.0	18.0
Exports				24.0	25.1	36.3	37.9	39.8	55.0	73.3	81.2	54.0

Annual U.S. Installations (MW)	Source: *The 2002 National Survey Report of Photovoltaic Power Applications in the United States*, prepared by Paul D. Maycock and Ward Bower, May 31, 2003, prepared for the IEA, Table 1. http://www.oja-services.nl/iea-pvps/nsr02/download/usa.pdf; and PV News, Vol. 23 No. 5.										
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Grid-Connected Distributed				1.5	2.0	2.0	2.2	3.7	5.5	12.0	22.0	32.0
Off-Grid Consumer				3.5	4.0	4.2	4.5	5.5	6.0	7.0	8.4	9.0
Government				0.8	1.2	1.5	1.5	2.5	2.5	1.0	1.0	1.0
Off-Grid Industrial/Commercial				4.0	4.4	4.8	5.2	6.5	7.5	9.0	13.0	16.0
Consumer (<40 w)				2.0	2.2	2.2	2.4	2.5	2.5	3.0	4.0	4.0
Central Station				0	0	0	0	0	0	0	0	5.0
Total				11.8	13.8	14.7	15.8	20.7	24.0	32.0	48.4	67.0

Cumulative U.S. Installations* (MW)	Source: *The 2002 National Survey Report of Photovoltaic Power Applications in the United States,* prepared by Paul D. Maycock and Ward Bower, May 31, 2003, prepared for the IEA, Table 1 http://www.oja-services.nl/iea-pvps/nsr02/usa2.htm.											
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Off-grid Residential				19.3	23.3	27.5	32.0	37.5	43.5	50.5		
Off-grid Nonresidential				25.8	30.2	35.0	40.2	46.7	55.2	64.7		
On-grid Distributed				9.7	11.0	13.7	15.9	21.1	28.1	40.6		
On-grid Centralized				12.0	12.0	12.0	12.0	12.0	12.0	12.0		
Total				66.8	76.5	88.2	100.1	117.3	138.8	167.8		

* Excludes installations less than 40kW.

Annual World Installations (MW)	Source: *Renewable Energy World,* July-August 2003, Volume 6, Number 4.										
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Consumer Products			16		22	26	30	35	40	45	60
U.S. Off-Grid Residential			3		8	9	10	13	15	19	25
World Off-Grid Rural			6		15	19	24	31	38	45	60
Communications/ Signal	N/A	N/A	14	N/A	23	28	31	35	40	46	60
PV/Diesel, Commercial			7		12	16	20	25	30	36	45
Grid-Conn Res., Commercial			1		7	27	36	60	120	199	270
Central Station (>100kW)			1		2	2	2	2	5	5	5
Total			48		89	127	153	201	288	395	525

Annual U.S. Shipments by Cell Type (MW)	Source: *PV News,* Vol. 15, No. 2, Feb. 1996; Vol. 16, No. 2, Feb. 1997; Vol. 17, No. 2, Feb. 1998; Vol. 18, No. 2, Feb. 1999; Vol. 19, No. 3, March 2000; Vol. 20, No. 3, March 2001; Vol. 21, No. 3, March 2002; Vol. 22, No. 5, May 2003; and *Renewable Energy World*, July-August 2003, Volume 6, Number 4.										
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Single Crystal				22.0	24.1	31.8	30.0	36.6	44.0	63.0	71.9
Flat-Plate Polycrystal (other than ribbon)				9.0	10.3	14.0	14.7	16.0	17.0	20.6	24
Amorphous Silicon				1.3	1.1	2.5	3.8	5.3	6.5	7.3	11
Crystal Silicon Concentrators				0.3	0.7	0.7	0.2	0.5	0.5	0.5	0.5
Ribbon Silicon	N/A	N/A	N/A	2.0	3.0	4.0	4.0	4.2	5.0	6.9	6.9
Cadmium Telluride				0.1	0.4	0	0	0	0	0.6	1.6
Microcrystal SI/Single SI										0	-
SI on Low-Cost-Sub				0.1	0.3	0.5	1.0	2.0	2.0	1.7	1.7
A-SI on Cz Slice									0	0	-
Total				34.8	39.9	53.5	53.7	64.6	75	100.6	120.6

Annual World Shipments by Cell Type (MW)	Source: *PV News,* Vol. 15, No. 2, Feb. 1996; Vol. 16, No. 2, Feb. 1997; Vol. 17, No. 2, Feb. 1998; Vol. 18, No. 2, Feb. 1999; Vol. 19, No. 3, March 2000; Vol. 20, No. 3, March 2001; Vol. 21, No. 3, March 2002; Vol. 22, No. 5, May 2003; and *Renewable Energy World*, July-August 2003, Volume 6, Number 4.										
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Single Crystal				46.7	48.5	62.8	59.8	73	89.7	150.41	162.31
Flat-Plate Polycrystal				20.1	24	43	66.3	88.4	140.6	278.9	306.55
Amorphous Silicon				9.1	11.7	15	19.2	23.9	27	28.01	32.51
Crystal Silicon Concentrators				0.3	0.7	0.2	0.2	0.5	0.5	0.5	0.5
Ribbon Silicon	N/A	N/A	N/A	2	3	4	4	4.2	14.7	16.9	16.9
Cadmium Telluride				1.3	1.6	1.2	1.2	1.2	1.2	2.1	4.6
Microcrystal SI/Single SI										3.7	3.7
SI on Low-Cost-Sub				0.1	0.3	0.5	1	2	2	1.7	1.7
A-SI on Cz Slice								8.1	12	30	30
Total				79.5	89.8	126.7	151.7	201.3	287.7	512.22	561.77

Annual U.S. Shipments by Cell Type (MW)	Source: EIA, Solar Collector Manufacturing Activity annual reports, 1982-1992 and EIA, *Renewable Energy Annual 1997,* Table 27, REA 2000 Table 26, REA 2002, Table 28.										
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Single-Crystal Silicon				19.9	21.7	30	30.8	47.2	51.9	54.7	74.7
Cast and Ribbon Crystalline Silicon				9.9	12.3	14.3	16.4	26.2	33.2	29.9	29.4
Crystalline Silicon Total		5.5	12.5	29.8	34	44.3	47.2	73.5	85.2	84.7	104.1
Thin-Film Silicon	N/A	0.3	1.3	1.3	1.4	1.9	3.3	3.3	2.7	12.5	7.4
Concentrator Silicon				0.1	0.2	0.2	0.1	0.1	0.3	0.5	0.6
Other											
Total		5.8	13.8	31.2	35.6	46.3	50.6	76.8	88.2	97.7	112.1

Annual Grid-Connected Capacity (MW)	Source: *The 2002 National Survey Report of Photovoltaic Power Applications in the United States*, prepared by Paul D. Maycock and Ward Bower, May 31, 2003, prepared for the IEA, derived from Table 1 http://www.oja-services.nl/iea-pvps/nsr02/usa2.htm. Japan data from *PV News*, Vol. 23, No. 1, January 2004.											
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
U.S.					1.3	2.7	2.2	5.2	7.0	12.5		
Japan				3.9	7.5	19.5	24.1	57.7	74.4	91.0	155.0	168.0

Note: Japan data not necessarily grid-connected

Cumulative Grid-Connected Capacity (MW)	Source: *The 2002 National Survey Report of Photovoltaic Power Applications in the United States*, prepared by Paul D. Maycock and Ward Bower, May 31, 2003, prepared for the IEA, derived from Table 1 http://www.oja-services.nl/iea-pvps/nsr02/usa2.htm. Japan data from *PV News*, Vol. 23, No. 1, January 2004.											
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
U.S.				21.7	23.0	25.7	27.9	33.1	40.1	52.6		
Japan				5.8	13.3	32.8	56.9	114.6	189.0	280.0	435.0	603.0

Japan Grid-Connected Capacity (MW)	Source: IEA Photovoltaic Power Systems Program, *National Survey Report of PV Power Applications in Japan* 2002, http://www.oja-services.nl/iea-pvps/nsr02/jpn2.htm Table 1.										
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Annual				6.0	9.7	22.6	34.7	71.3	114.8	119.3	178.2
Cumulative				13.7	23.4	46.0	80.7	151.9	266.7	386.0	564.2

Annual U.S.-Installed Capacity (MW)	Source: *Renewable Electric Plant Information System (REPiS), Version 7, NREL, 2003.*											
Top 10 States	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
California		0.034	0.016	0.720	0.900	0.606	0.577	2.993	5.833	7.236	16.072	7.452
Arizona		0.004		0.026	0.067	0.724	0.301	0.574	0.177	2.516	1.333	0.008
New York			0.013	0.067	0.425	0.021	0.246	0.041	0.377		1.078	
Ohio						0.001	0.001	0.010	0.144	0.004	1.986	
Hawaii				0.000	0.046	0.008	0.291	0.113	0.250	0.275		
Texas	0.006	0.015	0.002	0.008		0.010	0.133	0.248	0.089	0.028	0.020	
Colorado				0.018	0.100	0.006	0.132	0.344	0.137			
Georgia					0.352			0.019	0.221		0.003	0.032
Florida	0.009		0.008	0.018		0.036	0.047	0.106	0.202	0.031	0.050	
Illinois						0.002	0.005	0.034	0.043	0.449	0.044	
Total U.S.	0.015	0.078	0.049	1.029	2.131	1.670	1.899	5.140	8.244	10.807	21.251	8.008

2003 data not complete as REPiS database is updated through 2002.

Cumulative U.S.-Installed Capacity (MW)	Source: *Renewable Electric Plant Information System (REPiS), Version 7, NREL, 2003.*											
Top 10 States	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
California	0.002	1.369	2.803	6.495	7.396	8.002	8.579	11.572	17.405	24.641	40.713	48.164
Arizona	0.008	0.032	0.048	0.097	0.164	0.888	1.190	1.764	1.941	4.457	5.790	5.798
New York	0	0	0.013	0.226	0.650	0.671	0.917	0.958	1.334	1.334	2.412	2.412
Ohio	0	0	0	0	0	0.001	0.002	0.012	0.155	0.159	2.145	2.145
Hawaii	0	0.014	0.033	0.033	0.079	0.087	0.378	0.491	0.741	1.016	1.016	1.016
Texas	0.006	0.021	0.366	0.437	0.437	0.446	0.579	0.828	0.917	0.945	0.965	0.965
Colorado	0	0	0.010	0.040	0.140	0.146	0.278	0.622	0.759	0.759	0.759	0.759
Georgia	0	0	0	0	0.352	0.352	0.352	0.371	0.592	0.592	0.595	0.627
Florida	0.009	0.093	0.117	0.135	0.135	0.171	0.218	0.325	0.527	0.558	0.609	0.609
Illinois	0	0	0.021	0.021	0.021	0.023	0.029	0.062	0.105	0.554	0.598	0.598
Total U.S. [1]	0.025	2.104	4.170	8.560	10.691	12.362	14.261	19.401	27.645	38.452	59.703	67.710

[1] There are an additional 3.4 MW of photovoltaic capacity that are not accounted for here because they have no specific online date.
2003 data not complete as REPiS database is updated through 2002.

Technology Performance

Source: *Renewable Energy Technology Characterizations,* EPRI TR-109496, 1997.
(Note that this document is currently being updated by DOE, and the values most likely will change).

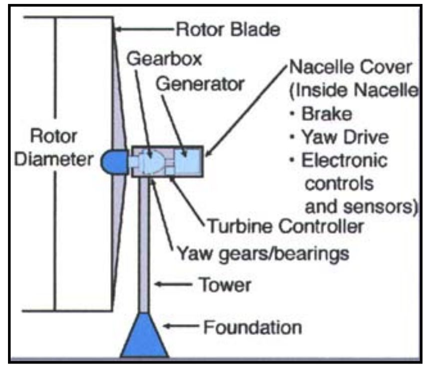
Efficiency		**1980**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Cell (%)	Crystalline Silicon			24.0	24.7				
	Thin Film			18.0	19.0	20.0	21.0	21.5	22.0
	Concentrator			20.0	23.0	26.0	33.0	35.0	37.0
Module (%)	Crystalline Silicon			14.0	16.0	17.0	18.0	18.5	19.0
	Thin Film	N/A	N/A	10.0	12.0	15.0	17.0	17.5	18.0
	Concentrator								
System (%)	Crystalline Silicon			11.3	13.1	14.1	15.1	15.6	16.1
	Thin Film			4.8	7.2	8.8	11.2	12.0	12.8
	Concentrator			13.8	15.1	17.1	21.7	23.0	24.3
Cost		**1980**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Module ($/Wp)	Crystalline Silicon			3.8	3.0	2.3	1.8	1.4	1.1
	Thin Film			3.8	2.2	1.0	0.5	0.4	0.4
	Concentrator			1.8	1.5	0.7	0.6	0.5	0.5
BOS ($/Wp)	Crystalline Silicon			2.7	2.1	1.6	1.2	0.9	0.7
	Thin Film			3.7	2.1	1.3	0.7	0.6	0.5
	Concentrator	N/A	N/A	3.6	2.7	1.2	1.0	0.8	0.7
Total ($/Wp)	Crystalline Silicon *			6.5	5.1	3.9	3.0	2.4	1.8
	Thin Film			7.5	4.3	2.3	1.2	1.1	0.9
	Concentrator			7.6	4.0	2.0	1.6	1.3	1.1
O&M ($/kWh)	Crystalline Silicon			0.008	0.007	0.006	0.006	0.006	0.005
	Thin Film			0.023	0.008	0.003	0.002	0.002	0.001
	Concentrator			0.047	0.020	0.010	0.008	0.007	0.006

* Range in total capital cost for crystalline silicon in 2000 is $5.1/Wp to $9.1/Wp depending on market supply and demand. (Source: John Mortensen, *Factors Associated with Photovoltaic System Costs*, June 2001, NREL/TP 620.29649, Page 3).

Wind Energy

Technology Description

Wind-turbine technology converts the kinetic energy in the wind to mechanical energy and ultimately to electricity. Grid-connected wind power reduces GHG emissions by displacing the need for natural gas- and coal-fired generation. Village and off-grid applications are important for displacing diesel generation and for improving quality of life, especially overseas.



System Concepts

- The principle of wind energy conversion is simple: Wind passing over the blade creates lift, producing a torque on the rotor shaft that turns a gearbox. The gearbox is coupled to an electric generator that produces power at the frequency of the host power system. Some new innovative designs use low-speed generators, which eliminate the need for a gearbox.

Representative Technologies

- Two major design approaches are being used: (1) typical of historic European technology—three-bladed, up-wind, stiff, heavy machines that resist cyclic and extreme loads, and (2) lightweight, flexible machines that bend and absorb loads, primarily being developed by U.S. designers. Several alternative configurations within each approach are being pursued.

Technology Applications

- Thirty-seven states have land area with good winds (13 mph annual average at 10 m height, wind Class 4, or better).
- For wind-farm or wholesale power applications, the principal competition is natural gas for new construction and natural gas in existing units for fuel saving. Utility restructuring is a critical challenge to increased deployment in the near-term because it emphasizes short-term, low capital-cost alternatives and lacks public policy to support deployment of sustainable technologies such as wind energy.

Current Status

- Wind technology is competitive today in bulk power markets with support from the production tax credit, and in high-value niche applications or markets that recognize noncost attributes.
- Current performance is characterized by levelized costs of 4 to 6¢/kWh (depending on resource intensity and financing structure), capacity factors of 30 to 40 percent, availability of 95 to 98%, total installed project costs ("overnight" – not including construction financing) of $800 to $1,100/kW, and efficiencies of 65% to 75% of the theoretical (Betz limit) maximum.
- The worldwide annual market growth rate for wind technology is at a level of 30% with new markets opening in many developing countries. Domestic public interest in environmentally responsible electric generation technology is reflected by new state energy policies and in the success of "green marketing" of wind power across the country.
- Preliminary estimates are that installed capacity at the end of 2001 was 4,260 MW in the United States, and 23,300 MW worldwide; compared to 2,550 MW in the United States and 17,653 worldwide in 2000; and 2,450 MW in the United States and 13,598 MW worldwide in 1999.

Wind installations have grown in the United States at an average rate of 15% in the past ten years. Installed capacity expanded by nearly 10% in the United States during 2002 to 4685 MW, with 410 MW of new equipment going into use that year. Worldwide installations currently total 39 GW.

- U.S. energy generation from wind was nearly 11 TWh out of a worldwide total of 69 TWh in 2003 up from 4.5 TWh out of an approximate total of 26 TWh in 1999.

• The top ten states had between 2,000 MW and 176 MW of large wind-turbine capacity at the end of 2003.
• In the United States, the wind industry is thinly capitalized, except for the acquisition of Enron Wind Corporation by General Electric Co. About six manufacturers and six to 10 developers characterize the U.S. industry.
• Enron Wind Corporation has been acquired by General Electric Corporation, Power Turbine Division.
• In Europe, there are about 12 turbine manufacturers and about 20 to 30 project developers. European manufacturers have established North American manufacturing facilities and are actively participating in the U.S. market.
• Current leading wind companies and sales volume are shown below:

	U.S. Market (2003)		World Market (2003)	
	MW	Percent	MW	Percent
Vestas (DK)	347	20.9	1,812	21.7
GE Wind (USA)	874	52.6	1,503	18
Enercon (D)	-	-	1218	14.6
Gamesa (ESP)	55	3.3	956	11.5
NEG Micon (DK)	146	8.8	855	10.2
Bonus (DK)	15	0.9	552	6.6
Repower (D)	-	-	291	3.5
MADE (ESP)	-	-	243	2.9
Nordex (DK)	-	-	242	2.9
Mitsubishi (JP)	201	12.1	218	2.6
Others	-	-	441	5.3

Sources: U.S. Market: NREL estimate based on BTM Consult, ApS, "World Market Update 2003", World Market: BTM Consult, ApS, "World Market Update 2003"

Technology History

• Prior to 1980, DOE sponsored, and NASA managed, large-scale turbine development – starting with hundred-kilowatt machines and culminating in the late 1980s with the 3.2-MW, DOE-supported Mod-5 machine built by Boeing.
• Small-scale (2-20 kW) turbine development efforts also were supported by DOE at the Rocky Flats test site. Numerous designs were available commercially for residential and farm uses.
• In 1981, the first wind farms were installed in California by a small group of entrepreneurial companies. PURPA provided substantial regulatory support for this initial surge.
• During the next five years, the market boomed, installing U.S., Danish, and Dutch turbines.
• By 1985, annual market growth had peaked at 400 MW. Following that, federal tax credits were abruptly ended, and California incentives weakened the following year.
• In 1988, European market exceeded the United States for the first time, spurred by ambitious national programs. A number of new companies emerged in the U.K. and Germany.
• In 1989, DOE's focus changed to supporting industry-driven research on components and systems. At the same time, many U.S. companies became proficient in operating the 1,600 MW of installed capacity in California. They launched into value engineering and incremental increases in turbine size.
• DOE program supported value-engineering efforts and other advanced turbine-development efforts.
• In 1992, Congress passed the Renewable Energy Production Tax Credit (REPI), which provided a 1.5 cent/kWh tax credit for wind-produced electricity. Coupled with several state programs and mandates, installations in the United States began to increase.
• In 1997, Enron purchased Zond Energy Systems, one of the value-engineered turbine manufacturers. In 2002, General Electric Co. purchased Enron Wind Corporation.
• In FY2001, DOE initiated a low wind-speed turbine development program to broaden the U.S. cost-competitive resource base.

Technology Future

The levelized cost of electricity for wind energy technology is projected to be:

	2000	2002	2010	2020
Class 4	6.0	5.5	3.0	2.7
Class 6	4.2	4.0	2.4	2.2

Assumptions include: 30-year levelized cost, constant January 2002 dollars, generation company ownership/financial assumptions; wind plant comprised of 100 turbines; no financial incentives included.
Source: FY03 U.S. DOE Wind Program Internal Planning Documents, Summer 2001

- Wind energy's competitiveness by 2005 will be affected by policies regarding ancillary services and transmission and distribution regulations. Substantial cost reductions are expected for wind turbines designed to operate economically in low wind-speed sites, which will increase the amount of economical wind resource areas by 20-fold, and will be within 100 miles of most load centers.
- Initial lower levels of wind deployment (up to 15–20% of the total U.S. electric system capacity) are not expected to introduce significant grid reliability issues. Inasmuch as the wind blows only intermittently, intensive use of this technology at larger penetrations may require modification to system operations or ancillary services. Transmission infrastructure upgrades and expansion will be required for large penetrations of wind energy to service major load centers.
- Over the long term, as more high wind sites become used, emphasis will shift toward installation in lower wind-speed sites. Advances in technology will include various combinations of the following improvements, accomplished through continuing R&D:

*Tower*s – taller for more energy, softer to shed loads, advanced materials, and erection techniques to save cost.

Rotors – Improving airfoils and plan forms to increase energy capture. For instance, a variable rotor diameter; larger rotors at the same cost or small cost increase by optimizing design and manufacturing, using lighter materials, and implementing controls to mitigate loads.

Drive Train and Generators – New designs to reduce weight and cost. Advances in power electronics and operational algorithms to optimize drive-train efficiencies, especially by increasing low efficiencies in ranges of operation that are currently much lower than those in the peak range. In addition to new power electronics and operational approaches, possible advances include permanent magnet generators, and use of single-stage transmissions coupled with multiple smaller, simpler, off-the-shelf generators that can be purchased from high-volume manufacturers.

Controls – By reducing loads felt throughout the turbine, various approaches for passive and active control of turbines will enable larger, taller structures to be built for comparatively small cost increases, resulting in improvements in system cost of energy.

Design Codes – Reductions in design margins also will decrease the cost of turbines and allow for larger turbines to be built for comparatively small increases in cost, resulting in improvements in system cost of energy.

Foundations – New designs to lower cost.

Utility Grid Integration – Models and tools to analyze the steady and dynamic impact and operational characteristics of large wind farms on the electric grid will facilitate wind power integration. Improved wind forecasting and development of various enabling technologies will increase the value of wind power.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003

Wind

Market Data

Grid-Connected Wind Capacity (MW) — Source: Reference IEA (data supplemented by *Windpower Monthly*, April 2001), 2001 data from *Windpower Monthly*, January 2002, 2002 data from AWEA "Global Wind Energy Market Report 2004".

Cumulative	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
U.S.	10	1,039	1,525	1,770	1,794	1,741	1,890	2,455	2,554	4,240	4,685	6,374
Germany	2	3	60	1,137	1,576	2,082	2,874	4,445	6,095	8,100	11,994	14,609
Spain	0	0	9	126	216	421	834	1,539	2,334	3,175	4,825	6,202
Denmark	3	50	310	630	785	1,100	1,400	1,752	2,338	2,417	2,889	3,110
Netherlands	0	0	49	255	305	325	364	416	447	483	693	912
Italy			3	22	70	103	180	282	427	682	788	904
UK	0	0	6	193	264	324	331	344	391	477	552	649
Europe	5	58	450	2,494	3,384	4,644	6,420	9,399	12,961	16,362	23,308	28,706
India	0	0	20	550	820	933	968	1,095	1,220	1,426	1,702	2110
Japan	0	0	1	10	14	7	32	75	121	250	415	686
Rest of World	0	0	6	63	106	254	315	574	797	992	1,270	1,418
World Total	15	1,097	2,002	4,887	6,118	7,579	9,625	13,598	17,653	23,270	31,128	39,294

Installed U.S. Wind Capacity (MW) — Source: *Renewable Energy Project Information System (REPiS), Version 7, NREL, 2003.*

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003 [2]
Annual	0.023	337	154	37	8	8	173	695	124	1,843	454	12
Cumulative[1]	0.060	674	1,569	1,773	1,781	1,788	1,961	2,656	2,780	4,623	5,078	5,090

[1] There are an additional 48 MW of wind capacity that are not accounted for here because they have no specific online date.

[2] 2003 data not complete as REPiS database is updated through 2002.

Annual Market Shares — Source: *US DOE- 1982-87 wind turbine shipment database; 1988-94. DOE Wind Program Data Sheets; 1996-2000 American Wind Energy Association*

	1980	1985	1990	1995	1996	1997	1998	1999	2000
U.S. Mfg Share of U.S. Market	98%	44%	36%	67%	NA	38%	78%	44%	0%
U.S. Mfg Share of World Market	65%	42%	20%	5%	2%	4%	13%	9%	6%

State-Installed Capacity — Source: *American Wind Energy Association. http://www.awea.org/projects/index.html*

Annual State-Installed Capacity (MW)

Top 10 States	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
California*		N/A	N/A	3	0	8.4	0.7	250	0	67.1	108	198.8
Texas		0	0	41	0	0	0	139.2	0	915.2	0	197.5
Minnesota		0	0	0	0	0.2	109.2	137.6	17.8	28.6	16.8	228.2
Iowa		0	0	0.1	0	1.2	3.1	237.5	0	81.8	98.5	49.8
Wyoming		0	0	0	0.1	0	1.2	71.3	18.1	50	0	144
Oregon		0	0	0	0	0	25.1	0	0	132.4	60.9	41
Washington		0	0	0	0	0	0	0	0	178.2	50.0	15.6
Colorado		0	0	0	0	0	0	21.6	0	39.6	0	162.0
New Mexico		0	0	0	0	0	0	1.3	0	0	0	204.0
Oklahoma		0	0	0	0	0	0	0	0	0	0	176.3
Total of 10 States		N/A	N/A	44	0	10	139	859	36	1,493	334	1,417
Total U.S.		N/A	N/A	44	1	16	142	884	67	1,694	410	1669.1

Top 10 States	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
California*		N/A	N/A	1,387	1,387	1,396	1,396	1,646	1,646	1,714	1,822	2,043
Texas		0	0	41	41	41	41	180.2	180.2	1095.5	1095.5	1,293
Minnesota		0	0	25.7	25.7	25.9	135.1	272.7	290.5	319.1	335.9	563
Iowa		0	0	0.7	0.8	2	5	242.5	242.5	324.2	422.7	471
Wyoming		0	0	0	0.1	0.1	1.3	72.5	90.6	140.6	140.6	285
Oregon		0	0	0	0	0	25.1	25.1	25.1	157.5	218.4	259
Washington		0	0	0	0	0	0	0	0	178.2	228.2	244
Colorado		0	0	0	0	0	0	21.6	21.6	61.2	61.2	223
New Mexico		0	0	0	0	0	0	1.3	1.3	1.3	1.3	207
Oklahoma		0	0	0	0	0	0	0	0	0	0	176
Total of 10 states		N/A	N/A	1,454	1,455	1,465	1,604	2,462	2,498	3,992	4,326	5,763
Total U.S.	10	1,039	1,525	1,697	1,698	1,706	1,848	2,511	2,578	4,275	4,685	6,374

* The data set includes 1,193.53 MW of wind in California that is not given a specific installation year, but rather a range of years (1072.36 MW in 1981-1995, 87.98 in 1982-1987, and 33.19 MW in "mid-1980's"), this has led to the "Not Available" values for 1985 and 1990 for California and the totals, and this data is not listed in the annual installations, but has been added to the cumulative totals for 1995 and on.

Cumulative Installed Capacity (MW)

Source: U.S. - EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.11a; IEA R&D Wind Countries - IEA Wind Energy Annual Reports, 1995-2003. IEA Total - "Renewables Information 2002," IEA, 2002.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002[1]	2003
U.S.	N/A	17.5	1,799	1,731	1,678	1,610	1,720	2,252	2,377	3,864	4,417	4,854
IEA R&D Wind Countries[2]								10,040	15,440	21,553	27,935	35,275
IEA Total			2,386	4,235	5,124	6,228	8,001	11,390	16,103			

1. Wind capacity in 2002 will be revised upward to at least 4.4 million kilowatts, as the Energy Information Administration continues to identify new wind facilities.
2. Data for IEA R&D Wind Countries through 2001 included 16 IEA countries. Ireland and Switzerland were added in 2002 and Portugal was added in 2003.

Annual Generation from Cumulative Installed Capacity (Billion kWh)

Source: U.S. - EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004),Table 8.2a; IEA R&D Wind Countries - IEA Wind Energy Annual Reports, 1995-2003. IEA Total - "Renewables Information 2002", IEA, 2002.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
U.S.	N/A	0.006	2.8	3.2	3.2	3.3	3.0	4.5	5.6	6.7	10.4	10.7
IEA R&D Wind Countries[2]				7.1	8.4	10.9	11.3	22.0	26.4	37.2	49.0	69.0
IEA Total			3.8	7.3	8.4	10.7	14.4	19.1	28.9			

2. Data for International Energy Agency R&D Wind Countries through 2001 included 16 IEA countries. Ireland and Switzerland were added in 2002 and Portugal was added in 2003.

Annual Wind Energy Consumption for Electric Generation (Trillion Btu)

Source: EIA, *Annual Energy Review 2003,* DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.4a

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
U.S. Total	N/A	(s)	29.0	32.6	33.4	33.6	30.9	45.9	57.1	68.4	104.8	108.4

(s)=Less than 0.5 trillion Btu.

Technology Performance

Energy Production		Source: *U.S.DOE Wind Program,* 1980-1995, FY03 U.S.DOE Wind Program Internal Planning Documents, Summer 2001, 2000-2020									
			1980	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
	Capacity Factor (%)	Class 4		10	15	20	25.2	32.6	44.7	46.5	47.1
		Class 6		20	22	25	39.4	44.3	49.6	50.9	53.8
	Specific Energy (kWh/m^2*)	Class 4		500	800	850	900	1,110	1,260	1,310	1,330
		Class 6		900	1,150	1,300	1,400	1,650	1,700	1,740	1,760
	Production Efficiency** (kWh/kW)	Class 4	200	650	1,300	1,750	2,200	2,860	3,500	3,600	3,600
		Class 6	800	1,700	1,900	2,200	3,450	3,880	4,350	4,450	4,700

* m^2 is the rotor swept area.

** Production Efficiency is the net energy per unit of installed capacity.

Cost (Jan. 2002 dollars)		Source: FY03 U.S. DOE Wind Program Internal Planning Documents, Summer 2001.									
			1980	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
	Project Cost ($/kW)	Class 4					1,000	915	910	880	860
	(Overnight costs)	Class 6					1,000	900	800	770	750
	O&M ($/kW)	Class 4					11.0	7.9	7.0	6.9	6.6
		Class 6					17.3	8.0	7.8	7.6	7.5
	Fixed O&M & Land	Class 4					8.0	8.0	8.0	8.0	8.0
	($/kW)	Class 6					8.0	8.0	8.0	8.0	8.0

Specific Cost* (Project Capital Cost Per Rotor Captured Area - $/m2) (Jan. 2002 dollars)	Source: *FY03 U.S. DOE Wind Program Internal Planning Documents, Summer 2001, 2000-2020.*									
		1980	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
	Class 4					382	357	293	283	277
	Class 6					414	340	312	300	276

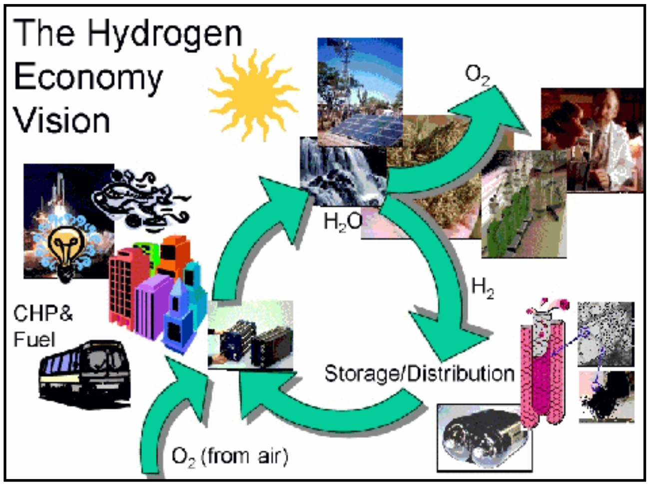
Levelized Cost of Energy* ($/kWh) (Jan. 2002 dollars)	Source: *U.S. DOE Wind Program 1980-1985; FY03 U.S. DOE Wind Program Internal Planning Documents, Summer 2001, 2000-2020*									
		1980	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
	Class 4			0.12	0.080	0.060	0.041	0.030	0.028	0.027
	Class 6			0.08	0.060	0.042	0.027	0.024	0.023	0.022

* 30-year term. Generation Company Ownership/Financial Assumptions. Wind plant comprised of 100 turbines. No financial incentives are included.

Hydrogen

Technology Description

Similar to electricity, hydrogen can be produced from many sources, including fossil fuels, renewable resources, and nuclear energy. Hydrogen and electricity can be converted from one to the other using electrolyzers (electricity to hydrogen) and fuel cells (hydrogen to electricity). Hydrogen is an effective energy storage medium, particularly for distributed generation. When hydrogen produced from renewable resources is used in fuel cell vehicles or power devices, there are very few emissions—the major byproduct is water. With improved conventional energy conversion and carbon-capture technologies, hydrogen from fossil resources can be used efficiently with few emissions.



The Hydrogen Economy vision is based on a clean and elegant cycle: separate water into hydrogen and oxygen using renewable or nuclear energy, or fossil resources with carbon sequestration. Use the hydrogen to power a fuel cell, internal combustion engine, or turbine, where hydrogen and oxygen (from air) recombine to produce electrical energy, heat, and water to complete the cycle. This process produces no particulates, no carbon dioxide, and no pollution.

System Concepts

- Hydrogen made via electrolysis from excess nuclear or renewable energy can be used as a sustainable transportation fuel or stored to meet peak-power demand. It also can be used as a feedstock in chemical processes.
- Hydrogen produced by decarbonization of fossil fuels followed by sequestration of the carbon can enable the continued, clean use of fossil fuels during the transition to a carbon-free Hydrogen Economy.
- A hydrogen system is comprised of production, storage, distribution, and use.
- A fuel cell works like a battery but does not run down or need recharging. It will produce electricity and heat as long as fuel (hydrogen) is supplied. A fuel cell consists of two electrodes—a negative electrode (or anode) and a positive electrode (or cathode)—sandwiched around an electrolyte. Hydrogen is fed to the anode, and oxygen is fed to the cathode. Activated by a catalyst, hydrogen atoms separate into protons and electrons, which take different paths to the cathode. The electrons go through an external circuit, creating a flow of electricity. The protons migrate through the electrolyte to the cathode, where they reunite with oxygen and the electrons to produce water and heat. Fuel cells can be used to power vehicles, or to provide electricity and heat to buildings.

Representative Technologies

Hydrogen production

- Thermochemical conversion of fossil fuels, biomass, and wastes to produce hydrogen and CO_2 with the CO_2 available for sequestration (large-scale steam methane reforming is widely commercialized)
- Renewable (wind, solar, geothermal, hydro) and nuclear electricity converted to hydrogen by electrolysis of water (commercially available electrolyzers supply a small but important part of the super-high-purity hydrogen market)
- Photoelectrochemical and photobiological processes for direct production of hydrogen from sunlight and water.

Hydrogen storage
- Pressurized gas and cryogenic liquid (commercial today)
- Higher pressure (10,000 psi), carbon-wrapped conformable gas cylinders
- Cryogenic gas
- Chemically bound as metal or chemical hydrides or physically adsorbed on carbon nanostructures

Hydrogen distribution
- By pipeline (relatively significant pipeline networks exist in industrial areas of the Gulf Coast region, and near Chicago)
- By decentralized or point-of-use production using natural gas or electricity
- By truck (liquid and compressed hydrogen delivery is practiced commercially)

Hydrogen use
- Transportation sector: internal combustion engines or fuel cells to power vehicles with electric power trains. Potential long-term use as an aviation fuel and in marine applications
- Industrial sector: ammonia production, reductant in metal production, hydrotreating of crude oils, hydrogenation of oils in the food industry, reducing agent in electronics industry, etc.
- Buildings sector: combined heat, power, and fuel applications using fuel cells
- Power sector: fuel cells, gas turbines, generators for distributed power generation

Technology Applications

- In the United States, nearly all of the hydrogen used as a chemical (i.e. for petroleum refining and upgrading, ammonia production) is produced from natural gas. The current main use of hydrogen as a fuel is by NASA to propel rockets.
- Hydrogen's potential use in fuel and energy applications includes powering vehicles, running turbines or fuel cells to produce electricity, and generating heat and electricity for buildings. The current focus is on hydrogen's use in fuel cells.

The primary fuel cell technologies under development are:

Phosphoric acid fuel cell (PAFC) - A phosphoric acid fuel cell (PAFC) consists of an anode and a cathode made of a finely dispersed platinum catalyst on carbon paper, and a silicon carbide matrix that holds the phosphoric acid electrolyte. This is the most commercially developed type of fuel cell and is being used in hotels, hospitals, and office buildings. More than 250 commercial units exist in 19 countries on five continents. This fuel cell also can be used in large vehicles, such as buses.

Proton-exchange membrane (PEM) - The proton-exchange membrane (PEM) fuel cell uses a fluorocarbon ion exchange with a polymeric membrane as the electrolyte. The PEM cell appears to be more adaptable to automobile use than the PAFC type of cell. These cells operate at relatively low temperatures and can vary their output to meet shifting power demands. These cells are the best candidates for light-duty vehicles, for buildings, and much smaller applications.

Solid oxide fuel cells (SOFC) - Solid oxide fuel cells (SOFC) currently under development use a thin layer of zirconium oxide as a solid ceramic electrolyte, and include a lanthanum manganate cathode and a nickel-zirconia anode. This is a promising option for high-powered applications, such as industrial uses or central electricity generating stations.

Direct-methanol fuel cell (DMFC) - A relatively new member of the fuel cell family, the direct-methanol fuel cell (DMFC) is similar to the PEM cell in that it uses a polymer membrane as an electrolyte. However, a catalyst on the DMFC anode draws hydrogen from liquid methanol, eliminating the need for a fuel reformer.

Molten carbonate fuel cell (MCFC) - The molten carbonate fuel cell uses a molten carbonate salt as the electrolyte. It has the potential to be fueled with coal-derived fuel gases or natural gas.

Alkaline fuel cell - The alkaline fuel cell uses an alkaline electrolyte such as potassium hydroxide. Originally used by NASA on missions, it is now finding applications in hydrogen-powered vehicles.

Regenerative or Reversible Fuel Cells - This special class of fuel cells produces electricity from hydrogen and oxygen, but can be reversed and powered with electricity to produce hydrogen and oxygen.

Current Status

- Currently, 48% of the worldwide production of hydrogen is via large-scale steam reforming of natural gas. Today, we safely use about 90 billion cubic meters (3.2 trillion cubic feet) of hydrogen yearly.
- Direct conversion of sunlight to hydrogen using a semiconductor-based photoelectrochemical cell was recently demonstrated at 12.4% efficiency.
- Hydrogen technologies are in various stages of development across the system:

Production - Hydrogen production from conventional fossil-fuel feedstocks is commercial, and results in significant CO_2 emissions. Large-scale CO_2 sequestration options have not been proved and require R&D. Current commercial electrolyzers are 70-80% efficient, but the cost of hydrogen is strongly dependent on the cost of electricity. Production processes using wastes and biomass are under development, with a number of engineering scale-up projects underway.

Storage - Liquid and compressed gas tanks are available and have been demonstrated in a small number of bus and automobile demonstration projects. Lightweight, fiber-wrapped tanks have been developed and tested for higher-pressure hydrogen storage. Experimental metal hydride tanks have been used in automobile demonstrations. Alternative solid-state storage systems using alanates and carbon nanotubes are under development.

Use - Small demonstrations by domestic and foreign auto and bus companies have been undertaken. Small-scale power systems using fuel cells are being beta-tested. Small fuel cells for battery replacement applications have been developed. Much work remains.

- There have been important advances in storage energy densities in recent years: High-pressure composite tanks have been demonstrated with 7.5 wt.% storage capacity, exceeding the current DOE target, and new chemical hydrides have demonstrated a reversible capacity of 5 wt.% hydrogen. The composite tank development is a successful technology partnership among the national labs, DOE, and industry. Industrial investment in chemical hydride development recently has been initiated.
- SunLine Transit receives support to operate a variety of hydrogen production processes for its bus fleet. The California Fuel Cell Partnership has installed hydrogen refueling equipment (liquid delivered to the facility)
- Major industrial companies are pursuing R&D in fuel cells and hydrogen reformation technologies with a mid-term time frame for deployment of these technologies for both stationary and vehicular applications. These companies include:

ExxonMobil	Toyota
Shell	Daimler-Chrysler
Texaco	Honda
BP	International Fuel Cells
General Motors	Ballard
Ford	Air Products
Daimler-Chrysler	Praxair
Toyota	Plug Power Systems

Technology History

- From the early 1800s to the mid-1900s, a gaseous product called town gas (manufactured from coal) supplied lighting and heating for America and Europe. Town gas is 50% hydrogen, with the rest comprised of mostly methane and carbon dioxide, with 3% to 6% carbon monoxide. Then, large natural gas fields were discovered, and networks of natural gas pipelines displaced town gas. (Town gas is still found in limited use today in Europe and Asia.)
- From 1958 to present, the National Aeronautics and Space Administration (NASA) has continued work on using hydrogen as a rocket fuel and electricity source via fuel cells. NASA became the worldwide largest user of liquid hydrogen and is renowned for its safe handling of hydrogen.
- During the 20th century, hydrogen was used extensively as a key component in the manufacture of

ammonia, methanol, gasoline, and heating oil. It was—and still is—also used to make fertilizers, glass, refined metals, vitamins, cosmetics, semiconductor circuits, soaps, lubricants, cleaners, margarine, and peanut butter.

- Recently, (in the late 20th century/dawn of 21st century) many industries worldwide have begun producing hydrogen, hydrogen-powered vehicles, hydrogen fuel cells, and other hydrogen products. From Japan's hydrogen delivery trucks to BMW's liquid-hydrogen passenger cars; to Ballard's fuel cell transit buses in Chicago and Vancouver, B.C.; to Palm Desert's Renewable Transportation Project; to Iceland's commitment to be the first hydrogen economy by 2030; to the forward-thinking work of many hydrogen organizations worldwide; to Hydrogen Now!'s public education work; the dynamic progress in Germany, Europe, Japan, Canada, the United States, Australia, Iceland, and several other countries launch hydrogen onto the main stage of the world's energy scene. Specific U.S.-based examples of hydrogen production and uses are as follows:

- A fully functional integrated renewable hydrogen utility system for the generation of hydrogen using concentrated solar power was demonstrated by cooperative project between industry and an Arizona utility company.
- A renewable energy fuel cell system in Reno, Nevada, produced hydrogen via electrolysis using intermittent renewable resources such as wind and solar energy.
- An industry-led project has developed fueling systems for small fleets and home refueling of passenger vehicles. The refueling systems deliver gaseous hydrogen up to 5,000 psi to the vehicle.

A transit agency in California installed an autothermal reformer, generating hydrogen for buses and other vehicles. This facility also operates a PV-powered electrolysis system to provide renewable hydrogen to their fleet.

Technology Future

- Fuel cells are a promising technology for use as a source of heat and electricity for buildings, and as an electrical power source for electric vehicles. Although these applications would ideally run off pure hydrogen, in the near-term they are likely to be fueled with natural gas, methanol, or even gasoline. Reforming these fuels to create hydrogen will allow the use of much of our current energy infrastructure—gas stations, natural gas pipelines, etc.—while fuel cells are phased in. The electricity grid and the natural gas pipeline system will serve to supply primary energy to hydrogen producers.
- By 2005, if DOE R&D goals are met, (1) onboard hydrogen storage in metal hydrides at >5 wt% will be developed; (2) complete engineering design of a small-scale, mass-producible reformer for natural gas will be completed; and (3) an integrated biomass-to-hydrogen system will be demonstrated.
- By 2010, advances will be made in photobiological and photoelectrochemical processes for hydrogen production, efficiencies of fuel cells for electric power generation will increase, and advances will be made in fuel cell systems based on carbon structures, alanates, and metal hydrides. The RD&D target for 2010 is $45/kW for internal combustion engines operating on hydrogen; the cost goal is $30/kW by 2015.
- Although comparatively little hydrogen is currently used as fuel or as an energy carrier, the long-term potential is for us to make a transition to a hydrogen-based economy in which hydrogen will join electricity as a major energy carrier. Furthermore, much of the hydrogen will be derived from domestically plentiful renewable energy or fossil resources, making the Hydrogen Economy synonymous with sustainable development and energy security.
- In summary, future fuel cell technology will be characterized by reduced costs and increased reliability for transportation and stationary (power) applications.
- To enable the transition to a hydrogen economy, the cost of hydrogen energy is targeted to be equivalent to gasoline market prices ($1.50/gallon in 2001 dollars).
- For a fully developed hydrogen energy system, a new hydrogen infrastructure/delivery system will be required.

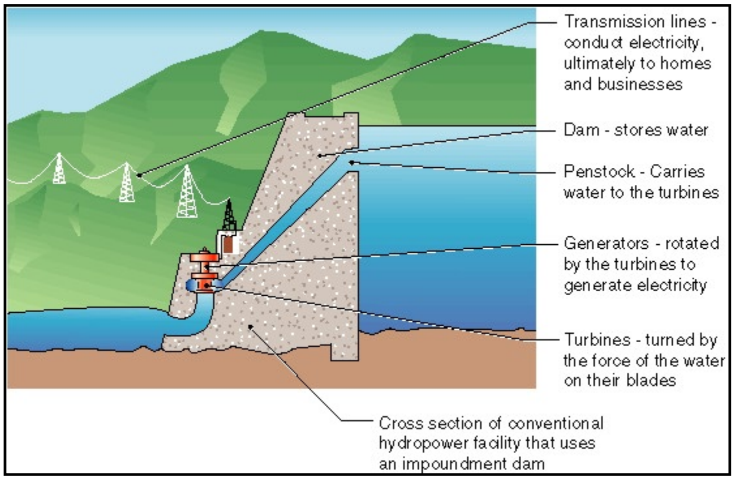
- In the future, hydrogen also could join electricity as an important *energy carrier*. An energy carrier stores, moves, and delivers energy in a usable form to consumers. Renewable energy sources, such as the sun or wind, can't produce energy all the time. The sun doesn't always shine nor the wind blow. But hydrogen can store this energy until it is needed and it can be transported to where it is needed.
- Some experts think that hydrogen will form the basic energy infrastructure that will power future societies, replacing today's natural gas, oil, coal, and electricity infrastructures. They see a new *hydrogen economy* to replace our current energy economies, although that vision probably won't happen until far in the future.

Sources: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term*. DOE/PI-0002. November 2003; and National Renewable Energy Laboratory. *Gas-Fired Distributed Energy Resource Technology Characterizations.* NREL/TP-620/34783. November 2003.

Advanced Hydropower

Technology Description

Advanced hydropower is new technology for producing hydroelectricity more efficiently, with improved environmental performance. Current technology often has adverse environmental effects, such as fish mortality and changes to downstream water quality and quantity. The goal of advanced hydropower technology is to maximize the use of water for hydroelectric generation while eliminating these adverse side effects—in many cases both increased energy and improved environmental conditions can be achieved.



System Concepts

- Conventional hydropower projects use either impulse or reaction turbines to convert kinetic energy in flowing or falling water into turbine torque and power. Source water may be from free-flowing rivers/streams/canals or released from upstream storage reservoirs.
- Improvements and efficiency measures can be made in dam structures, turbines, generators, substations, transmission lines, and systems operation that will help sustain hydropower's role as a clean, renewable energy source.

Representative Technologies

- Turbine designs that minimize entrainment mortality of fish during passage through the power plant.
- Autoventing turbines to increase dissolved oxygen in discharges downstream of dams.
- Reregulating and aerating weirs used to stabilize tailwater discharges and improve water quality.
- Adjustable-speed generators producing hydroelectricity over a wider range of heads and providing more uniform instream flow releases without sacrificing generation opportunities.
- New assessment methods to balance instream flow needs of fish with water for energy production.
- Advanced instrumentation and control systems that modify turbine operation to maximize environmental benefits and energy production.

Technology Applications

- Advanced hydropower products can be applied at more than 80% of existing hydropower projects (installed conventional capacity is now 78 GW); the potential market also includes 15–20 GW at existing dams without hydropower facilities (i.e., no new dams required for development) and about 30 GW at undeveloped sites that have been identified as suitable for new dams.
- The nation's largest hydropower plant is the 7,600 megawatt Grand Coulee power station on the Columbia River in Washington State. The plant is being upscaled to 10,080 megawatts, which will make it the third largest in the world.
- There would be significant environmental benefits from installing advanced hydropower technology, including enhancement of fish stocks, tailwater ecosystems, and recreational opportunities. These benefits would occur because the advanced technology reverses adverse effects of the past.
- Additional benefits would come from the protection of a wide range of ancillary benefits that are provided at hydropower projects but are at extreme risk of becoming lost in the new deregulated environment.

Current Status
• Hydropower (also called hydroelectric power) facilities in the United States can generate enough power to supply 28 million households with electricity, the equivalent of nearly 500 million barrels of oil. The total U.S. hydropower capacity—including pumped storage facilities—is about 95,000 megawatts. Researchers are working on advanced turbine technologies that will not only help maximize the use of hydropower but also minimize adverse environmental effects. • According to EIA, hydropower provided 12.6% of the nation's electricity generating capability in 1999 and 80% of the electricity produced from renewable energy sources. • DOE estimates current capital costs for large hydropower plants to be $1,700 to $2,300 per kW (although no new plants are currently being built in the United States and O&M is estimated at approximately 0.7 cents/kWh). • Worldwide, hydropower plants have a combined capacity of 675,000 megawatts and annually produce more than 2.3 trillion kilowatt-hours of electricity, the energy equivalent of 3.6 billion barrels of oil. • Existing hydropower generation is declining because of a combination of real and perceived environmental problems, regulatory pressures, and changes in energy economics (deregulation, etc.); potential hydropower resources are not being developed for similar reasons. • The current trend is to replace hydropower with electricity from fossil fuels. • Some new, environmentally friendly technologies are being implemented (e.g., National Hydropower Association's awards for Outstanding Stewardship of America's Rivers). • DOE's Advanced Hydropower Turbine System (AHTS) program constructed a test facility to pilot test a new turbine design to evaluate hydraulic and biological performance; testing at this facility was completed in 2003. This program is demonstrating that new turbine designs are feasible, but additional support is needed to fully evaluate these new designs in full-scale applications. • There is insufficient understanding of how fish respond to turbulent flows in draft tubes and tailraces to support biological design criteria for those zones of power plants. • Fish resource management agencies do not recognize that the route through turbines is acceptable for fish—this perception could be overcome if field-testing continues to show mortality through turbines is not greater than other passage routes. • TVA's Lake Improvement Plan has demonstrated that improved turbine designs can be implemented with significant economic and environmental benefits. This effort has shown increases in hydroelectric plants' energy production by 12% with significantly improvements of downstream fish resources. • Field-testing of the Minimum Gap Runner (MGR) designs for Kaplan turbines indicate that fish survival up to 98% is possible, if conventional turbines are modified. • FERC instituted a short-term reduction in regulatory barriers on the West Coast in 2001—this resulted in more than 100,000 MWh of additional generation and a significant shift from nonpeak to peak production, without significant adverse environmental effects. • Regulatory trends in relicensing are to shift operation from peaking to baseload, effectively reducing the energy value of hydroelectricity; higher instream flow requirements are also reducing total energy production to protect downstream ecosystems, but scientific justification is weak. • Frequent calls for dam removal is making relicensing more costly to dam owners. • Regional efforts by Army Corps of Engineers and Bonneville Power Administration are producing some site-specific new understanding, especially in the Columbia River basin; but commercial applications are unlikely because of pressures from industry deregulation and environmental regulation. • Voith-Siemans Hydro and TVA have established a limited partnership to market environmentally friendly technology at hydropower facilities. Their products were developed in part by funding provided by DOE and the Corps of Engineers, as well as private sources. • Flash Technology is developing strobe lighting systems to force fish away from hydropower intakes and to avoid entrainment mortality in turbines.

Technology History
• Since the time of ancient Egypt, people have used the energy in flowing water to operate machinery and grind grain and corn. However, hydropower had a greater influence on people's lives during the 20th century than at any other time in history. Hydropower played a major role in making the wonders of electricity a part of everyday life and helped spur industrial development. Hydropower continues to produce 24% of the world's electricity and supply more than 1 billion people with power. • The first hydroelectric power plant was built in 1882 in Appleton, Wisconsin, to provide 12.5 kilowatts to light two paper mills and a home. Today's hydropower plants generally range in size from several hundred kilowatts to several hundred megawatts, but a few mammoth plants have capacities up to 10,000 megawatts and supply electricity to millions of people. • By 1920, 25% of electrical generation in the United States was from hydropower; and, by 1940, was 40%. • Most hydropower plants are built through federal or local agencies as part of a multipurpose project. In addition to generating electricity, dams and reservoirs provide flood control, water supply, irrigation, transportation, recreation, and refuges for fish and birds. Private utilities also build hydropower plants, although not as many as government agencies.
Technology Future
• By 2003, a quantitative understanding of the responses of fish to multiple stresses inside a turbine should be developed. Biological performance criteria for use in advanced turbine design also should be available. • By 2005, environmental mitigation studies should be available on topics such as in-stream flow needs to produce more efficient and less controversial regulatory compliance. In addition, pilot-scale testing of new runner designs, including field evaluation of environmental performance, will allow full-scale prototype construction and testing to proceed. • By 2010, full-scale prototype testing of AHTS designs should be completed, including verified biological performance of AHTS in the field. This will allow AHTS technology to be transferred to the market.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003.

Hydroelectric Power

Market Data

U.S. Installed Capacity (MW)*	Source: Renewable Energy Project Information System (REPiS), Version 7, NREL, 2003.											
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Annual	1,391	3,237	862	1,054	19.9	64.0	7.6	179.3	1.1	11	0.002	21.0
Cumulative	80,491	87,839	90,955	94,052	94,072	94,136	94,143	94,323	94,324	94,335	94,335	94,356

* There are an additional 21 MW of hydroelectric capacity that are not accounted for here because they have no specific online date.
2003 data not complete as REPiS database is updated through 2002.

Cumulative Grid-Connected Hydro Capacity (MW)[1]	Source: U.S. data from EIA, AER 2003 Table 8.11a, World Total from EIA, International Energy Annual, 1996-2003, Table 6.4. International data from International Energy Agency, Electricity Information 2004.											
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
U.S.												
Conventional and other Hydro	81,700	88,900	73,923	78,562	76,437	79,415	79,151	79,393	79,359	79,484	79,354	79,366
Pumped Storage[2]	N/A	N/A	19,462	21,387	21,110	19,310	19,518	19,565	19,522	19,096	20,373	20,373
U.S. Hydro Total	81,700	88,900	93,385	99,948	97,548	98,725	98,669	98,958	98,881	98,580	99,727	99,739
OECD Europe[3]	124,184	124,577	130,886	132,893	134,902	135,939	133,307	136,251	140,779	141,913	147,580	NA
IEA Europe[4]	123,960	124,357	130,663	132,666	134,038	135,074	132,315	135,254	138,093	138,912	144,010	NA
Japan	21,377	19,980	20,825	21,171	21,222	21,277	21,477	21,555	22,019	22,081	21,690	NA
OECD Total	286,969	300,725	316,291	340,259	342,893	346,342	342,673	346,446	351,513	352,564	338,130	NA
IEA Total	286,745	300,505	316,068	330,703	331,947	335,395	331,930	335,768	339,145	339,880	324,920	NA
World Total	470,669	537,734	600,206	650,936	661,237	673,797	680,610	697,749	712,689	723,581	NA	NA

1. Excludes pumped storage, except for specific U.S. pumped storage capacity listed.

2. Pumped storage values for 1980-1985 are included in "Conventional and other Hydro"
3. OECD included 24 countries as of 1980. Mexico, Czech Republic, Hungary, Poland, South Korea, Slovak Republic joined after 1980. Countries' data are included only after the year they joined.

4. IEA included 26 countries as of 2003. Countries' data are included only after the year they joined the OECD.
NA = Not Available; Updated international data not available at time of publication

Annual Generation from Cumulative Installed Capacity (Billion kWh)	Source: EIA, *International Energy Annual 2002*, DOE/EIA-0219(02), Table 1.5.										
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
United States	279	284	289	308	344	352	319	313	270	208	255
Canada	251	301	294	332	352	347	329	342	355	330	315
Mexico	17	26	23	27	31	26	24	32	33	28	25
Brazil	128	177	205	251	263	276	289	290	302	265	282
Western Europe	432	453	453	506	491	506	523	531	555	553	503
Former U.S.S.R.	184	205	231	238	215	216	225	227	228	239	243
Eastern Europe	27	26	23	34	34	36	35	35	31	30	32
China	58	91	125	184	185	193	203	211	241	258	309
Japan	88	82	88	81	80	89	92	86	86	83	81
Rest of World	273	328	435	504	515	522	533	541	558	571	581
World Total	1,736	1,973	2,167	2,466	2,511	2,564	2,571	2,609	2,658	2,565	2,627

State Generating Capability* (MW)	Source: EIA, Electric Power Annual 2002 – Spreadsheets, "1990 - 2002 Existing Nameplate and Net Summer Capacity by Energy Source and Producer Type (EIA-860)" http://www.eia.doe.gov/cneaf/electricity/epa/existing_capacity_state.xls										
Top 10 States	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Washington			19,935	20,487	20,431	20,923	21,012	21,011	21,011	21,006	21,016
California			12,687	13,519	13,500	13,475	13,383	13,445	13,475	13,471	13,523
Oregon			8,221	8,268	8,267	8,264	8,265	8,249	8,261	8,240	8,211
New York			5,345	5,545	5,557	5,565	5,668	5,662	5,659	5,712	5,804
Tennessee			3,717	3,818	3,818	3,937	3,950	3,950	3,950	3,948	3,948
Georgia			2,453	3,287	3,005	3,305	3,314	3,314	3,313	3,313	3,613
South Carolina			2,367	3,468	3,468	3,442	3,442	3,452	3,455	3,453	3,453
Virginia			3,072	3,126	3,149	3,082	3,093	3,090	3,091	3,088	3,088

Alabama			2,857	2,868	2,864	2,904	2,961	2,961	2,961	2,959	2,959
Arizona			2,685	2,885	2,885	2,893	2,893	2,890	2,890	2,890	2,893
U.S. Total			89,828	94,513	94,372	95,222	95,496	95,802	95,879	95,844	96,343

* Values are nameplate capacity for total electric industry

State Annual Generation from Cumulative Installed Capacity* (Billion kWh)	Source: EIA, Electric Power Annual 2002 – Spreadsheets, "1990 - 2002 Net Generation by State by Type of Producer by Energy Source (EIA-906)" http://www.eia.doe.gov/cneaf/electricity/epa/generation_state.xls										
Top 10 States	**1980**	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Washington			87.5	82.5	98.5	104.2	79.8	97.0	80.3	54.7	78.2
Oregon			41.2	40.8	44.9	46.7	39.9	45.6	38.1	28.6	34.4
California			24.8	50.5	46.9	42.1	50.8	40.4	39.3	25.2	30.9
New York			27.1	24.8	27.8	29.5	28.2	23.6	23.9	22.2	24.1
Montana			10.7	10.7	13.8	13.4	11.1	13.8	9.6	6.6	9.6
Alabama			10.4	9.5	11.1	11.5	10.6	7.8	5.8	8.4	8.8
Idaho			9.1	11.0	13.3	14.7	12.9	13.5	11.0	7.2	8.8
Arizona			7.7	8.5	9.5	12.4	11.2	10.1	8.6	7.9	7.6
Tennessee			9.5	9.0	10.8	10.4	10.2	7.2	5.7	6.2	7.3
South Dakota			3.9	6.0	8.0	9.0	5.8	6.7	5.7	3.4	4.4
U.S. Total			289.4	308.1	344.1	352.4	318.9	313.4	270.0	208.1	255.6

* Values are for total electric industry. Years before 1998 do not include nonutility generation.

Annual Hydroelectric Consumption for Electric Generation (Trillion Btu)	Source: *EIA, Annual Energy Review 2003, DOE/EIA-0384(2003) (Washington, D.C., September 2004) Table 8.4a*											
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
U.S. Total	2,900	2,970	3,046	3,205	3,590	3,640	3,297	3,268	2,811	2,201	2,675	2,779
Note: Conventional hydroelectric power only, for all sectors.												
Hydroelectric data through 1988 include industrial plants as well as electric utilities. Beginning in 1989, data are for electric utilities, independent power producers, commercial plants, and industrial plants.												

Solar Buildings

Technology Description

Solar building technologies deliver heat, electricity, light, hot water, and cooling to residential and commercial buildings. By combining solar thermal and electric building technologies with very energy-efficient construction methods, lighting, and appliances, it is possible to build "Zero Energy Homes" (see photo for a demonstration-home example). Zero Energy Buildings (residential and commercial) have a zero net need for off-site energy on an annual basis and also have no carbon emissions.

System Concepts

- In solar heating systems, solar-thermal collectors convert solar energy into heat at the point of use, usually for domestic hot water and space heating.
- In solar cooling systems, solar-thermal collectors convert solar energy into heat for absorption chillers or desiccant regeneration.
- In solar lighting systems, sunlight is transmitted into the interior of buildings using glazed apertures, light pipes, and/or optical fibers.

Representative Technologies

- Active solar-heating systems use pumps and controls to circulate a heat transfer fluid between the solar collector(s) and storage. System sizes can range from 1 to 100 kW.
- Passive solar-heating systems do not use pumps and controls but rather rely on natural circulation to transfer heat into storage. System sizes can range from 1 to 10 kW.
- Transpired solar collectors heat ventilation air for industrial and commercial building applications. A transpired collector is a thin sheet of perforated metal that absorbs solar radiation and heats fresh air drawn through its perforations.
- Hybrid solar lighting systems focus concentrated sunlight on optical fibers in order to combine natural daylight with conventional illumination. Hybrid Solar Lighting (HSL) has the potential to more than double the efficiency and affordability of solar energy in commercial buildings by simultaneously separating and using different portions of the solar-energy spectrum for different end-use purposes, i.e. lighting and distributed power generation.

Technology Applications

- More than 1,000 MW of solar water-heating systems are operating successfully in the United States, generating more than 3 million MW-hrs per year.
- Based on peer-reviewed market penetration estimates, there will be approximately 1 million new solar water-heating systems installed by 2020, offering an energy savings of 0.16 quads (164 trillion Btus).
- Retrofit markets: There are 73 million existing single-family homes in the United States. An estimate of the potential replacement market of 29 million solar water-heating systems assumes that only 40% of these existing homes have suitable orientation and nonshading. (9.2 million replacement electric and gas water heaters.)
- New construction: In 2000, 1.2 million new single-family homes were built in the United States. Assuming 70% of these new homes could be sited to enable proper orientation of solar water-heating systems, this presents another 840,000 possible system installations annually.
- While the ultimate market for the zero-energy building concept is all new building construction; the near-term focus is on residential buildings; particularly, single-family homes in the Sunbelt areas of the

country. Of the 1.2 million new single-family homes built in the United States in 2000, 44% of these new homes were in the southern region of the country and 25% were in the western region, both areas with favorable solar resources.

Current Status

- About 1.2 million solar water-heating systems have been installed in the United States, mostly in the 1970s and 1980s. Due to relatively low energy prices and other factors, there are approximately only 8,000 installations per year.
- Typical residential solar systems use glazed flat-plate collectors combined with storage tanks to provide 40% to 70% of residential water-heating requirements. Typical systems generate 2500 kWh of energy per year and cost $1 to $2/Watt, or 8¢/kWh.
- The energy costs of solar thermal systems have declined by more than 50% due to technology improvements. This cost reduction has saved more than five million MWh/year in U.S. primary energy consumption.
- Typical solar pool-heating systems use unglazed polymer collectors to provide 50% to 100% of residential pool-heating requirements. Typical systems generate 1,600 therms or 46,000 kWh of energy per year and cost $0.30 to $0.50/Watt
- Four multidisciplinary homebuilding teams have begun the initial phase of designing and constructing "Zero Energy Homes" for various new construction markets in the United States. Several homebuilders have started building houses with Zero Energy Home features—solar electric systems, solar water heating, and energy-efficient construction.
- Key companies developing or selling solar water heaters include:

Alternative Energy Technologies
Aquatherm
FAFCO
Radco Products
Sun Systems
Harter Industries
Duke Solar
Heliodyne, Inc.
Sun Earth
Thermal Conversion Technologies

Technology History

- 1890s- First commercially available solar water heaters produced in southern California. Initial designs were roof-mounted tanks and later glazed tubular solar collectors in thermosiphon configuration. Several thousand systems were sold to homeowners.
- 1900s- Solar water-heating technology advanced to roughly its present design in 1908 when William J. Bailey of the Carnegie Steel Company, invented a collector with an insulated box and copper coils.
- 1940s- Bailey sold 4,000 units by the end of WWI, and a Florida businessperson who bought the patent rights sold nearly 60,000 units by 1941.
- 1950s- Industry virtually expires due to inability to compete against cheap and available natural gas and electric service.
- 1970s- The modern solar industry began in response to the OPEC oil embargo in 1973-74, with a number of federal and state incentives established to promote solar energy. President Jimmy Carter put solar water-heating panels on the White House. FAFCO, a California company specializing in solar pool heating; and Solaron, a Colorado company that specialized in solar space and water heating, became the first national solar manufacturers in the United States. In 1974, more than 20 companies started production of flat-plate solar collectors, most using active systems with antifreeze capabilities. Sales in 1979 were estimated at 50,000 systems. In Israel, Japan, and Australia, commercial markets and manufacturing had developed with fairly widespread use.
- 1980s- In 1980, the Solar Rating and Certification Corp (SRCC) was established for testing and certification of solar equipment to meet set standards. In 1984, the year before solar tax credits expired,

an estimated 100,000-plus solar hot-water systems were sold. Incentives from the 1970s helped create the 150-business manufacturing industry for solar systems with more than $800 million in annual sales by 1985. When the tax credits expired in 1985, the industry declined significantly. During the Gulf War, sales again increased by about 10% to 20% to its peak level, more than 11,000 square feet per year (sq.ft./yr) in 1989 and 1990.

- 1990s- Solar water-heating collector manufacturing activity declined slightly, but has hovered around 6,000 to 8,000 sq.ft./yr. Today's industry represents the few strong survivors: More than 1.2 million buildings in the United States have solar water-heating systems, and 250,000 solar-heated swimming pools exist. Unglazed, low-temperature solar water heaters for swimming pools have been a real success story, with more than a doubling of growth in square footage of collectors shipped from 1995 to 2001.

Reference: American Solar Energy Society and Solar Energy Industry Association

Technology Future

- Near-term solar heating and cooling RD&D goals are to reduce the costs of solar water-heating systems to 4¢/kWh from their current cost of 8¢/kWh using polymer materials and manufacturing enhancements. This corresponds to a 50% reduction in capital cost.
- Near-term Zero Energy Building RD&D goals are to reduce the annual energy bill for an average-size home by 50% to $600 by 2004 and to $0 by 2020.
- Near-term solar lighting RD&D goals are to reduce the costs of solar lighting systems to 5¢/kWh.
- Zero-energy building RD&D efforts are targeted to optimize various energy efficiency and renewable energy combinations, integrate solar technologies into building materials and the building envelope, and incorporate solar technologies into building codes and standards.
- Solar heating and cooling RD&D efforts are targeted to reduce manufacturing and installation costs, improve durability and lifetime, and provide advanced designs for system integration.

The RD&D goal by 2025 is to research, develop, and demonstrate marketable and advanced energy systems needed to achieve “net-zero” energy use in new residential and commercial buildings. To achieve this, a 70% reduction in building energy use is needed; this can be achieved through high-performance lighting, HVAC, and appliances. The balance of the energy requirements will be met by renewable energy sources.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003.

Solar Buildings

Market Data

U.S. Installations (Thousands of Sq. Ft.)

Source: EIA, *Renewable Energy Annual 2003* Table 18 and Table 10, REA 2002 Table 18, REA 1997- 2000 Table 16, REA 1996 Table 18

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Annual												
DHW				755	765	595	463	373	367	274	423	511
Pool Heaters				6,763	6,787	7,528	7,201	8,141	7,863	10,797	11,073	10,800
Total Solar Thermal 1	18,283	19,166	11,164	7,136	7,162	7,759	7,396	8,046	7,857	10,349	11,004	10,926
Cumulative												
DHW												
Pool Heaters												
Total Solar Thermal 1	62,829	153,035	199,459	233,386	240,548	248,307	255,703	263,749	271,606	281,955	292,959	303,885

1. Domestic shipments - total shipments minus export shipments

U.S. Annual Shipments (Thousand Sq. Ft.)

Source: EIA, *Renewable Energy Annual 2003* Table 11 and REA 1999 Table 11.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total	19,398	N/A	11,409	7,666	7,616	8,138	7,756	8,583	8,354	11,189	11,663	11,444
Imports		N/A	1,562	2,037	1,930	2,102	2,206	2,352	2,201	3,502	3,068	2,986
Exports	1,115	N/A	245	530	454	379	360	537	496	840	659	518

U.S. Shipments by Cell Type (thousands of sq. ft.)

Source: EIA *Annual Energy Review 2003* Table 10.3 and *Renewable Energy Annual 2003* Table 12.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
Low-Temperature Collectors	12,233	N/A	3,645	6,813	6,821	7,524	7,292	8,152	7,948	10,919	11,126	10,877
Medium-Temperature Collectors	7,165	N/A	2,527	840	785	606	443	427	400	268	535	560

High-Temperature Collectors	N/A	N/A	5,237	13	10	7	21	4	5	2	2	7
Total	19,398	N/A	11,409	7,666	7,616	8,137	7,756	8,583	8,353	11,189	11,661	11,444

1985 values not available.

U.S. Shipments of High Temperature Collectors by Market Sector, and End Use (Thousands of Sq. Ft.)

Source: EIA, *Renewable Energy Annual 2003* Table 18, REA 2002 Table 18, REA 1996 Table F9, REA 1997, 1999-2000 Table 16, and REA 1998 Table 19.

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Market Sector												
Residential				0	0	0	0	0		0	0	0
Commercial				1	7	7	18	0		1	2	7
Industrial				0	2	0	0	0		0	0	0
Utility				9	0	0	2	4		1	0	0
Other				3	0	0	1	0		0	0	0
Total				13	10	7	21	4		2	2	7
End Use												
Pool Heating				0	0	0	0	0		0	0	0
Hot Water				0	7	7	18	0		0	0	0
Space Heating				0	0	0	0	0		0	0	0
Space Cooling				1	0	0	0	0		0	0	0
Combined Space and Water Heating				0	0	0	0	0		0	2	7
Process Heating				0	2	0	0	0		0	0	0
Electricity Generation				9	0	0	2	4		2	0	0
Other				2	0	0	1	0		0	0	0
Total				13	10	7	21	4		2	2	7

2000 data not published by EIA

U.S. Shipments of Medium-Temperature Collectors by Market Sector, and End Use (Thousands of Sq. Ft.)	Source: EIA, *Renewable Energy Annual 2003* Table 18, REA 2002 Table 18, REA 1996 Table F9, REA 1997, 1999-2000 Table 16, and REA 1998 Table 19.										
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Market Sector												
Residential				774	728	569	355	366		238	481	507
Commercial				51	50	35	70	59		23	69	44
Industrial				12	1	0	18	0		5	60	0
Utility				0	0	0	0	0		0	4	0
Other				3	7	2	0	2		1	1	2
Total				839	786	606	443	426		268	614	553
End Use												
Pool Heating				32	21	11	36	12		16	28	22
Hot Water				743	754	588	384	373		231	421	510
Space Heating				62	6	2	13	24		9	145	4
Space Cooling				0	0	0	0	0		0	0	0
Combined Space and Water Heating				2	2	3	8	16		12	15	16
Process Heating				0	1	0	0	0		0	4	0
Electricity Generation				0	0	0	0	0		0	0	0
Other				0	0	1	1	2		0	0	0
Total				839	784	605	442	427		268	614	553

2000 data not published by EIA

U.S. Shipments of Low- Temperature Collectors by Market Sector, and End Use (Thousands of Sq. Ft.)	Source: EIA, Renewable Energy Annual 2003 Table 18, REA 2002 Table 18, REA 1996 Table F9, REA 1997, 1999-2000 Table 16, and REA 1998 Table 19.											
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2002**
Market Sector												
Residential				6,192	6,146	6,791	6,810	7,408		9,885	10,519	9,993

Commercial	552	625	726	429	726	987	524	813
Industrial	69	51	7	44	18	12	2	71
Utility	0	0	0	0	0	0	0	0
Other	0	0	0	2	0	34	0	0
Total	6,813	6,822	7,524	7,285	8,152	10,919	11,046	10,877
End Use								
Pool Heating	6,731	6,766	7,517	7,164	8,129	10,782	11,045	10,778
Hot Water	11	4	0	60	0	42	1	0
Space Heating	70	51	7	53	18	61	0	65
Space Cooling	0	0	0	0	0	0	0	0
Combined Space and Water Heating	*	0	0	8	0	0	0	0
Process Heating	0	0	0	0	5	34	0	34
Electricity Generation	0	0	0	0	0	0	0	0
Other	0	0	0	0	0	0	0	0
Total	6,813	6,821	7,524	7,285	8,152	10,919	11,046	10,877

2000 data not published by EIA

Technology Performance

Energy Production	Source: Arthur D. Little, *Review of FY 2001 Office of Power Technology's Solar Buildings Program Planning Unit Summary*, December 1999.								
	1980	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Energy Savings									
DHW (kWh/yr)					2,750				
Pool Heater (therms/yr)					1,600				

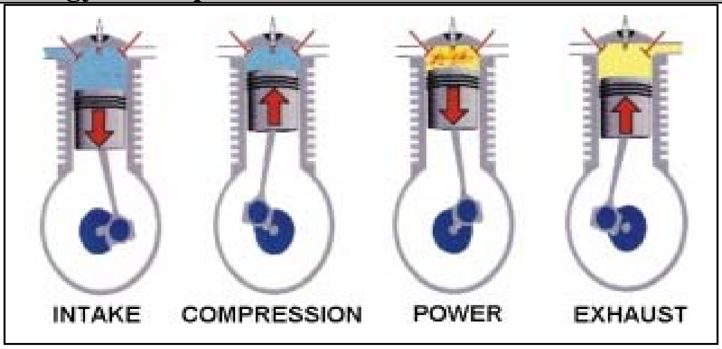
Cost	Source: Hot-Water Heater data from Arthur D. Little, *Water-Heating Situation Analysis*, November 1996, page 53, and Pool-Heater data from Ken Sheinkopf, *Solar Today,* Nov/Dec 1997, pp. 22-25.								
	1980	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Capital Cost* ($/System)									
Domestic Hot-Water Heater					1,900 - 2,500				
Pool Heater					3,300 - 4,000				
O&M ($/System-yr)									
Domestic Hot-Water Heater					25 - 30				
Pool Heater					0				

* Costs represent a range of technologies, with the lower bounds representing advanced technologies, such as a low-cost polymer integral collector for domestic hot-water heaters, which are expected to become commercially available after 2010.

Reciprocating Engines

Technology Description

Reciprocating engines, also known as internal combustion engines, require fuel, air, compression, and a combustion source to function. They make up the largest share of the small power generation market and can be used in a variety of applications due to their small size, low unit costs, and useful thermal output.



System Concepts

- Reciprocating engines fall into one of two categories depending on the ignition source: spark ignition (SI), typically fueled by gasoline or natural gas; or compression ignition (CI), typically fueled by diesel oil.
- Reciprocating engines also are categorized by the number of revolutions it takes to complete a combustion cycle. A two-stroke engine completes its combustion cycle in one revolution and a four-stroke engine completes the combustion process in two revolutions.

Representative Technologies

- The four-stroke SI engine has an intake, compression, power, and exhaust cycle. In the intake stroke, as the piston moves downward in its cylinder, the intake valve opens and the upper portion of the cylinder fills with fuel and air. When the piston returns upward in the compression cycle, the spark plug fires, igniting the fuel/air mixture. This controlled combustion forces the piston down in the power stroke, turning the crankshaft and producing useful shaft power. Finally the piston moves up again, exhausting the burnt fuel and air in the exhaust stroke.
- The four-stroke CI engine operates in a similar manner, except diesel fuel and air ignite when the piston compresses the mixture to a critical pressure. At this pressure, no spark or ignition system is needed because the mixture ignites spontaneously, providing the energy to push the piston down in the power stroke.
- The two-stroke engine, whether SI or CI, has a higher power density, because it requires half as many crankshaft revolutions to produce power. However, two-stroke engines are prone to let more fuel pass through, resulting in higher hydrocarbon emissions in the form of unburned fuel.

Technology Applications

- Reciprocating engines can be installed to accommodate baseload, peaking, emergency or standby power applications. Commercially available engines range in size from 10 kW to more than 7 MW making them suitable for many distributed-power applications. Utility substations and small municipalities can install engines to provide baseload or peak shaving power. However, the most promising markets for reciprocating engines are on-site at commercial, industrial, and institutional facilities. With fast start-up time, reciprocating engines can play integral backup roles in many building energy systems. On-site reciprocating engines become even more attractive in regions with high electric rates (energy/demand charges).
- When properly treated, the engines can run on fuel generated by waste treatment (methane) and other biofuels.
- By using the recuperators that capture and return waste exhaust heat, reciprocating engines can be used in combined heat and power (CHP) systems to achieve energy efficiency levels approaching 80%. In fact, reciprocating engines make up a large portion of the CHP or cogeneration market.

Current Status

- Commercially available engines have electrical efficiencies (LHV) between 28% and 50% and yield NOx emissions of 0.5-2.0 grams per horsepower hour (hp-hr) for lean-burn natural gas engines and 3.5-6.0 g/bhp-hr for conventional dual-fuel engines. CHP engines achieve electrical efficiencies (LHV) of 70-80%.
- Installed cost for reciprocating engines range between $695 and $1,350/ kW depending on size and whether the unit is for a straight generation or cogeneration application. Operating and maintenance costs range 0.8 -1.8 ¢/kWh. Production costs are generally lowest for high-speed engines.
- Exhaust temperature for most reciprocating engines is 700-1200° F in non-CHP mode and 350-500°F in a CHP system after heat recovery.
- Noise levels with sound enclosures are typically between 70-80 dB.
- The reciprocating-engine systems typically include several major parts: fuel storage, handling, and conditioning, prime mover (engine), emission controls, waste recovery (CHP systems) and rejections (radiators), and electrical switchgear.
- Annual shipments of reciprocating engines (sized 10MW or less) have almost doubled to 18 GW between 1997 and 2000. The growth is overwhelming in the diesel market, which represented 16 GW shipments compared with 2 GW of natural gas reciprocating engine shipments in 2000.
- The cost of full maintenance contracts range from 0.7 to 2.0 cents/kWh. Remote monitoring is now available as a part of service contracts.

(**Source**: Diesel and Gas Turbine Worldwide).

Key indicators for stationary reciprocating engines:

Installed Worldwide Capacity	Installed US Capacity	Number of CHP sites using Recips in the U.S. in 2000
146 GW	52 GW	1,055

Sources: Distributed Generation: The Power Paradigm for the New Millenium, 2001; "Gas Fired Distributed Energy Resource Technology Characterizations (2003)."

Manufacturers of reciprocating engines include:

Caterpillar	Hess Microgen, Inc.
Coast Intelligen, Inc.	Jenbacher
Cooper Energy Systems	Kohler Power Systems
Cummins	Tecogen, Inc.
	Wartsila
Fairbanks-Morse Engine Company	Waukesha

Technology History

- Natural gas-reciprocating engines have been used for power generation since the 1940s. The earliest engines were derived from diesel blocks and incorporated the same components of the diesel engine. Spark plugs and carburetors replaced fuel injectors, and lower compression-ratio pistons were substituted to run the engine on gaseous fuels. These engines were designed to run without regard to fuel efficiency or emission levels. They were used mainly to produce power at local utilities and to drive pumps and compressors.
- In the mid-1980s, manufacturers were facing pressure to lower NOx emissions and increase fuel economy. Leaner air-fuel mixtures were developed using turbochargers and charge air coolers, and in combination with lower in-cylinder fire temperatures, the engines reduced NOx from 20 to 5 g/bhp-hr. The lower in-cylinder fire temperatures also meant that the BMEP (Brake Mean Effective Pressure) could increase without damaging the valves and manifolds.

• Reciprocating-engine sales have grown more then five-fold from 1988 (2 GW) to 1998 (11.5 GW). Gas-fired engine sales in 1990 were 4% compared to 14% in 1998. The trend is likely to continue for gas-fired reciprocating engines due to strict air-emission regulations and because performance has been steadily improving for the past 15 years. • More than 35 million reciprocating engine units are produced in North America annually for automobiles, trucks, construction and mining equipment, marine propulsion, lawn care and a diverse range of power generation applications.
Technology Future
The U.S. Department of Energy, in partnership with the Gas Technology Institute, the Southwest Research Institute, and equipment manufacturers, supports the Advanced Reciprocating Engines Systems (ARES) consortium, aimed at further advancing the performance of the engine. Performance targets include: *High Efficiency*- Target fuel-to-electricity conversion efficiency (LHV) is 50 % by 2010. *Environment* – Engine improvements in efficiency, combustion strategy, and emissions reductions will substantially reduce overall emissions to the environments. The NOx target for the ARES program is 0.1 g/hp-hr, a 90% decrease from today's NOx emissions rate. *Fuel Flexibility* – Natural gas-fired engines are to be adapted to handle biogas, renewables, propane and hydrogen, as well as dual fuel capabilities. *Cost of Power* – The target for energy costs, including operating and maintenance costs is 10 % less than current state-of-the-art engine systems. *Availability, Reliability, and Maintainability* – The goal is to maintain levels equivalents to current state-of-the-art systems. Other R&D directions include: new turbocharger methods, heat recovery equipment specific to the reciprocating engine, alternate ignition system, emission-control technologies, improved generator technology, frequency inverters, controls/sensors, higher compression ratio, and dedicated natural-gas cylinder heads.

Source: National Renewable Energy Laboratory. *Gas-Fired Distributed Energy Resource Technology Characterizations.* NREL/TP-620-34783. November 2003.

Reciprocating Engines

Technology Performance

Power Ranges (kW) of Selected Manufacturers	Low	High	Source: Manufacturer Specs
Caterpillar	150	3,350	
Waukesha	200	2,800	
Cummins	5	1,750	
Jenbacher	200	2,600	
Wartsila	500	5,000	

Market Data

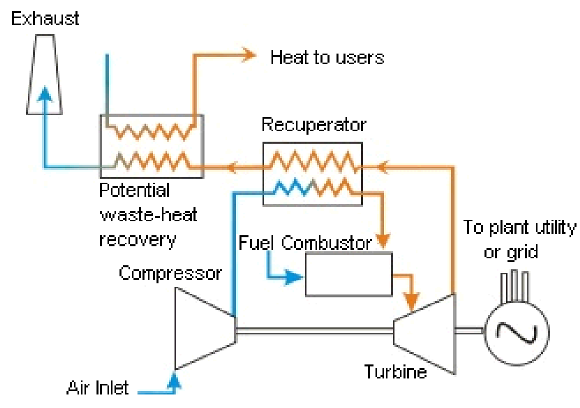
Market Shipments
(GW of units under 10 MW in size)

Source: Debbie Haught, DOE, communication 2/26/02 - from Diesel and Gas Turbine Worldwide.

	1996	1997	1998	1999	2000
Diesel Recips	7.96	7.51	8.23	10.02	16.46
Gas Recips	0.73	1.35	1.19	1.63	2.07

Microturbines

Technology Description



Microturbines are small combustion turbines of a size comparable to a refrigerator and with outputs of 30 kW to 400 kW. They are used for stationary energy generation applications at sites with space limitations for power production. They are fuel-flexible machines that can run on natural gas, biogas, propane, butane, diesel, and kerosene. Microturbines have few moving parts, high efficiency, low emissions, low electricity costs, and waste heat utilization opportunities; and are lightweight and compact in size. Waste heat recovery can be used in combined heat and power (CHP) systems to achieve energy efficiency levels greater than 80%.

System Concepts

- Microturbines consist of a compressor, combustor, turbine, alternator, recuperator, and generator.
- Microturbines are classified by the physical arrangement of the component parts: single shaft or two-shaft, simple cycle or recuperated, inter-cooled, and reheat. The machines generally operate at more than 40,000 rpm, while some machines operate at more than 100,000 rpm.
- A single shaft is the more common design because it is simpler and less expensive to build. Conversely, the split shaft is necessary for machine-drive applications, which do not require an inverter to change the frequency of the AC power.
- Efficiency gains can be achieved with greater use of materials like ceramics, which perform well at higher engine-operating temperatures.

Representative Technologies

- Microturbines in a simple cycle, or unrecuperated, turbine; heated, compressed air is mixed with fuel and burned under constant pressure conditions. The resulting hot gas is allowed to expand through a turbine to perform work. Simple-cycle microturbines have lower cost, higher reliability, and more heat available for CHP applications than recuperated units.
- Recuperated units use a sheet-metal heat exchanger that recovers some of the heat from an exhaust stream and transfers it to the incoming air stream. The preheated air is then used in the combustion process. If the air is preheated, less fuel is necessary to raise its temperature to the required level at the turbine inlet. Recuperated units have a higher efficiency and thermal-to-electric ratio than unrecuperated units, and yield 30-40% fuel savings from preheating.

Technology Applications

- Microturbines can be used in a wide range of applications in the commercial, industrial, and institutional sectors, microgrid power parks, remote off-grid locations, and premium power markets.
- Microturbines can be used for backup power, baseload power, premium power, remote power, grid support, peak shaving, cooling and heating power, mechanical drive, and use of wastes and biofuels.
- Microturbines can be paired with other distributed energy resources such as energy-storage devices and thermally activated technologies.

Current Status

- Microturbine systems have recently entered the market and the manufacturers are targeting both traditional and nontraditional applications in the industrial and buildings sectors, including CHP, backup power, continuous power generation, and peak shaving.
- The most popular microturbine installed to date is the 30-kW system manufactured by Capstone. Microturbine efficiencies are 25-29% (LHV).
- The typical 30 kW unit package cost averages $1,100/kW. For gas-fired microturbines, the present installation cost (site preparation and natural gas hookup) for a typical 30 kW commercial unit averages $2,263/kW for power only systems and $2,636 for CHP systems. Service contracts are available at 1 to 2 cents/kWh
- Honeywell pulled out of the microturbine business in December 2001, leaving the following manufacturers in the microturbine market:

  Capstone Turbine Corporation — Ingersoll-Rand

  Elliot Energy Systems — Bowman Power

  Turbec

- Capstone, Ingersoll-Rand, Elliott, and Turbec combined have shipped more than 2,100 units (156 MW) worldwide during the past four years.

Technology History

- Microturbines represent a relatively new technology, which entered the commercial market in 1999-2000. The technology used in microturbines is derived from aircraft auxiliary power systems, diesel-engine turbochargers, and automotive designs.
- In 1988, Capstone Turbine Corporation began developing the microturbine concept; and in 1998, Capstone was the first manufacturer to offer commercial power products using microturbine technology.

Technology Future

- The market for microturbines is expected to range from $2.4-to-$8 billion by 2010, with 50% of sales concentrated in North America.
- The acceptable cost target for microturbine energy is $0.05/kWh, which would present a cost advantage over most nonbaseload utility power.
- The next generation of "ultra-clean, high-efficiency" microturbine product designs will focus on the following DOE performance targets:
  - High Efficiency — Fuel-to-electricity conversion efficiency of at least 40%.
  - Environment — NOx < 7 ppm (natural gas).
  - Durability — 1,000 hours of reliable operations between major overhauls and a service life of at least 45,000 hours.
  - Cost of Power — System costs < $500/kW, costs of electricity that are competitive with alternatives (including grid) for market applications by 2005 (for units in the 30-60 kW range)
  - Fuel Flexibility — Options for using multiple fuels including diesel, ethanol, landfill gas, and biofuels.

Source: National Renewable Energy Laboratory. *Gas-Fired Distributed Energy Resource Technology Characterizations.* NREL/TP-620-34783. November 2003.

Microturbines

Market Data

Microturbine Shipments	Source: Debbie Haught, communications 2/26/02. Capstone sales reported in Quarterly SEC filings, others estimated.			
No. of units	**1998**	**1999**	**2000**	**2001**
Capstone	2	211	790	1,033
Other Manufacturers				120
MW				
Capstone		6	23.7	38.1
Other Manufacturers				10.2

Technology Performance

Source: Manufacturer Surveys, Arthur D. Little (ADL) estimates.

Current System Efficiency (%)	LHV: 17-20% unrecuperated, 25-30%+ recuperated	
Lifetime (years)	5-10 years, depending on duty cycle	
Emissions (natural gas fuel)	Current	Future (2010
CO_2	670 - 1,180 g/kWh (17-30% efficiency)	
SO_2	Negligible (natural gas)	Negligible
NO_x	9-25 ppm	<9 ppm
CO	25-50 ppm	<9 ppm
PM	Negligible	Negligible
Typical System Size	Current Products: 25-100 kW Units can be bundled or "ganged" to produce power in larger increments	Future Products: up to 1 MW
Maintenance Requirements (Expected)	10,000-12,000 hr before major overhaul (rotor replacement)	
Footprint [ft^2/kW]	0.2-0.4	

Technology Performance

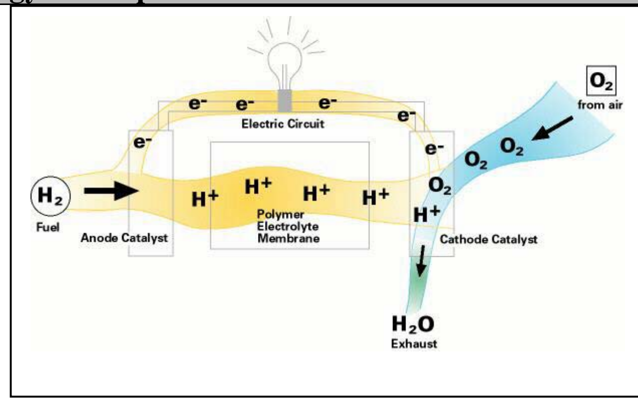
Sources: Debbie Haught, DOE, communication 2/26/02 and Energetics, Inc. *Distributed Energy Technology Simulator: Microturbine Validation*, July 12 2001.

	Capstone Turbine Corporation		Elliot Energy Systems	Ingersoll-Rand Energy Services	Turbec	DTE Energy Technologies
Model Name	Model 330	Capstone 60	TA-80	PowerWorks		ENT 400 recuperated
Size	30 kW	60 kW	80 kW	70 kW	100 kW	300 kW
Voltage	400-480 VAC				400 VAC	480/277 VAC
Fuel Flexibility	natural gas, medium Btu gas, diesel, kerosene		natural gas	natural gas	natural gas, biogas, ethanol, diesel	natural gas (diesel, propane future)
Fuel Efficiency (cf/kWh)	13.73	14.23			11.2	
Efficiency	26% (+/-2%)	28% (+/- 2%)	28%	30-33%	30%	28% (+/- 2%)
	70-90% CHP	70-90% CHP	80% CHP		80% CHP	74% CHP
Emissions	NO_x <9ppmV @15% O_2		NO_x diesel <60ppm, NO_x NG <25ppm, CO diesel <400ppm, CO NG <85ppm	NO_x <9ppmV @15% O_2, CO <9ppmV @15% O_2	NO_x <15ppmV @15% O_2, CO <15ppm, UHC <10ppm	NOx <9ppmV @15% O_2
Units Sold	1999: 211 units			2000: 2 precommercial units, expected commercial in 2001	2000: 20 units in the European market	Available late 2001
	2000: 790 units					
	2001: 1,033 units		2001: 100 units			
Unit Cost	$1000/kW				$75,000	
Cold Start-Up Time	3 min					3 min emergency, 7 min normal
Web site	www.capstone.com		www.elliott-turbo.com/new/products_microtubines.html	www.irco.com/energysystems/powerworks.html	www.turbec.com	www.dtetech.com/energynow/portfolio/2_1_4.asp

Fuel Cells

Technology Description

A fuel cell is an electrochemical energy conversion device that converts hydrogen and oxygen into electricity and water. This unique process is practically silent, nearly eliminates emissions, and has no moving parts.



System Concepts

- Similar to a battery, fuel cells have an anode and a cathode separated by an electrolyte.
- Hydrogen enters the anode and air (oxygen) enters the cathode. The hydrogen and oxygen are separated into ions and electrons, in the presence of a catalyst. Ions are conducted through the electrolyte while the electrons flow through the anode and the cathode via an external circuit. The current produced can be utilized for electricity. The ions and electrons then recombine, with water and heat as the only byproducts.
- Fuel cell systems today typically consist of a fuel processor, fuel cell stack, and power conditioner. The fuel processor, or reformer, converts hydrocarbon fuels to a mixture of hydrogen-rich gases and, depending on the type of fuel cell, can remove contaminants to provide pure hydrogen. The fuel cell stack is where the hydrogen and oxygen electrochemically combine to produce electricity. The electricity produced is direct current (DC) and the power conditioner converts the DC electricity to alternating current (AC) electricity, for which most of the end-use technologies are designed. As a hydrogen infrastructure emerges, the need for the reformer will disappear as pure hydrogen will be available near point of use.

Representative Technologies

- Fuel cells are categorized by the kind of electrolyte they use.
- Alkaline Fuel Cells (AFCs) were the first type of fuel cell to be used in space applications. AFCs contain a potassium hydroxide (KOH) solution as the electrolyte and operate at temperatures between 60 and 260°C (140 to 500°F). The fuel supplied to an AFC must be pure hydrogen. Carbon monoxide poisons an AFC, and carbon dioxide (even the small amount in the air) reacts with the electrolyte to form potassium carbonate.
- Phosphoric Acid Fuel Cells (PAFCs) were the first fuel cells to be commercialized. These fuel cells operate at 190-210°C (374-410°F) and achieve 35 to 45% fuel-to-electricity efficiencies LHV. Commercially-validated reliabilities are 90-95%. The largest market barrier is cost ($4,500 - $5,500/kW), which is why PAFCs are being phased out of commercial production
- Proton Exchange Membrane Fuel Cells (PEMFCs) operate at relatively low temperatures of 70-100°C (150-180°F), have high power density, can vary their output quickly to meet shifts in power demand, and are suited for applications where quick start-up is required (e.g., transportation and power generation). The PEM is a thin fluorinated plastic sheet that allows hydrogen ions (protons) to pass through it. The membrane is coated on both sides with highly dispersed metal alloy particles (mostly platinum) that are active catalysts.
- Molten Carbonate Fuel Cell (MCFC) technology has the potential to reach fuel-to-electricity efficiencies of 45 to 60% on a higher heating value basis (HHV). Operating temperatures for MCFCs are around 650° C (1,200°F), which allows total system thermal efficiencies up to 50% HHV in combined-cycle applications. MCFCs have been operated on hydrogen, carbon monoxide, natural gas, propane, landfill gas, marine diesel, and simulated coal gasification products.

- Solid Oxide Fuel Cells (SOFCs) operate at temperatures up to 1,000°C (1,800°F), which further enhances combined-cycle performance. A solid oxide system usually uses a hard ceramic material instead of a liquid electrolyte. The solid-state ceramic construction enables the high temperatures, allows more flexibility in fuel choice, and contributes to stability and reliability. As with MCFCs, SOFCs are capable of fuel-to-electricity efficiencies of 45% to 55% LHV and total system thermal efficiencies up to 85% LHV in combined-cycle applications.

Technology Applications

- Fuel cell systems can be sized for grid-connected applications or customer-sited applications in residential, commercial, and industrial facilities. Depending on the type of fuel cell (most likely SOFC and MCFC), useful heat can be captured and used in combined heat and power systems (CHP).
- Premium power applications are an important niche market for fuel cells. Multiple fuel cells can be used to provide extremely high (more then six-nines) reliability and high-quality power for critical loads.
- Data centers and sensitive manufacturing processes are ideal settings for fuel cells.
- Fuel cells also can provide power for vehicles and portable power. PEMFCs are a leading candidate for powering the next generation of vehicles. The military is interested in the high-efficiency, low-noise, small-footprint portable power.

Current Status

- Fuel cells are still too expensive to compete in widespread domestic and international markets without significant subsidies.
- PAFC – More than 250 PAFC systems are in service worldwide, with those installed by ONSI having surpassed 2 million total operating hours with excellent operational characteristics and high availability.

Economic Specifications of the PAFC (200 kW)

Expense	**Description**	**Cost**
Capital Cost	1 complete PAFC power plant	$850,000
Installation	Electrical, plumbing, and foundation	$40,000
Operation	Natural gas costs	$5.35/MMcf
Minor Maintenance	Service events, semiannual and annual maintenance	$20,000/yr
Major Overhaul	Replacement of the cell stack	$320,000/5 yrs

Source: Energetics, Distributed Energy Technology Simulator: Phosphoric Acid Fuel Cell Validation, May 2001.

PEMFC – Ballard's first 250 kW commercial unit is under test. PEM systems up to 200 kW are also operating in several hydrogen-powered buses. Most units are small (<10 kW). PEMFCs currently cost several thousand dollars per kW.

SOFC – A small, 25 kW natural gas tubular SOFC systems has accumulated more than 70,000 hours of operations, displaying all the essential systems parameters needed to proceed to commercial configurations. Both 5 kW and 250 kW models are in demonstration.

MCFC – 50 kW and 2 MW systems have been field-tested. Commercial offerings in the 250 kW-2 MW range are under development.

Some fuel cell developers include:

Acumentrics Corporation
Anuva Corporation
Avista Laboratories
Ballard Power Systems, Inc
Ceramatec
Electrochem, Inc.
FuelCell Energy
Hydrogenics Corporation
IdaTech
McDermitt Technologies, Inc.
Mitsubishi Electric Corporation
ONSI Corporation (IFC/United Technologies)
Plug Power, LLC
Siemens Westinghouse Power Corporation
Solid State Energy Conversion Alliance
Toshiba Corporation
UTC Fuel Cells
Ztek Corporation

Fuel Cell Type	**Electrolyte**	**Operating Temp (°C)**	**Electrical Efficiency (% HHV)**	**Commercial Availability**	**Typical Unit Size Range**	**Start-up time (hours)**
AFC	KOH	260	32-40	1960s		
PEMFC	Nafion	65-85	30-40	2000-2001	5-250 kW	< 0.1
PAFC	Phosphoric Acid	190-210	35-45	1992	200 kW	1-4
MCFC	Lithium, potassium, carbonate salt	650-700	40-50	Post 2003	250 kW-2 MW	5-10
SOFC	Yttrium & zirconium oxides	750-1000	45-55	Post 2003	5-250 kW	5-10

Sources: Anne Marie Borbely and Jan F. Kreider. *Distributed Generation: The Power Paradigm for the New Millennium*, CRC Press, 2001, and Arthur D. Little, Distributed Generation Primer: Building the Factual Foundation (multiclient study), February 2000

Technology History

- In 1839, William Grove, a British jurist and amateur physicist, first discovered the principle of the fuel cell. Grove utilized four large cells, each containing hydrogen and oxygen, to produce electric power which was then used to split the water in the smaller upper cell into hydrogen and oxygen.
- In the 1960s, alkaline fuel cells were developed for space applications that required strict environmental and efficiency performance. The successful demonstration of the fuel cells in space led to their serious consideration for terrestrial applications in the 1970s.
- In the early 1970s, DuPont introduced the Nafion® membrane, which has traditionally become the electrolyte for PEMFC.
- In 1993, ONSI introduced the first commercially available PAFC. Its collaborative agreement with the U.S. Department of Defense enabled more than 100 PAFCs to be installed and operated at military installations.
- The emergence of new fuel cell types (SOFC, MCFC) in the past decade has led to a tremendous expansion of potential products and applications for fuel cells.

Technology Future
• According to the Business Communications Company, the market for fuel cells was about $218 million in 2000, will increase to $2.4 billion by 2004, and will reach $7 billion by 2009. • Fuel cells are being developed for stationary power generation through a partnership of the U.S DOE and the private sector. • Industry will introduce high-temperature natural gas-fueled MCFC and SOFC at $1,000 -$1,500 per kW that are capable of 60% efficiency, ultra-low emissions, and 40,000 hour stack life. • DOE is also working with industry to test and validate the PEM technology at the 1–kW level and to transfer technology to the Department of Defense. Other efforts include raising the operating temperature of the PEM fuel cell for building, cooling, heating, and power applications and improve reformer technologies to extract hydrogen from a variety of fuels, including natural gas, propane, and methanol.

Sources: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003; and National Renewable Energy Laboratory. *Gas-Fired Distributed Energy Resource Technology Characterizations*. NREL/TP-620/34783. November 2003.

Fuel Cells

Technology Performance

Source: Arthur D. Little (ADL) estimates, survey of equipment manufacturers.

Only industrial applications; table does not address residential/commercial-scale fuel cells.

		2000 Characteristics						2005 Characteristics					
		Installed Cost ($/kW)		Non-Fuel O&M (cents/kWh)		Electrical Efficiency (LHV)		Installed Cost ($/kW)		Non-Fuel O&M (cents/kWh)		Electrical Efficiency (LHV)	
Technology	Size Range (kW)	Low	High	Low	High	High	Low	Low	High	Low	High	High	Low
Low Temperature Fuel Cell (PEM)	200-250	2,000	3,000	1.5	2.0	40%	30%	1,000	2,000	1.0	1.8	43%	33%
High Temperature Fuel Cell (SOFC & MCFC)	250-1,000	NA						1,500	2,000	1.0	2.0	55%	45%

Source: Energetics, *Distributed Energy Technology Simulator: PAFC Validation,* May 2001.

	Size (kW)	Capital Cost	Installation (Site Preparation)	Operation Costs (Natural Gas)	Minor Maintenance	Major Overhaul
Installation of a commercially available PAFC	200	$850,000	$40,000	$5.35/MMcf	$20,000/yr	$320,000/5 yrs

Technology Performance

There have been more than 25 fuel cell demonstrations funded by the private sector, the government, or a cofunded partnership of both. The objectives for most have been to validate a specific technology advance or application, and most of these demonstrations have been funded by the Office of Fossil Energy.

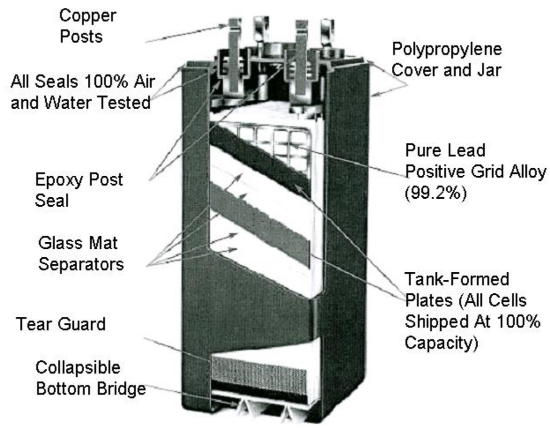
This is a listing of the demonstrations that have taken place between 1990 and today that have been published. All of the demonstrations were deemed a success, even if the testing had to end before its scheduled completion point. All of the manufacturers claimed they learned a great deal from each test. All the OPT-funded demonstrations were used to prove new higher performance-based technology either without lower catalyst levels, metal separator plates, carbon paper in lieu of machined carbon plates, or new membrane materials. Only the Plug Power fuel cell tested for the Remote Power Project failed, due to an electrical fire.

Fuel Cell Type	**Company**	**Objective**
Phosphoric Acid Fuel Cell	UT Fuel Cells (IFC)/FE	12.5 kW prototype using a new membrane assembly. (60 units) 40 kW power plant (46 units) 100 kW prototype for Georgetown Bus. (2 units) Methanol 200 kW first manufacturing prototype for PC25 (4 units) including natural gas reformer
Phosphoric Acid Fuel Cell	IFC/OPT	200 kW hydrogen version of PC 25 without a reformer, lower cost assembly
Solid Oxide	Westinghouse/FE	2 MW SOFC at Toshiba for fuels and tubular geometry testing 100 kW plannar unit to test seals, Netherlands 250 kW hybrid(57/50) w/turbine SoCal Ed 250 kW tubular SOFC combined heat and power, Ontario Power
Molten Carbonate	Fuel Cell Energy/FE	250 kW 8,800 hours Danbury Ct. first precommercial prototype 3 MW four years to build, Lexington Clean Coal Project 2 MW San Diego failed early
Proton Exchange Membrane	Plug Power/OTT Plug Power/OPT	10 kW prototype for vehicles 50 kW unsuccessful 25 kW prototype for Alaska, integrated with diesel reformer 50 kW prototype for Las Vegas refueling station, integrated with natural gas reformer

Proton Exchange Membrane	IFC/OTT	10 kW prototype sent to LANL for evaluation 50 kW prototype sent to GM for evaluation, reduced Pt catalyst 75 kW prototype installed in Hundai SUV, prototype for all transportation devices
Proton Exchange Membrane	Schatz Energy Center/OPT	(3) 5 kW Personal Utility Vehicles, (1) 15 kW Neighborhood Electric Vehicle Palm Desert each incorporated different levels of Pt catalyst, different membranes, all hydrogen fueled 1.3 kW Portable Power Unit
Proton Exchange Membrane	Enable/OPT	(3) 100 W Portable Power Units to demonstrate radial design (2) 1.5 kW Portable Power Units incorporating the LANL adiabatic fuel cell design (1) 1 kW “air breather” design for wheelchair
Proton Exchange Membrane	Ballard: no DOE funds	(6) 250 kW 40 foot passenger buses, hydrogen fueled: 3 Chicago, 2 Vancouver, 1 Palm Desert (1) 100 kW powerplant for Ford “Think” car (1) 250 kW stationary powerplant new manufacturing design
Proton Exchange Membrane	Nuvera/OPT	3 kW powerplant using metal separator plate technology for Alaska evaluated by SNL and University of Alaska
Proton Exchange Membrane	Coleman Powermate/Ballard no DOE funds	(3) 1.3 kW precommercial prototype UPS systems, metal hydride storage, under evaluation at United Laboratories for rating
Proton Exchange Membrane	Reliant Energy	7.5 kW precommercial prototype of radial stack geometry with conductive plastic separator plates
Alkaline	Zetec	25 kW precommercial prototype to demonstrate regenerative carbon dioxide scrubber
Alkaline	Hamilton Standard/IFC	(100) 12.5 kW commercial units for NASA
Alkaline	Union Carbide	(2) 50 kW fuel cells for GM van and car

Batteries

Technology Description



Batteries are likely the most widely known type of energy storage. They all store and release electricity through electrochemical processes and come in a variety of shapes and sizes. Some are small enough to fit on a computer circuit board while others are large enough to power a submarine. Some batteries are used several times a day while others may sit idle for 10 or 20 years before they are ever used. Obviously for such a diversity of uses, a variety of battery types are necessary. But all of them work from the same basic principles.

System Concepts

Battery electrode plates, typically consisting of chemically reactive materials, are placed in an electrolyte, which facilitates the transfer of ions in the battery. The negative electrode gives up electrons during the discharge cycle. This flow of electrons creates electricity that is supplied to any load connected to the battery. The electrons are then transported to the positive electrode. This process is reversed during charging. Batteries store and deliver direct current (DC) electricity. Thus, power-conversion equipment is required to connect a battery to the alternating current (AC) electric grid.

Representative Technologies

- The most mature battery systems are based on lead-acid technology. There are two major kinds of lead acid batteries: flooded lead acid batteries and valve-regulated-lead-acid (VRLA) batteries.
- There are several rechargeable, advanced batteries under development for stationary and mobile applications, including lithium-ion, lithium polymer, nickel metal hydride, zinc-air, zinc-bromine, sodium sulfur, and sodium bromide.
- These advanced batteries offer potential advantages over lead acid batteries in terms of cost, energy density, footprint, lifetime, operating characteristics reduced maintenance, and improved performance.

Technology Applications

- Lead-acid batteries are the most common energy storage technology for stationary and mobile applications. They offer maximum efficiency and reliability for the widest variety of stationary applications: telecommunications, utility switchgear and control, uninterruptible power supplies (UPS), photovoltaic, and nuclear power plants. They provide instantaneous discharge for a few seconds or a few hours.
- Installations can be any size. The largest system to date is 20 MW. Lead-acid batteries provide power quality, reliability, peak shaving, spinning reserve, and other ancillary services. The disadvantages of the flooded lead-acid battery include the need for periodic addition of water, and the need for adequate ventilation since the batteries can give off hydrogen gas when charging.
- VRLA batteries are sealed batteries fitted with pressure-release valves. They have been called low-maintenance batteries because they do not require periodic adding of water. They can be stacked horizontally as well as vertically, resulting in a smaller footprint than flooded lead-acid batteries. Disadvantages include higher cost and increased sensitivity to the charging cycle used. High temperature results in reduced battery life and performance.

- Several advanced “flow batteries” are under development. The zinc-bromine battery consists of a zinc positive electrode and a bromine negative electrode separated by a microporous separator. An aqueous solution of zinc/bromide is circulated through the two compartments of the cell from two separate reservoirs. Zinc-bromine batteries are currently being demonstrated in a number of hybrid installations, with microturbines and diesel generators. Sodium bromide/sodium bromine batteries are similar to zinc-bromine batteries in function and are under development for large-scale, utility applications. The advantages of flow-battery technologies are low cost, modularity, scalability, transportability, low weight, flexible operation, and all components are easily recyclable. Their major disadvantages are a relatively low cycle efficiency.
- Other advanced batteries include the lithium-ion, lithium-polymer, and sodium-sulfur batteries. The advantages of lithium batteries include their high specific energy (four times that of lead-acid batteries) and charge retention. Sodium sulfur batteries operate at high temperature and are being tested for utility load-leveling applications.

Current Status

- Energy storage systems for large-scale power quality applications (~10 MW) are economically viable now with sales from one manufacturer doubling from 2000 to 2001.
- Lead-acid battery annual sales have tripled between 1993 and 2000. The relative importance of battery sales for switchgear and UPS applications shrunk during this period from 45% to 26% of annual sales by 2000. VRLA and flooded battery sales were 534 and 171 million dollars, respectively, in 2000. Recently, lead-acid battery manufacturers have seen sales drop with the collapse of the telecommunications bubble in 2001. They saw significant growth in sales in 2000, due to the demand from communications firms, and invested in production and marketing in anticipation of further growth.
- Many manufacturers have been subject to mergers and acquisitions. A few dozen manufacturers in the United States and abroad still make batteries.
- Government and private industry are currently developing a variety of advanced batteries for transportation and defense applications: lithium-ion, lithium polymer, nickel metal hydride, sodium metal chloride, sodium sulfur, and zinc bromine.
- Rechargeable lithium batteries already have been introduced in the market for consumer electronics and other portable equipment.
- There are two demonstration sites of ZBB’s Zinc Bromine batteries in Michigan and two additional ones in Australia.
- Utility-grade batteries are sized 17-40 MWh and range in efficiency from 70 to 80%. Such batteries have power densities ranging from 0.2 to 0.4 kW/kg and 30-50 Wh/kg in energy density.
- Batteries are the most common energy storage device.
- Currently, about 150 MW of utility peak-shaving batteries are in use in Japan.
- Two 10-MW flow battery systems are under construction; one system is in the U.K. and the other system is in the United States.

Representative Current Manufacturers

Flooded	VRLA	Nickel Cadmium, Lithium Ion	Zinc Bromine
East Penn Exide Rolls Trojan	Hawker GNB Panasonic Yuasa	SAFT Sanyo Panasonic	Medentia Powercell ZBB

Technology History
• Most historians date the invention of batteries to about 1800 when experiments by Alessandro Volta resulted in the generation of electrical current from chemical reactions between dissimilar metals. • Secondary batteries date back to 1860 when Raymond Gaston Planté invented the lead-acid battery. His cell used two thin lead plates separated by rubber sheets. He rolled the combination up and immersed it in a dilute sulfuric acid solution. Initial capacity was extremely limited since the positive plate had little active material available for reaction. • Others developed batteries using a paste of lead oxides for the positive plate active materials. This allowed much quicker formation and better plate efficiency than the solid Planté plate. Although the rudiments of the flooded lead-acid battery date back to the 1880s, there has been a continuing stream of improvements in the materials of construction and the manufacturing and formation processes. • Since many of the problems with flooded lead-acid batteries involved electrolyte leakage, many attempts have been made to eliminate free acid in the battery. German researchers developed the gelled-electrolyte lead-acid battery (a type of VRLA) in the early 1960s. Working from a different approach, Gates Energy Products developed a spiral-wound VRLA cell, which represents the state of the art today.
Technology Future
• Lead-acid batteries provide the best long-term power in terms of cycles and float life and, as a result, will likely remain a strong technology in the future. • Energy storage and battery systems in particular will play a significant role in the Distributed Energy Resource environment of the future. Local energy management and reliability are emerging as important economic incentives for companies. • A contraction in sales of lead-acid batteries that began in 2001 was expected to continue over the next few years until 9/11 occurred. Military demand for batteries may drastically alter the forecast for battery sales. • Battery manufacturers are working on incremental improvements in energy and power density. The battery industry is trying to improve manufacturing practices and build more batteries at lower costs to stay competitive. Gains in development of batteries for mobile applications will likely crossover to the stationary market. • Zinc Bromine batteries are expected to be commercialized in 2003 with a target cost of $400/kWh. A 10 MW-120 MWh sodium bromide system is under construction by the Tennessee Valley Authority A 40 MW nickel cadmium system is being built for transmission-line support and stabilization in Alaska.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003.

Batteries

Market Data

Recent Battery Sales Source: Battery Council International, Annual Sales Summary, October 2001.

	1993	**2000**	Growth
Flooded Batteries (Million $)	156.9	533.5	340%
VRLA Batteries (Million $)	79.6	170.6	214%
Total Lead-Acid Batteries (Million $)	236.5	704.1	298%

Percent Communications	58%	69%
Percent Switchgear/UPS	45%	26%

Market Predictions Source: Sandia National Laboratories, Battery Energy Storage Market Feasibility Study, September 1997.

Year	MW	($ Million)
2000	496	372
2005	805	443
2010	965	434

Technology Performance

Grid-Connected Energy Storage Technologies Costs and Efficiencies

Source: Sandia National Laboratories, *Characteristics and Technologies for Long- vs. Short-Term Energy Storage,* March 2001.

Energy-Storage System	Energy Related Cost ($/kWh)	Power Related Cost ($/kW)	Balance of Plant ($/kWh)	Discharge Efficiency
Lead-acid Batteries				
low	175	200	50	0.85
average	225	250	50	0.85
high	250	300	50	0.85
Power-Quality Batteries	100	250	40	0.85
Advanced Batteries	245	300	40	0.70

Technology Performance

Off-Grid Storage Applications, Their Requirements, and Potential Markets to 2010 According to Boeing

Source: Sandia National Laboratories, Energy Storage Systems Program Report for FY99, June 2000.

Application	Single Home: Developing Community	Developing Community: No Industry	Developing Community: Light Industry	Developing Community: Moderate Industry	Advanced Community or Military Base
Storage-System Attributes					
Power (kW)	0.5	8	40	400	1 MW
Energy (kWh)	3	45	240	3,600	1.5 MWh
Power					
Base (kW)	0.5	5	10	100	100
Peak (kW)		< 8	< 40	< 400	< 1000
Discharge Duration	5 to 72 hrs	5 to 72 hrs	5 to 24 hrs	5 to 24 hrs	0.5 to 1 hr
Total Projected Number of Systems	47 Million	137,000	40,000	84,000	131,000
Fraction of Market Captured by Storage	> 50	> 50	~ 30	~ 10	< 5
Total Number of Storage Systems to Capture Market Share	24 Million	69,000	12,000	8,000	< 7,000

Technology Performance

Advanced Batteries Characteristics

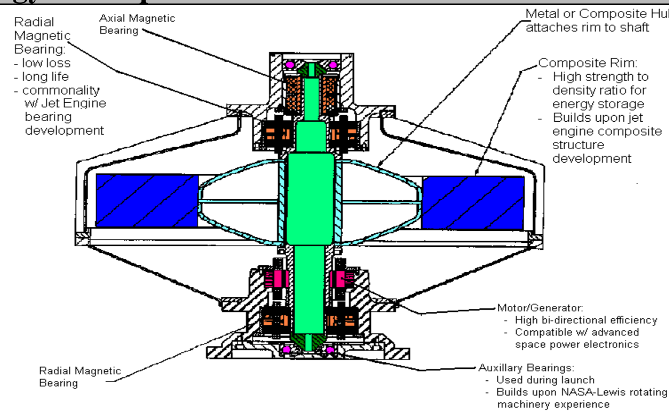
Source: DOE Energy Storage Systems Program Annual Peer Review FY01, Boulder City Battery Energy Storage, November 2001.

Energy Storage System	Sodium Sulfur	Vanadium Redox	Zinc Bromine
Field Experience	Over 30 Projects, 25 kW to 6 MW, Largest 48 MW	Several Projects 100kW to 3 MW (pulse power), Largest 1.15 MWh	Several Projects, 50 kW to 250 kW, Largest 400 kWh
Production Capacity	160 MWh/yr	30 MWh/yr	40 to 70 MWh/yr
Actual Production	50 MWh/yr	10 MWh/yr	4.5 MWh/yr
Life	15 yrs	7 to 15 yrs	10 to 20 yrs
Efficiency	72%	70to 80 %	65 to 70%
O&M Costs	$32.5k/yr	$50k/yr	$30 to $150k/yr

Advanced Energy Storage

Technology Description

The U.S. electric utility industry has been facing new challenges with deregulation and limitations on installing new transmission and distribution equipment. Advanced storage technologies under active development, in addition to advanced batteries, include processes that are mechanical (flywheels), purely electrical (supercapacitors, super conducting magnetic storage), and compressed-air energy storage. These advanced energy-storage solutions will help achieve more reliable and low-cost electricity storage.



Flywheel Cutaway

System Concepts

Flywheels (Low-Speed and High-Speed)
Flywheels store kinetic energy in a rotating mass. The amount of stored energy is dependent on the speed, mass, and configuration of the flywheel. They have been used as short-term energy storage devices for propulsion applications such as engines for large road vehicles. Today, flywheel energy storage systems are usually categorized as either low-speed or high-speed. High-speed wheels are made of high strength, low-density composite materials, making these systems considerably more compact than those employing lower-speed metallic wheels. However, the low-speed systems are still considerably less expensive per kWh.

Supercapacitors
Supercapacitors are also known as Electric Double Layer Capacitors, pseudocapacitors, or ultracapacitors. Charge is stored electrostatically in polarized liquid layers between an ionically conducting electrolyte and a conducting electrode. Though they are electrochemical devices, no chemical reactions occur in the energy-storage mechanism. Since the rate of charge and discharge is determined solely by its physical properties, an ultracapacitor can release energy much faster (i.e., with more power) than a battery, which relies on slow chemical reactions. Ultracapacitors deliver up to 100 times the energy of a conventional capacitor and deliver 10 times the power of ordinary batteries.

Compressed-Air Energy Storage (CAES)
CAES systems store energy by compressing air within a reservoir using off peak/low cost electric energy. During charging, the plant's generator operates in reverse – as a motor – to send air into the reservoir. When the plant discharges, it uses the compressed air to operate the combustion turbine generator. Natural gas is burned during plant discharge in the same fashion as a conventional turbine plant. However, during discharge, the combustion turbine in a CAES plant uses all of its mechanical energy to generate electricity; thus, the system is more efficient. CAES is an attractive energy-storage technology for large-scale storage.

Superconducting Magnetic Energy Storage (SMES)
SMES systems store energy in the magnetic field created by the flow of direct current in a coil of superconducting material. SMES systems provide rapid response to either charge or discharge, and their available energy is independent of their discharge rate. SMES systems have a high cycle life and, as a result, are suitable for applications that require constant, full cycling and a continuous mode of operation. SMES systems are ideal for high-power applications. Micro-SMES devices in the range of 1 to 10 MW are available commercially for power-quality applications.

Representative Technologies

- While the system-concepts section addressed energy-storage components exclusively, all advanced storage systems require power conditioning and balance of plant components.
- For vehicle applications, flywheels, CAES, and ultracapacitors are under development.
- A dozen companies are actively developing flywheels. Steel, low-speed flywheels, are commercially available now; composite, high-speed flywheels are rapidly approaching commercialization.
- Pneumatic storage (CAES) is feasible for energy storage on the order of hundreds of MWh.
- Prototype ultracapacitors have recently become commercially available.

Technology Applications

- A number of industries rely upon high power quality, especially the semiconductor manufacturing and banking industries. Power quality losses total more than $15 billion per year in the U.S.

Energy available in SMES is independent of its discharge rating, which makes it very attractive for high power and short time burst applications such as power quality.

- SMES are also useful in transmission enhancement as they can provide line stability, voltage and frequency regulation, as well as phase angle control.
- Flywheels are primarily used in transportation, defense, and power quality applications.
- Load management is another area where advanced energy-storage systems are used (e.g., CAES). Energy stored during off-peak hours is discharged at peak hours, achieving savings in peak energy, demand charges, and a more uniform load.
- Load management also enables the deferral of equipment upgrades required to meet an expanding load base which typically only overloads equipment for a few hours a day.
- Ultracapacitors are used in consumer electronics, power quality, transportation, and defense and have potential applications in combination with distributed generation equipment for following rapid load changes.

Current Status

- Utilities require high reliability, and per-kilowatt costs less than or equal to those of new power generation ($400–$600/kW). Compressed gas energy storage can cost as little as $1–$5/kWh. SMES has targets of $150/kW and $275/kWh. Batteries cost between $300 and $2,000 per kWh. Vehicles require storage costs of $300 to $1,000/kWh to achieve significant market penetration. The major hurdle for all storage technologies is cost reduction.
- Ultracapacitor development needs improved energy density from the current 1.9 W-h/kg for light-duty hybrid vehicles.

Efficiencies for these technologies are 70% for compressed gas, 70-84% for batteries, and 90+% for flywheels and SMES.

- Low-speed (7,000-9,000 rpm) steel flywheels are commercially available for power quality and UPS applications.
- There is one 110-MW CAES facility operated by an electric co-op in Alabama. One CAES facility is in operation in Germany.
- Nine SMES units have been installed in Wisconsin to stabilize a ring transmission system.

Representative Current Manufacturers

Flywheels	Supercapacitors	CAES	SMES
Active Power American Flywheel Systems Pillar	Nanolab Cooper Maxwell NEC	Ingersoll Rand ABB Dresser-Rand Alstrom	American Superconductor

Technology Future
• Developments in the vehicular systems will most likely crossover into the stationary market. • High-temperature (liquid-nitrogen temperatures) superconductors that are manufacturable and can carry high currents could reduce both capital and operating costs for SMES. • High-speed flywheels need further development of fail-safe designs and/or lightweight containment. Magnetic bearings will reduce parasitic loads and make flywheels attractive for small uninterruptible power supplies and small energy management applications. • Much of the R&D in advanced energy storage is being pursued outside the United States, in Europe, and Japan. U.S. government research funds have been very low, relative to industry investments. One exception has been the Defense Advanced Research Programs Agency, with its flywheel containment development effort with U.S. flywheel manufacturers, funded at $2 million annually. The total DOE Energy Storage Program budget hovers in the $4 million to $6 million range during the past 10 years.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003.

Advanced Energy Storage

Market Data

Market Predictions — Source: Sandia National Laboratories, Cost Analysis of Energy-Storage Systems for Electric Utility Applications, February 1997.

Energy-Storage System	Present Cost	Projected Cost Reduction
SMES	$54,000/MJ	5-10%
Flywheels	$200/kWh	443

Technology Performance

Energy-Storage Costs and Efficiencies — Source: Sandia National Laboratories, Characteristics and Technologies for Long- vs. Short-Term Energy Storage, March 2001.

Energy-Storage System	Energy-Related Cost ($/kWh)	Power Related Cost ($/kW)	Balance of Plant ($/kWh)	Discharge Efficiency
Micro-SMES	72,000	300	10,000	0.95
Mid-SMES	2,000	300	1,500	0.95
SMES	500	300	100	0.95
Flywheels (high-speed)	25,000	350	1,000	0.93
Flywheels (low-speed)	300	280	80	0.9
Ultracapacitors	82,000	300	10,000	0.95
CAES	3	425	50	0.79

Technology Performance

Energy-Storage Technology Profiles

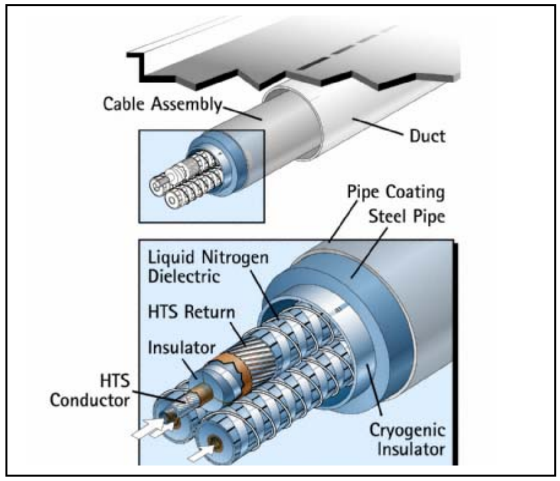
Source: DOE/EPRI, *Renewable Energy Technology Characterizations,* EPRI TR-109496, 1997, Appendix A.

Technology	Installed U.S. Total	Facility Size Range	Potential/Actual Applications
Flywheels	1-2 demo facilities, no commercial sites. In 2002, steel flywheels with rotational speeds of 7000-9000 rpm are commercially available for power quality and UPS applications.	kW scale	Electricity (Power Quality) Transportation, Defense
SMES	5 facilities with approx. 30 MW in 5 states	From 1-10 MW (micro-SMES) to 10-100 MW	Electricity (T&D, Power Quality)
Ultracapacitors	Millions of units for standby power; 1 defense unit	7-10 W commercial 10-20 kW prototype	Transportation Defense Consumer Electronics Electricity (Power Quality)
CAES	110 MW in Alabama	25 MW to 350 MW	Electricity (Peak-shaving, Spinning Reserve, T&D)

Superconducting Power Technology

Technology Description

Superconducting power technology refers to electric power equipment and devices that use superconducting wires and coils. High Temperature Superconductivity (HTS) enables electricity generation, delivery, and end use without the resistance losses encountered in conventional wires made from copper or aluminum. HTS wires currently carry 3 to 5 times the power, without the resistance losses of comparable diameter copper wires. HTS power equipment, such as motors, generators, and transformers, has the potential to be half the size and weight of conventional alternatives with the same power rating and only half the energy losses.



Source: American Superconductor

System Concepts

- HTS systems will be smaller, more efficient, and carry more power than a similarly rated conventional system.
- HTS systems will help the transmission and distribution system by allowing for greater power transfer capability, increased flexibility, and increased power reliability.

Representative Technologies

Transmission Cables	Current Limiters
Motors	Transformers
Generators	Flywheel Electricity Systems

Technology Applications

- Superconducting technology will modernize the electric grid and infrastructure, resulting in greater flexibility, efficiency, and cost effectiveness.
- Wire and Coils have reached a sufficient level of development to allow for their introduction into prototype applications of HTS systems such as motors, generators, transmission cables, current limiters, and transformers.
- Motors rated greater than 1,000 hp will primarily be used for pump and fan drives for utility and industrial markets.
- Current controllers will perform as a fast sub-cycle breaker when installed at strategic locations in the transmission and distribution system.
- Flywheel electricity systems can be applied to increase electric-utility efficiency in two areas—electric-load leveling and uninterruptible power systems (UPS) applications.
- Transformers are environmentally friendly and oil-free, making them particularly useful where transformers previously could not be sited, such as in high-density urban areas or inside buildings.
- Reciprocating Magnetic Separators can be used in the industrial processing of ores, waste solids, and waste gases, as well as performing isotope separations and water treatment.

Current Status

- Much of the research and development in HTS is focused on wire and system development and prototype system design and deployment.
- There are 18 manufacturers, eight National Laboratories, six utilities, and 17 universities participating in the U.S. Department of Energy Superconductivity Program alone. The list of manufacturers includes:

3M	ABB
American Superconductor	Pirelli Cables North America
IGC SuperPower	Waukesha Electric Systems
Southwire Company	

- Prototype power transmission cables have been developed and are being tested by two teams led by Pirelli Cable Company and Southwire Company respectively.
- A 1,000-horsepower prototype motor was produced and tested by Rockwell Automation/Reliance Electric Company. The results of these tests are being used to design a 5,000 hp motor.
- A team led by General Electric has developed a design for a 100 MW generator.
- A 15 kV current controller was tested at a Southern California Edison substation in July 1999.
- The design of a 3 kW/10 kWh flywheel system has been completed. The superconducting bearings, motor/generator, and control system have been constructed and are undergoing extensive testing. A rotor construction is underway.
- The design of the reciprocating magnetic separator has been finalized, and components for the system have been procured and assembled. The test site has been prepared, and cryogenic testing has begun.
- Use of HTS lines results in a 30% reduction in total losses. Total ownership costs are about 20% lower than traditional lines. HTS lines are nonflammable and do not contain oil or any other pollutant.

Technology History

- In 1911, after technology allowed liquid helium to be produced, Dutch physicist Heike Kammerlingh Onnes found that at 4.2 K, the electrical resistance of mercury decreased to almost zero. This marked the first discovery of superconducting materials.
- Until 1986, superconductivity applications were highly limited due to the high cost of cooling to such low temperatures, which resulted in costs higher than the benefits of using the new technology.
- In 1986, two IBM scientists, J. George Bednorz and Karl Müller achieved superconductivity on lanthanum copper oxides doped with barium or strontium at temperatures as high as 38 K.
- In 1987, the compound $Y_1Ba_2Cu_3O_7$ (YBCO) was given considerable attention, as it possessed the highest critical temperature at that time, at 93 K. In the following years, other copper oxide variations were found, such as bismuth lead strontium calcium copper oxide (110 K), and thallium barium calcium copper oxide (125 K).
- In 1990, the first (dc) HTS motor was demonstrated.
- In 1992, a 1-meter-long HTS cable was demonstrated.
- By 1996, a 200-horsepower HTS motor was tested and exceeded its design goals by 60%.
- A Pirelli Cable team installed a 120m HTS cable in Detroit, Michigan under the DOE Superconductivity Partnership Initiative. Since February 2000, Southwire's 30m prototype cable has been powering three manufacturing plants in Carrollton, Georgia.
- The first HTS cable, worldwide, to power industrial plants exceeded 13,000 hours of trouble-free service recently. The 30m cable was installed in Carrollton, Georgia, in June 2001. The cable has been unattended since then.

- HTS transformers have seen increased interest, as Waukesha Electric Systems demonstrated a 1-MVA prototype transformer in 1999. This team is also leading the development of a 5/10-MVA, 26.4-kV/4.2-kV three-phase prototype.
- A 750 kW HTS motor was demonstrated by Rockwell Automation in 2000. This team is now designing a motor with five times the rating.

Technology Future

Year of 50% Market Penetration

Motors	Transformers	Generators	Underground Cable
2018	2015	2019	2013

Source: ORNL - High Temperature Superconductivity: The Products and Their Benefits, 2002 Edition, Table ES-1.

- Low-cost, high-performance YBCO Coated Conductors will be available in 2005 in kilometer lengths.
- HTS wires will have 100 times the capacity of conventional wires.
- Payback periods will be within 2-5 years of operation.
- The present cost of BSCCO type HTS wire is $200/kA-m. By 2005, for applications in liquid nitrogen, the wire cost will be less than $50/kA-m; and for applications requiring cooling to temperatures of 20-60 K, the cost will be less than $30/kA-m.

By 2010, the cost-performance ratio will have improved by at least a factor of four. The cost target is $10/kA-m.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003.

Superconducting Power Technology

Market Data

Projected Market for HTS devices (Thousands of Dollars)	Source: *Oak Ridge National Laboratory - High Temperature Superconductivity: The Products and Their Benefits*, 2002 Edition, Total Market Benefits, p 40.								
	2004	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**	**2018**	**2020**
Motors	0	0	27.29	169.24	527.03	1310.49	3103.37	6360.31	11322.83
Transformers	0	3.8	14.22	37.47	90.63	197.73	371.87	605.23	877.71
Generators	0	0	0	4.09	15.56	41.12	101.16	224.26	426.61
Cables	0	0.17	0.59	1.44	2.81	4.86	7.7	11.21	15.17
Total	0	3.97	42.1	212.24	636.03	1554.2	3584.1	7201.01	12642.32

The report assumes electrical generation and equipment market growth averaging 2.5% per year through 2020. This number was chosen based on historic figures (the past fifteen years) and the assumption that electric demand will drive electric supply.

Underground Power Cables: Market Penetration and Benefits	Source: *Oak Ridge National Laboratory - High Temperature Superconductivity: The Products and Their Benefits,* 2002 Edition, Total Market Benefits, p 40.								
	2004	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**	**2018**	**2020**
% Market	0	6.7	15	27	40	56	69	77	80
Miles Sold this Year	0	13.89	32.68	61.77	96.19	141.47	183.15	214.73	234.35
Total Miles Installed	0	20.76	74.69	183.34	356.96	616.74	963.04	1379.11	1839.26
Total Annual Savings (10^6 $)	0	0.17	0.59	1.44	2.81	4.86	7.7	11.21	15.17

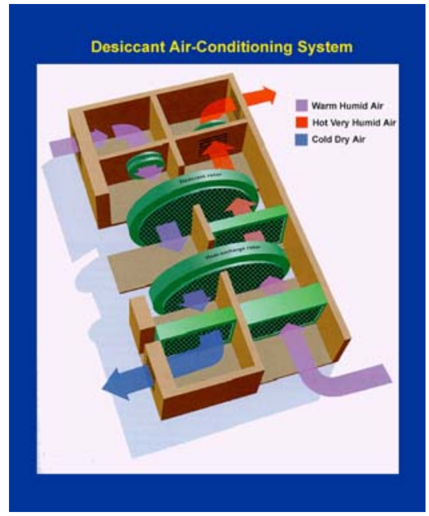
Technology Performance

HTS Energy Savings (GWh)	Source: *Oak Ridge National Laboratory - High Temperature Superconductivity: The Products and Their Benefits*, 2002 Edition, Tables M-2, T-1, G-1, C-2								
	2004	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**	**2018**	**2020**
Motors	0	0	0.4	3	8	21	48	98	172
Transformers	0	0.1	0.2	1	1	3	6	9	14
Generators	0	0	0	0.1	0.2	1	2	3	6
Cables	0	3	18	56	133	270	488	806	1,236
Total	0	4	19	60	143	294	544	916	1,428

Thermally Activated Technologies

Technology Description

Thermally Activated Technologies (TATs), such as heat pumps, absorption chillers, and desiccant units, provide on-site space conditioning and water heating, which greatly reduce the electric load of a residential or commercial facility. These technologies can greatly contribute to system reliability.



System Concepts

- TATs may be powered by natural gas, fuel oil, propane, or biogas, avoiding substantial energy conversion losses associated with electric power transmission, distribution, and generation.
- These technologies may use the waste heat from on-site power generation and provide total energy solutions for onsite cooling, heating, and power.

Representative Technologies

- Thermally activated heat pumps can revolutionize the way residential and commercial buildings are heated and cooled. This technology enables highly efficient heat pump cycles to replace the best natural gas furnaces, reducing energy use as much as 50%. Heat pumps take in heat at a lower temperature and release it a higher one, with a reversing valve that allows the heat pump to provide space heating or cooling as necessary. In the heating mode, heat is taken from outside air when the refrigerant evaporates and is delivered to the building interior when it condenses. In the cooling mode, the function of the two heat-exchanger coils is reversed, so heat moves inside to outside.
- Absorption chillers provide cooling to buildings by using heat. Unlike conventional electric chillers, which use mechanical energy in a vapor-compression process to provide refrigeration, absorption chillers primarily use heat energy with limited mechanical energy for pumping. The chiller transfers thermal energy from the heat source to the heat sink through an absorbent fluid and a refrigerant. The chiller achieves its refrigerative effect by absorbing and then releasing water vapor into and out of a lithium bromide solution. In the process, heat is applied at the generator and water vapor is driven off to a condenser. The cooled water vapor then passes through an expansion valve, reducing the pressure. The low-pressure water vapor then enters an evaporator, where ambient heat is added from a load and the actual cooling takes place. The heated, low-pressure vapor returns to the absorber, where it recombines with lithium bromide and becomes a low-pressure liquid. This low-pressure solution is pumped to a higher pressure and into the generator to repeat the process.
- Desiccant equipment is useful for mitigation of indoor air-quality problems and for improved humidity control in buildings. The desiccant is usually formed in a wheel made up of lightweight honeycomb or corrugated material (see figure). Commercially available desiccants include silica gel, activated alumina, natural and synthetic zeolites, lithium chloride, and synthetic polymers. The wheel is rotated through supply air, usually from the outside, and the material naturally attracts the moisture from the air before it is routed to the building. The desiccant is then regenerated using thermal energy from natural gas, the sun, or waste heat.

Technology Applications

- Thermally activated heat pumps are a new generation of advanced absorption cycle heat pumps that can efficiently condition residential and commercial space. Different heat pumps will be best suited for different applications. For example, the GAX heat pump is targeted for northern states because of its superior heating performance; and the Hi-Cool heat pump targets the South, where cooling is a priority.
- Absorption chillers can change a building's thermal and electric profile by shifting the cooling from an electric load to a thermal load. This shift can be very important for facilities with time-of-day electrical rates, high cooling-season rates, and high demand charges. Facilities with high thermal loads, such as data centers, grocery stores, and casinos, are promising markets for absorption chillers.
- Desiccant technology can either supplement a conventional air-conditioning system or act as a standalone operation. A desiccant can remove moisture, odors, and pollutants for a healthier and more comfortable indoor environment. Facilities with stringent indoor air-quality needs (schools, hospitals, grocery stores, hotels) have adapted desiccant technology.
- CHP applications are well suited for TATs. They offer a source of "free" fuel in the form of waste heat that can power heat pumps and absorption chillers, and regenerate desiccant units.

Current Status

Thermally activated heat pump technology can replace the best natural gas furnace and reduce energy use by as much as 50%, while also providing gas-fired technology.
Desiccant technology may be used in pharmaceutical manufacturing to extend the shelf life of products; refrigerated warehouses to prevent water vapor from forming on the walls, floors, and ceilings; operating rooms to remove moisture form the air, keeping duct work and sterile surfaces dry; and hotels, to prevent buildup of mold and mildew.
Companies that manufacture TAT equipment include:

York International	Broad
Trane	Air Technology Systems
Munters Corporation	American Power Conversion Company
Kathabar Systems	Goettl

Technology History

- In the 1930s, the concept of dehumidifying air by scrubbing it with lithium chloride was introduced, paving the way for development of the first desiccant unit.
- In 1970, Trane introduced a mass-produced, steam-fired, double-effect $LiBr/H_2O$ absorption chiller.
- In 1987, the National Appliance Energy Conversion Act instituted minimum efficiency standards for central air-conditioners and heat pumps.

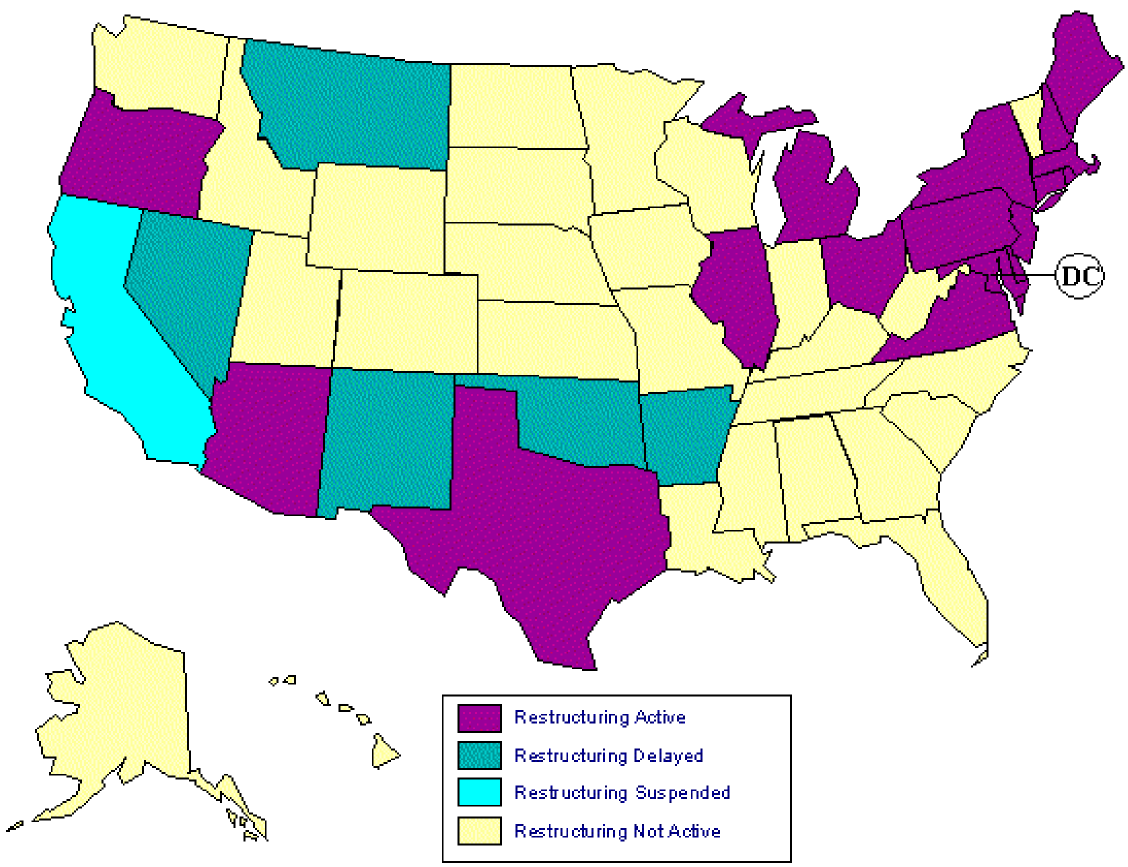
Technology Future

- Expand the residential market of the second-generation Hi-Cool residential absorption heat pump technology to include markets in southern states; the targeted 30% improvement in cooling performance can only be achieved with major new advancements in absorption technology or with an engine-driven system.
- Work in parallel with the first-generation GAX effort to determine the most attractive second-generation Hi-Cool technology.
- Fabricate and test the 8-ton advanced cycle VX GAX ammonia/water heat pump.
- Fabricate and test the 3-ton complex compound heat pump and chiller.
- Develop, test, and market an advanced Double Condenser Coupled commercial chiller, which is expected to be 50% more efficient than conventional chillers.
- Assess new equipment designs and concepts for desiccants using diagnostic techniques, such as infrared thermal performance mapping and advanced tracer gas-leak detection.

3.1 – States with Competitive Electricity Markets

Purple-colored states are active in the restructuring process, and these states have either enacted enabling legislation or issued a regulatory order to implement retail access. Retail access is either currently available to all or some customers, or will soon be available. Those states are Arizona, Connecticut, Delaware, District of Columbia, Illinois, Maine, Maryland, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, Texas, and Virginia. In Oregon, no customers are currently participating in the state's retail access program, but the law allows access to nonresidential customers.

A green-colored state signifies a delay in the restructuring process or the implementation of retail access. Those states are Arkansas, Montana, Nevada, New Mexico, and Oklahoma. California is the only blue-colored state because direct retail access has been suspended.

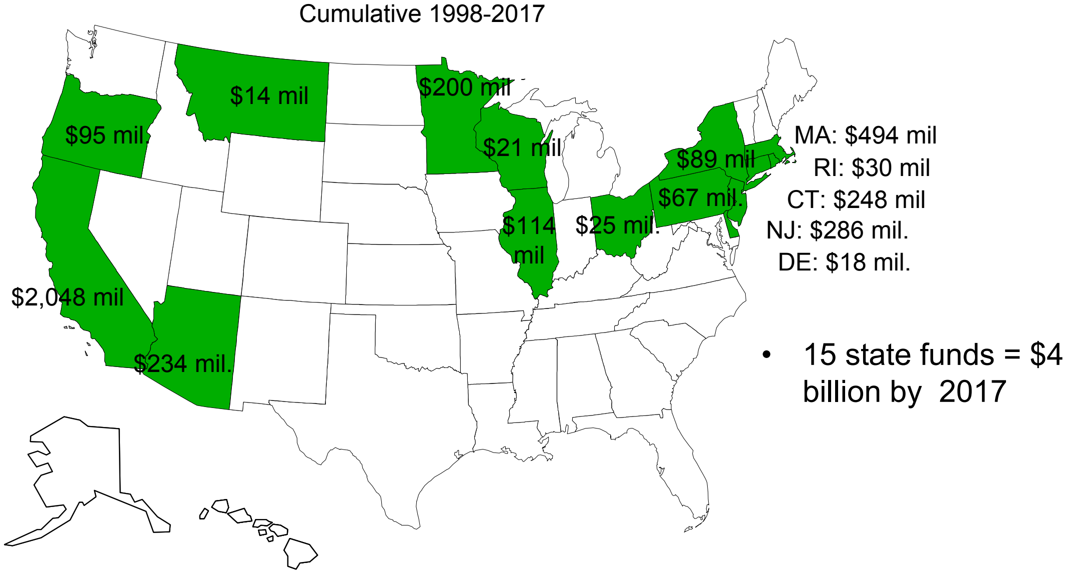


Source: U.S. DOE, Energy Information Administration
http://www.eia.doe.gov/cneaf/electricity/chg_str/regmap.html, last updated February 2003.

Figure 3.1.1. Status of Restructuring of State Electricity Markets

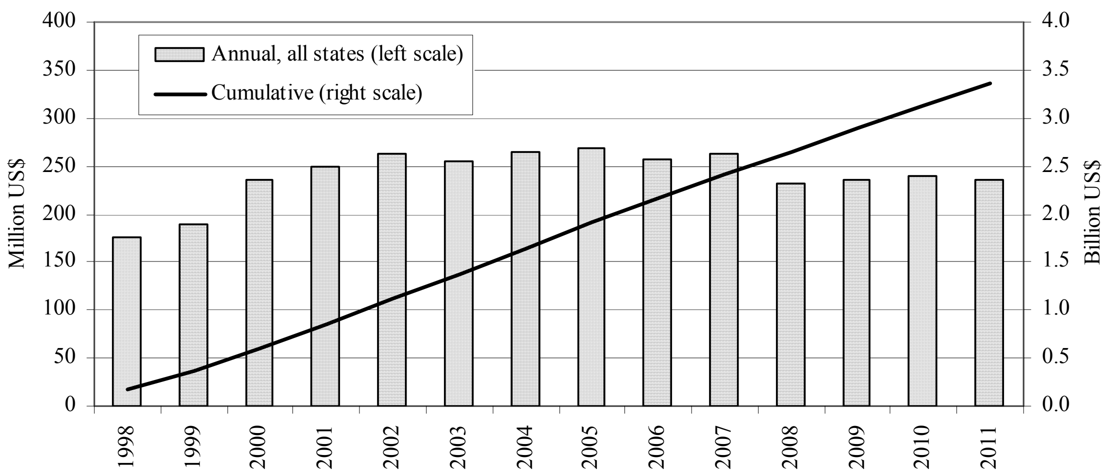
3.2 – States with System Benefit Charges (SBC)

A System Benefit Charge (SBC) is a small fee added to a customer's electricity bill used to fund programs that benefit the public, such as low-income energy assistance, energy-efficiency, and renewable energy. There are 15 states with SBCs, through which a portion of the money will be used to support renewable resources. Together, these states will collect about $4 billion in funds to support renewable resources between 1998 and 2017.



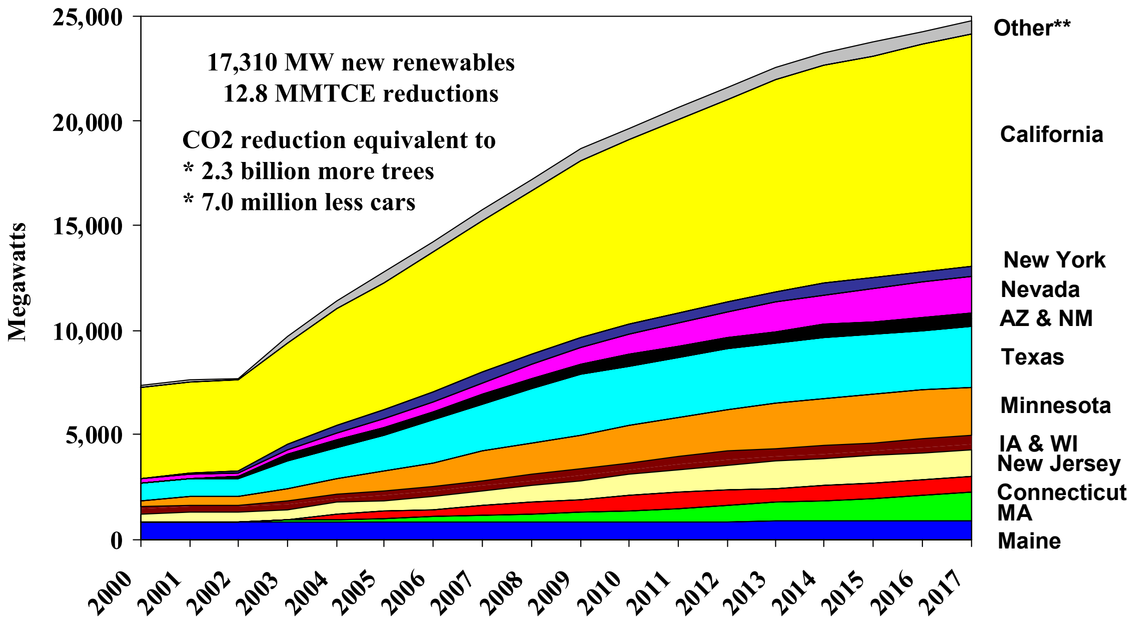
Source: Union of Concerned Scientists, June 2004

Figure 3.2.1. State System Benefit Funds



Source: Bolinger, M., R. Wiser, L. Milford, M. Stoddard, and K. Porter. *Clean Energy Funds: An Overview of State Support for Renewable Energy*, Lawrence Berkeley Laboratory, April 2001.

Figure 3.2.2. Aggregation Annual and Cumulative State Funding



*Does not include Maryland or Hawaii.
**Includes Illinois, Montana, Oregon, Pennsylvania and Rhode Island (Fund only).

Source: Union of Concerned Scientists, June 2004

Figure 3.2.3. The Future Impact of State Purchase Mandates and Renewable Energy Funds

Table 3.2.1. Renewable Energy Funding Levels and Program Duration

State	Approximate Annual Funding ($ Million)	$ Per-Capita Annual Funding	$ Per-MWh Funding	Funding Duration
CA	135	4.0	0.58	1998 - 2012
CT	15 → 30	4.4	0.50	2000 - indefinite
DE	1 (maximum)	1.3	0.09	10/1999 - indefinite
IL	5	0.4	0.04	1998 - 2007
MA	30→20	4.7	0.59	1998 - indefinite
MN	9	N/A	N/A	2000 - indefinite
MT	2	2.2	0.20	1999 - 7/2003
NJ	30	3.6	0.43	2001 - 2008
NM	4	2.2	0.22	2007 - indefinite
NY	6 → 14	0.7	0.11	7/1998 - 6/2006
OH	15 → 5 (portion of)	1.3	0.09	2001 - 2010
OR	8.6	2.5	0.17	10/2001 - 9/2010
PA	10.8 (portion of)	0.9	0.08	1999 - indefinite
RI	2	1.9	0.28	1997 - 2003
WI	1 → 4.8	0.9	0.07	4/1999 - indefinite

Note: Annual and per-MWh funding are based on funds expected in 2001.
Source: Bolinger et al., 2001

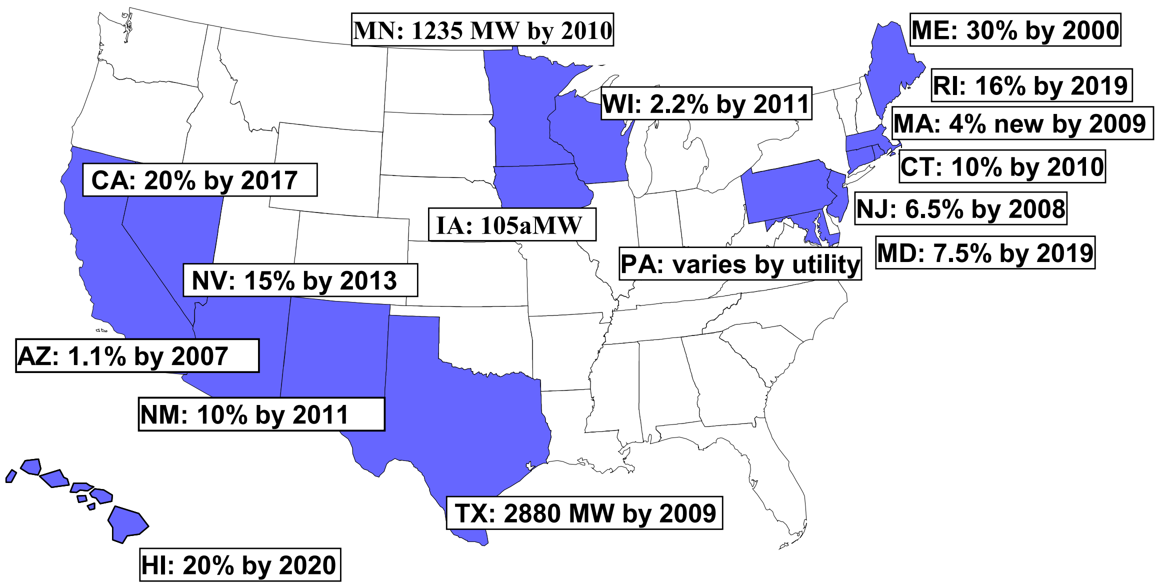
Table 3.2.2. State SBC Funding of Large-Scale Renewable Projects

State	Form of Funding Distribution	Level of Funding ($ Million)	Results[1]	Discounted cents/kWh Incentive over Five Years[2]
CA	Five-year production incentive	162 40 40	543 MW (assorted) 471 MW (assorted) 300 MW (assorted)	1.20 0.59 0.75
IL	Grant	0.55 1 0.352 0.55	3 MW landfill gas 3 MW hydro 1.2 MW hydro 15 MW landfill gas	0.57 1.86 1.63 0.11
MT	Three-year production incentive	1.5	3 MW wind	3.63
NY	Grants with performance guarantees	9 4	51.5 MW wind 6.6 MW wind	1.95 6.75
PA	Grant/ production incentive	6	67 MW wind	1.00

[1] Results are projected and are based on announced results of solicitations.
[2] Incentives have been normalized to their five-year production incentive equivalent using a 10% discount rate.
Source: Bolinger et al., 2001.

3.3 – States with Renewable Portfolio Standards (RPS)

A Renewable Portfolio Standard (RPS) is a policy that obligates a retail electricity supplier to include renewable resources in its electricity generation portfolio. Retail suppliers can meet the obligation by constructing or owning eligible renewable resources or purchasing the power from eligible generators. To date, 16 states have adopted RPS policies or renewable purchase obligations. Initially, most states adopted RPS policies as part of electric industry restructuring; but, more recently, a number of states have implemented policies by legislation or proceedings that are separate from restructuring activities. In conjunction with system benefits funds, RPS policies are expected to lead to the development of more than 17,000 MW of new renewable energy capacity by 2017 (see **Figure 3.3.1**).



Source: Updated by NREL July 2004 based on original map prepared by Lawrence Berkeley National Laboratory and Union of Concerned Scientists.

Figure 3.3.1. Renewable Portfolio Standards and Renewables Purchase Obligations by State

Table 3.3.1. State Renewable Portfolio Standards and Purchase Requirements

State	Purchase Requirements	Eligible Resources	Credit Trading	Penalties	Outside of state?
AZ	0.2% in 2001, rising by 0.2%/yr to 1% in 2005, then to 1.05% in 2006, and to 1.1% from 2007-2012. (2001: 50% from solar electric, 2004:60% from solar electric)	PV and solar thermal electric, R&D, solar hot water, and in-state landfill gas, wind, and biomass.	No central credit trading system	30 cents/kWh starting in 2004. Proceeds go to solar electric fund to finance solar projects.	Out-of-state solar eligible if power reaches AZ. Landfill gas, wind, and biomass must be in-state.
CA	Investor-owned utilities must add minimum 1% annually to 20% by 2017.	Biomass, solar thermal, photovoltaic, wind, geothermal, existing hydro < 30MW, fuel cells using renewable fuels, digester gas, landfill gas, ocean energy.	WREGIS system under development	To be determined	Out-of-state eligible if meets criteria for approval.
CT	3% Class I or II Technologies by Jan 1, 2004 Class I 1% Jan 1, 2004 increasing to 1.5% by 2005, 2% by 2006, 3.5% by 2007, 5% by 2008, 6% by 2009, and 7% by Jan 1, 2010	Class I: solar, wind, new sustainable biomass, landfill gas, fuel cells, ocean thermal, wave, tidal, advanced renewable energy conversion technologies, new run of river hydro (<5 MW). Class II: licensed hydro, MSW, and other biomass.	Yes. Using NEPOOL Generation Information System.	Penalty of 5.5¢/kWh paid to the Renewable Energy Investment Fund for the development of Class I renewables	New England resources or electricity delivered to New England are eligible.
IA	Investor-owned utilities to purchase 105 average MW (~2% of 1999 sales)	Solar, wind, methane recovery, and biomass	No	Unspecified	Out-of-state renewables not eligible.
HI	8% by end of 2005, 10% by 2010, 15% by 2015 and 20% by 2020	Wind, solar, hydropower, biomass including landfill gas, waste to energy, and fuels derived from organic sources, geothermal, ocean energy, fuel cells using hydrogen from renewables	Unspecified	Unspecified; standard to be revisited if utilities can not meet it in cost-effective manner	Unspecified
ME	30% of retail sales in 2000 and thereafter. PUC will revisit within 5 years.	Fuel cells, tidal, solar, wind, geothermal, hydro, biomass, and MSW (< 100MW); high efficiency cogeneration. Self-generation is not eligible. Resource supply under this definition exceeds RPS requirement.	No. However, PUC is considering adoption of NEPOOL Generation Information System.	Possible sanctions at discretion of PUC including license revocation, monetary penalties, or payment into renewables fund.	New England resources or electricity delivered to New England are eligible.

State	Purchase Requirements	Eligible Resources	Credit Trading	Penalties	Outside of state?
MD	3.5% by 2006 with 1% from Tier 1 sources, Tier 1 increasing by 1% every other year from 2007 to 2018, Tier II remains at 2.5%, 7.5% total by 2019 and in subsequent years	Tier 1: solar, wind, geothermal, qualifying biomass, small hydropower (<30MW), and landfill methane Tier II: existing large hydropower, poultry litter incineration, existing waste to energy	Yes	Alternative Compliance fee of 2¢/kWh for Tier 1 and 1.5¢/kWh for Tier 2 paid to Maryland Renewable Energy Fund	Trading system to work in conjunction with PJM system
MA	1% of sales to end-use customers from new renewables in 2003, +0.5%/yr to 4% in 2009 1%/yr increase thereafter until determined by Division of Energy Resources	New renewables placed into commercial operation after 1997, including solar, wind, ocean thermal, wave, tidal, fuel cells using renewable fuels, landfill gas, and low-emission advanced biomass. Excess production from existing generators over historical baseline eligible.	Yes. Using NEPOOL Generation Information System.	Entities may comply by paying 5¢/kWh. Non-complying retailers must submit a compliance plan. Revocation or suspension of license is possible.	New England resources or electricity delivered to New England are eligible.
MN	(Not true RPS) Applies to Xcel Energy only: 425 MW wind by 2002 and 110 MW biomass. Additional 400 MW wind by 2006 and 300 MW by 2010	Wind, biomass.	No, other than standard regulatory oversight.	No	Unspecified
NV	5% by 2003 increase 2%/yr until 15% in 2013. Minimum 5%/yr must come from solar.	Solar, wind, geothermal, & biomass (includes agricultural waste, wood, MSW, animal waste and aquatic plants). Distributed resources receives extra credit (1.15).	Yes. RECs valid for 4 years following year issued.	Financial penalties may be applied for noncompliance.	Out-of-state resources eligible with dedicated transmission line.
NJ	Class I or II: 2.5% Class I: 4% by 2008, with solar requirement of 0.16% retail sales (90MW)	Class I.: Solar, PV, wind, fuel cells, geothermal, wave, tidal, landfill methane, and sustainable biomass. Class II: hydro <30 MW and MSW facilities that meet air pollution requirements.	Legislation allows credit trading, PJM credit trading system under development.	Shortfalls must be made up in the following year or financial penalties, license revocation or suspension.	Eligible if power flows into PJM or NYISO. Class II must come from states open to retail competition.

State	Purchase Requirements	Eligible Resources	Credit Trading	Penalties	Outside of state?
NM	5% of retail sales by 2006. Increase by 1%/yr to 10% by January 1, 2011 and thereafter.	Solar, wind, hydro (<=5 MW), biomass, geothermal, and fuel cells. 1 kWh solar = 3kWh; 1 kWh biomass, geothermal, landfill gas, or fuel cells =2 kWh toward compliance	Yes. RECs valid for 4 years from date of issuance.	Yes, but to be determined.	Must be delivered in state.
PA	For PECO, West Penn, & PP&L, 20% of residential consumers served by competitive default provider: 2% in 2001 rising 0.5%/yr. For GPU 0.2% in 2001 for 20% customers, 40% of customers in 2002, 60% in 2003, 80% in 2004.	Solar, wind, ocean, geothermal, sustainable biomass.	No.	Unspecified.	Eligible
RI	3% by 2003, increasing 0.5% annually 2008-2010, increasing 1% annually 2011-2014, increasing 1.5% annually 2015-2019	Solar, wind, eligible biomass, including co-firing, geothermal, small hydropower, ocean, fuel cells using hydrogen derived from renewables.	Yes. Using NEPOOL Generation Information System.	Alternative compliance payments can be made to Renewable Energy Development Fund.	New England resources or electricity delivered to New England are eligible.
TX	1280 MW by 2003 increase to 2880 MW by 2009 (880 MW from existing) ~2.3% of 2009 sales.	Solar, wind, geothermal, hydro, wave, tidal, biomass, including landfill gas. New (operational after Sept. 1, 1999) or small (<2MW) facilities eligible.	Yes.	Lesser of 5¢/kWh or 200% of average market value of renewable energy credits. Under certain circumstances, penalty may not be assessed.	Not eligible unless dedicated transmission line into state.
WI	0.5% by 2001 increasing to 2.2% by 2011 (0.6% can come from facilities installed prior to 1998).	Wind, solar, biomass, geothermal, tidal, fuel cells that use renewable fuel, & hydro under 60 MW. Eligibility may be extended by PUC.	Yes. Utilities with excess RECs can trade or bank them.	Penalty of $5,000-$500,000 is allowed in legislation.	Eligible

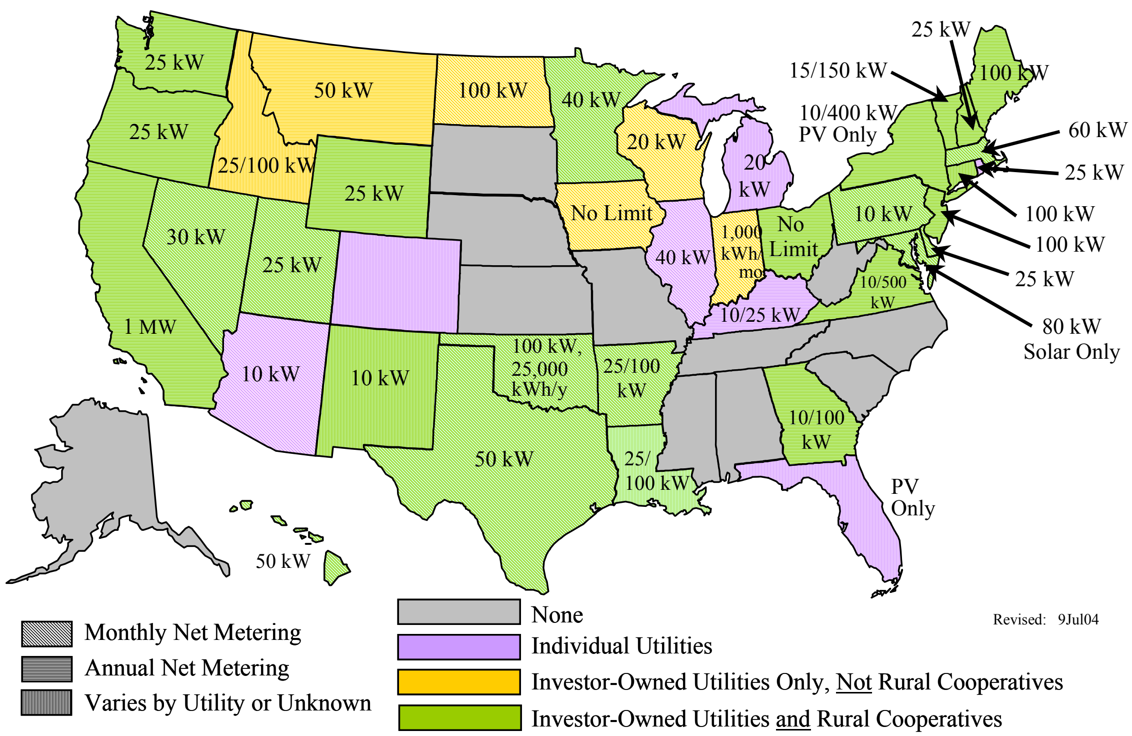
Source: Table updated by NREL July 2004. Derived from table in Wiser, R. Porter, K., Grace, R., Kappel, C. *Creating Geothermal Markets: Evaluating Experience with State Renewables Portfolio Standards*, report prepared for the National Geothermal Collaborative, 2003.

Table 3.3.2. State Renewable Energy Goals (Nonbinding)

State	Purchase Requirements	Eligible Resources
Illinois	5% by 2010; 15% in 2020	Wind, solar thermal, PV, organic waste biomass, & existing run-of-river hydro.
Minnesota	1% by 2005 increasing by at least 1%/year to 10% by 2015	Wind, solar, hydro (<60 MW), and biomass

3.4 – States with Net-Metering Policies

Net metering allows customers with generating facilities to turn their electric meters backward when their systems are producing energy in excess of their on-site demand. In this way, net metering enables customers to use their own generation to offset their consumption over a billing period. This offset means that customers receive retail prices for the excess electricity they generate. Without net metering, a second meter is usually installed to measure the electricity that flows back to the provider, with the provider purchasing the power at a rate much lower than the retail rate.



Source: J. Green, National Renewable Energy Laboratory, updated July 2004.
http://www.eere.energy.gov/greenpower/resources/maps/netmetering_map.shtml

Figure 3.4.1. Net-Metering Policies by State

Table 3.4.1. Summary of State Net-Metering Policies

State	Allowable Technology and Size	Allowable Customer	Statewide Limit	Treatment of Net Excess Generation (NEG)	Authority	Enacted	Scope of Program
AZ	≤10 kW; eligible technologies vary by utility	All customer classes	None	Annual NEG granted to utility	ACC; Utility Tariffs	1981	SRP and TEP
AR	Renewables, fuel cells and microturbines ≤25 kW residential ≤100 kW commercial	All customer classes	None	Monthly NEG granted to utilities	Legislature	2001	All utilities
CA	Solar and wind ≤1000 kW	All customer classes	0.5% of utilities peak demand	Annual NEG granted to utilities	Legislature	2002; 2001; 1995	All utilities
CO	Wind and PV 3 kW, 10 kW	Varies	NA	Varies	Utility tariffs	1997	Four Colorado utilities
CT	Renewables and fuel cells ≤100 kW	Residential	None	Not specified	Legislature	1990, updated 1998	All IOUs, No REC in state.
DE	Renewables ≤25 kW	All customer classes	None	Not specified	Legislature	1999	All utilities
FL	JEA: PV and wind ≤10 kW	JEA: Residential only; NSB: All customer classes	None	JEA and NSB: Monthly NEG granted to customer	Individual Utility Tariffs	2003 (JEA)	JEA, New Smyrna Beach
GA	Solar, wind, fuel cells ≤10 kW residential ≤100 kW commercial	Residential and commercial	0.2% of annual peak demand	Monthly NEG or total generation purchased at avoided cost or higher rate if green priced	Legislature	2001	All utilities
HI	Solar, wind, biomass, hydro ≤50 kW	Residential and small commercial	0.5% of annual peak demand	Monthly NEG granted to utilities	Legislature	2001	All utilities
ID	Eligible technologies vary by utility ≤25 kW residential ≤100 kW commercial (Avista ≤25 kW)	Residential and small commercial	None	NEG varies by utility	Public Utility Commission	1980	IOUs only, RECs are not rate-regulated
IL	Solar and wind ≤40 kW	All customer classes; ComEd only	0.1% of annual peak demand	NEG purchased at avoided cost	ComEd tariff	2000	Common-wealth Edison

State	Allowable Technology and Size	Allowable Customer	Statewide Limit	Treatment of Net Excess Generation (NEG)	Authority	Enacted	Scope of Program
IN	Renewables and cogeneration ≤1,000 kWh/month	All customer classes	None	Monthly NEG granted to utilities	Public Utility Commission	1985	IOUs only, RECs are not rate-regulated
IA	Renewables and cogeneration (No limit per system)	All customer classes	105 MW	Monthly NEG purchased at avoided cost	Iowa Utility Board	1993	IOUs only, RECs are not rate-regulated [2]
KY	Residential PV ≤ 15 kW	Not specified	0.1% of a supplier's single-hour peak load for previous year	Monthly NEG granted to customer	Legislature	2004	IOUs and RECs
LA	Residential ≤25 kW; ≤100 kW commercial and farm	Residential, commercial, farm	None	Not specified	Legislature	2003	All utilities
ME	Renewables and fuel cells ≤100 kW	All customer classes	None	Annual NEG granted to utilities	Public Utility Commission	1998	All utilities
MD	Solar and wind ≤80 kW	Residential, commercial, and nonprofit	0.2% of 1998 peak	Monthly NEG granted to utilities	Legislature	1997	All utilities
MA	Qualifying facilities ≤60 kW	All customer classes	None	Monthly NEG purchased at avoided cost	Legislature	1997	All utilities
MN	Qualifying facilities ≤40 kW	All customer classes	None	NEG purchased at utility average retail energy rate	Legislature	1983	All utilities
MT	Solar, wind and hydro ≤50 kW	All customer classes	None	Annual NEG granted to utilities at the end of each calendar year.	Legislature	1999	IOUs only
NV	Biomass, geothermal, solar, wind, hydro ≤30 kW	All customer classes	None	Monthly or annual NEG granted to utilities	Legislature	2001; 1997	All utilities
NH	Solar, wind and hydro ≤25 kW	All customers classes	0.05% of utility's annual peak	NEG credited to next month	Legislature	1998	All utilities
NJ	PV and wind ≤100 kW	Residential and small commercial	0.1% of peak or $2M annual financial impact	Annualized NEG purchased at avoided cost	Legislature	1999	All utilities

State	Allowable Technology and Size	Allowable Customer	Statewide Limit	Treatment of Net Excess Generation (NEG)	Authority	Enacted	Scope of Program
NM	Renewables and cogeneration ≤10 kW	All customer classes	None	NEG credited to next month, or monthly NEG purchased at avoided cost (utility choice)	Public Utility Commission	1999	All utilities
NY	Solar residential ≤10 kW; wind residential ≤ 25 kW; Farm biogas systems <400 kW; Farm wind ≤ 125 kW	Residential; farm systems	0.1% 1996 peak demand	Annualized NEG purchased at avoided cost	Legislature	2002; 1997	All utilities
ND	Renewables and cogeneration ≤100 kW	All customer classes	None	Monthly NEG purchased at avoided cost	Public Utility Commission	1991	IOUs only, RECs are not rate-regulated
OH	Renewables, microturbines, and fuel cells (no limit per system)	All customer classes	1.0% of aggregate customer demand	NEG credited to next month	Legislature	1999	All utilities
OK	Renewables and cogeneration ≤100 kW and ≤25,000 kWh/year	All customer classes	None	Monthly NEG granted to utility	Oklahoma Corporation Commission	1988	All utilities
OR	Solar, wind, fuel cell and hydro ≤25 kW	All customer classes	0.5% of peak demand	Annual NEG granted to low-income programs, credited to customer, or other use determined by Commission	Legislature	1999	All utilities
PA	Renewables and fuel cells ≤10 kW	Residential	None	Monthly NEG granted to utility	Legislature	1998	All utilities
RI	Renewables and fuel cells ≤25 kW	All customer classes	1 MW for Narragansett Electric Company	Annual NEG granted to utilities	Public Utility Commission	1998	Narragansett Electric Company
TX	Renewables only ≤50 kW	All customer classes	None	Monthly NEG purchased at avoided cost	Public Utility Commission	1986	All IOUs and RECs
VT	PV, wind, fuel cells ≤15 kW Farm biogas ≤150 kW	Residential, commercial and agricultural	1% of 1996 peak	Annual NEG granted to utilities	Legislature	1998	All utilities

State	Allowable Technology and Size	Allowable Customer	Statewide Limit	Treatment of Net Excess Generation (NEG)	Authority	Enacted	Scope of Program
VA	Solar, wind and hydro Residential ≤10 kW Non-residential ≤500 kW	All customer classes	0.1% of peak of previous year	Annual NEG granted to utilities (power purchase agreement is allowed)	Legislature	1999	All utilities
WA	Solar, wind, fuel cells and hydro ≤25 kW	All customer classes	0.1% of 1996 peak demand	Annual NEG granted to utility	Legislature	1998	All utilities
WI	All technologies ≤20 kW	All retail customers	None	Monthly NEG purchased at retail rate for renewables, avoided cost for non-renewables	Public Service Commission	1993	IOUs only, RECs are not rate-regulated
WY	Solar, wind, hydro, and biomass ≤ 25 kW	All customer classes	None	Annual NEG purchased at avoided cost	Legislature	2001	All IOUs, RECs, and munis

Source: National Renewable Energy Lab based on original table by Tom Starrs of Kelso Starrs and Associates. July 2004. http://www.eere.energy.gov/greenpower/markets/netmetering.shtml

Notes:

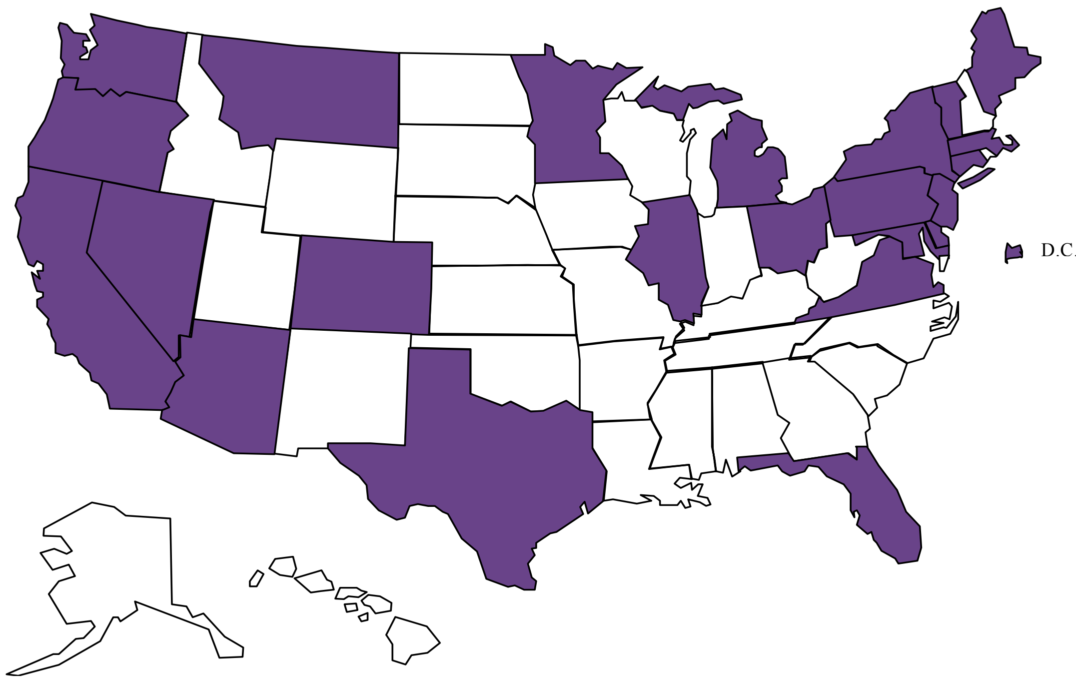
IOU — Investor-owned utility

GandT — Generation and transmission cooperatives

REC — Rural electric cooperative

3.5 – States with Environmental Disclosure Policies

As electricity markets open to competition, retail consumers are increasingly gaining the ability to choose their electricity suppliers. With this choice comes the need for consumers to have access to information about the price, source, and environmental characteristics of their electricity. For green power marketers in particular, it is important that consumers understand the environmental implications of their energy consumption decisions. To date, 23 states and the District of Columbia have *environmental disclosure* policies in place, requiring electricity suppliers to provide information on fuel sources and, in some cases, emissions associated with electricity generation. Although most of these policies have been adopted in states with retail competition, a handful of states with no plans to implement restructuring have required environmental disclosure.



Source: DSIRE database, June 2004.

Figure 3.5.1. Environmental Disclosure Requirements by State

3.6 – Green Power Markets

There are three distinct markets for green power in the United States. In regulated markets, a single utility may provide a green power option to its customers through "green pricing," which is an optional service or tariff offered to customers. These utilities include investor-owned utilities, rural electric cooperatives, and other publicly owned utilities. More than 500 utilities in 34 states offer green pricing or are in the process of preparing programs.

In restructured (or competitive) electricity markets, retail electricity customers can choose from among multiple electricity suppliers, some of which may offer green power. Electricity markets are now open to full competition in a number of states, while others are phasing in competition.

Finally, consumers can purchase green power through "renewable energy certificates." These certificates represent the environmental attributes of renewable energy generation and can be sold to customers in either type of market, whether or not they already have access to a green power product from their existing retail power provider.

Utility market research shows that majorities of customer respondents are likely to state that they would pay at least $5 more per month for renewable energy. And business and other nonresidential customers, including colleges and universities, and government entities are increasingly interested in green power.

Table 3.6.1. New Renewable Capacity Supplying Green Power Markets as of December 2003 (in MW)

Source	MW in Place	%	MW Planned	%
Wind	1544.6	93.8	306.7	78.0
Biomass	77.4	4.7	60.3	15.3
Solar	5.6	0.3	1.3	0.3
Geothermal	10.5	0.6	25.0	6.4
Small Hydro	9.3	0.6	0.0	0.0
Total	1647.3	100.0	393.4	100.0

Source: L.Bird and B. Swezey, Estimates of Renewable Energy Capacity Serving U.S. Green Power Markets, National Renewable Energy Laboratory, June 2004.
http://www.eere.energy.gov/greenpower/resources/tables/new_gp_cap.shtml

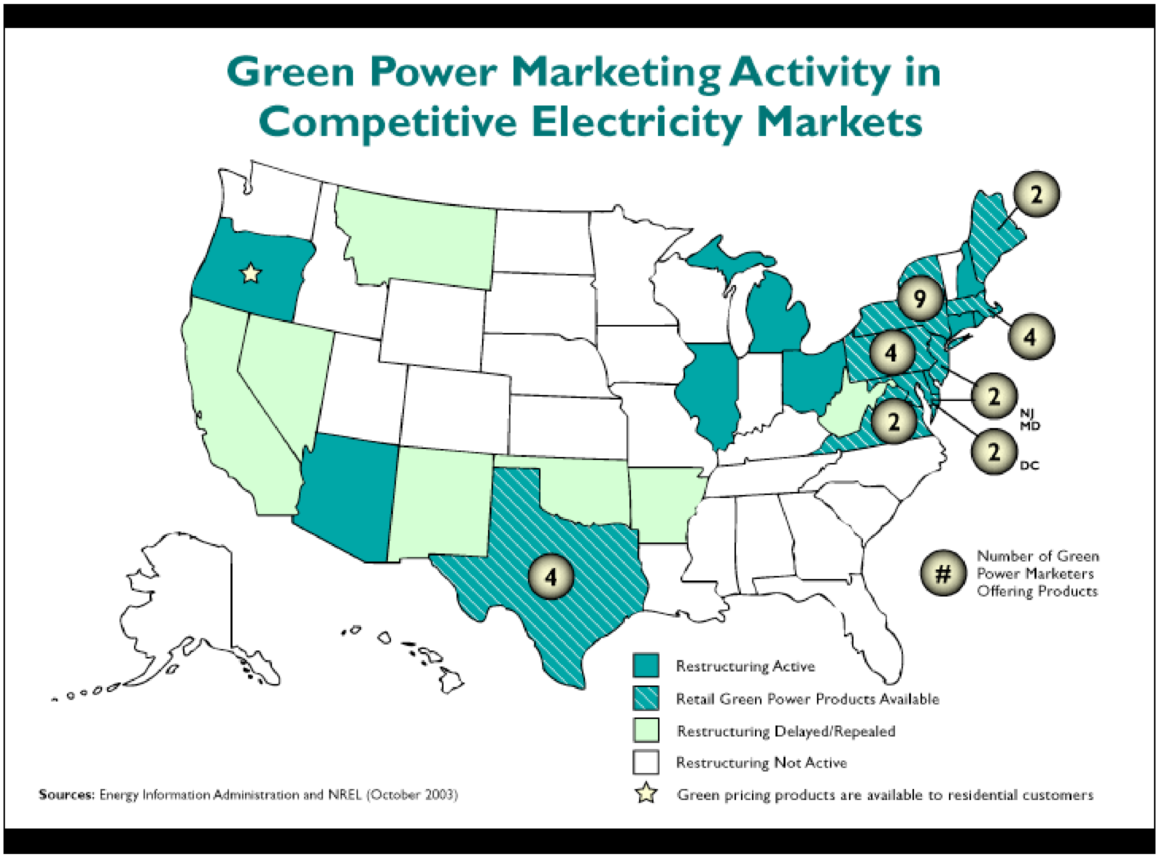
Table 3.6.2: Estimated Green Power Customers and Sales by Market Segment (2003)

Segment	Customers	Sales (Billions of kWh)*
Utility Green Pricing	265,000	1.3
Competitive Markets	150,000	1.9
REC Markets	5,000	0.7
Retail Total	420,000	3.9

*Includes sales of new and existing renewable energy.
Source: Bird, L. and B. Swezey, 2004. *Green Power Marketing in the United States: A Status Report (Seventh Edition)*, NREL/TP-620-36823. Golden, CO: National Renewable Energy Laboratory, September. http://www.eere.energy.gov/greenpower/pdfs/36823.pdf

3.7 – States with Competitive Green Power Offerings

Green power marketing refers to selling green power in the competitive marketplace, in which multiple suppliers and service offerings exist. Electricity markets are now open to full competition in a number of states, while others are phasing in competition, allowing some customers to choose their electricity supplier. As of mid-2004, competitive marketers offer green power to retail or wholesale customers in Maine, Maryland, Massachusetts, Pennsylvania, New Jersey, New York, Rhode Island, Texas, Virginia, and the District of Columbia.



Source: L. Bird and B. Swezey, National Renewable Energy Laboratory. Updated July 2004.
http://www.eere.energy.gov/greenpower/markets/marketing.shtml?page=4

Figure 3.7.1. Green Power Marketing Map

Table 3.7.1. New Renewables Capacity Supplying Competitive Markets and Renewable Energy Certificates, as of December 2003 (in MW)

Source	MW in Place	%	MW Planned	%
Wind	1,119.2	99.3	173.3	77.5
Biomass	1.7	0.1	50.3	22.5
Solar	0.7	0.1	0.0	0.0
Geothermal	5.0	0.4	0.0	0.0
Small Hydro	0.0	0.0	0.0	0.0
Total	1,126.5	100.0	223.7	100.0

Source: L.Bird and B. Swezey, Estimates of Renewable Energy Capacity Serving U.S. Green Power Markets, National Renewable Energy Laboratory, June 2004.
http://www.eere.energy.gov/greenpower/resources/tables/new_gp_cap.shtml

Table 3.7.2. Competitive Electricity Markets Retail Green Power Product Offerings as of July 2004

State/Company	Product Name	Residential Price Premium[1]	Fee	Resource Mix[2]	Certification
District of Columbia					
Washington Gas Energy Services/Community Energy	New Wind Energy	2.5¢/kWh	—	100 kWh blocks of new wind	
PEPCO Energy Services[3]	100% Green Electricity	3.41¢/kWh	—	100% biomass	—
	51% Green Electricity	3.05¢/kWh	—	51% biomass and 1% hydro	—
	10% Green Electricity	2.74¢/kWh	—	10% biomass	—
	100% NewWind Energy	4.3¢kWh		100% new wind	—
	51% NewWind Energy	3.42¢kWh		51% new wind	—
	Non-residential product	N/A	—	50% to 100% eligible renewables	Green-e
Maine[4]					
Maine Renewable Energy/Maine Interfaith Power & Light	Green Supply	1.5¢/kwh	—	>= 50% small hydro, <=50% wood-fired biomass	—
Constellation New Energy/Maine Power Options	Maine Made (non-residential)	NA	—	50% small hydro and 50% biomass	—
	Commercial Renewable Energy (non-residential)	NA	—	Various	Green-e
Maryland					
Washington Gas Energy Services/Community Energy	New Wind Energy	2.5¢/kWh	—	100 kWh blocks of new wind	—
PEPCO Energy Services[5]	100% Green Electricity	3.44¢/kWh	—	100% biomass	—
	51% Green Electricity	3.08¢/kWh	—	51% biomass and 1% hydro	—
	10% Green Electricity	2.77¢/kWh		10% biomass, 2% hydro	—
	100% NewWind Energy	4.97¢/kWh		100% new wind	—

	51% NewWind Energy	4.09¢/kWh		51% new wind	—
	Non-residential product	N/A	—	50% to 100% eligible renewables	Green-e
Massachusetts					
Constellation New Energy	Commercial Renewable Energy (non-residential)	NA	—	Various	Green-e
Massachusetts Electric/Nantucket Electric/ CET & Conservation Services Group	GreenerWatts New England 100%	1.9¢/kWh	—	75% small hydro, 14% new* landfill gas, 10% wind, 1% new* solar	Green-e
	GreenerWatts New England 50%	0.95¢/kWh	—	37.5% small hydro, 7% new* biomass, 5% wind, 0.5% new* solar	—
Massachusetts Electric/Nantucket Electric/ Community Energy	New Wind Energy 100%	2.4¢/kWh	—	50% small hydro, 50% new* wind	Green-e
	New Wind Energy 50%	1.2¢/kWh	—	25% small hydro, 25% new* wind	Green-e
Massachusetts Electric/Nantucket Electric/ Mass Energy Consumers Alliance	New England GreenStart 100%	2.5¢/kWh		<=70% small hydro, >=19% biomass, 10.5% wind, 0.5% solar (>=25% of all green power is new*)	Green-e
	New England GreenStart 50%	1.25¢/kWh	—	<=36.5% small hydro, >=10% biomass, 5.25% wind, 0.25% solar (>=15% of all green power is new*)	—
Massachusetts Electric/Nantucket Electric/ Sterling Planet	Sterling Premium	1.2¢/kWh	—	65% small hydro, 25% biomass, 10% wind	—
	Sterling Premium Plus	2.2¢/kWh	—	75% small hydro, 15% new* biomass, 10% wind	—

New Jersey					
Constellation New Energy	Commercial Renewable Energy (non-residential)	NA	—	Various	Green-e
Green Mountain Energy Company[6]	Enviro Blend	0.13¢/kWh	$3.95/mo.	25% biomass, 20% small hydro, 5% wind, 50% large hydro	Green-e
New York					
1st Rochdale/Sterling Planet	Sterling Green	1.5¢/kWh	—	40% new wind, 30% small hydro, 30% biogas	Environmental Resources Trust
Agway Energy Products/Sterling Planet	Sterling Green Renewable Electricity	1.5¢/kWh	—	40% new wind, 30% small hydro, 30% biogas	—
ConEdison Solutions[7] / Community Energy	GREEN Power / New Wind Energy	0.5¢/kWh	—	25% new wind, 75% small hydro	Green-e
	GREEN Power / New Wind Energy (Non-residential)	NA	—	100% new wind	Green-e
Constellation New Energy	Commercial Renewable Energy (non-residential)	NA	—	Various	Green-e
Energy Cooperative of New York[8]	Renewable Electricity	0.5¢/kWh to 0.75¢/kWh	—	25% new wind, 75% existing landfill gas	—
Long Island Power Authority / Community Energy	Green Choice / New Wind Energy	2.0¢/kWh		100% new wind	—
	Green Choice / New Wind Energy and Water	1.0¢/kWh		60% new wind, 40% small hydro	—
Long Island Power Authority / EnviroGen	Green Choice / Green Power Program	1.0¢/kWh		75% landfill gas, 25% small hydro	—
Long Island Power Authority / Sterling Planet	Green Choice / Sterling Green	1.5¢/kWh		40% wind, 30% small hydro, 30% bioenergy	—
	Green Choice / New York Clean	1.0¢/kWh		55% small hydro, 35% bioenergy, 10% wind	—

Niagara Mohawk/Community Energy	60% New Wind Energy and 40% Small Hydro	1.0¢/kWh	—	60% new wind, 40% hydro	Green-e
	100% NewWind Energy	2.0¢/kWh	—	100% new wind	Green-e
	Blocks of NewWind Energy	2.0¢/kWh	—	100 kWh blocks of new wind	Green-e
Niagara Mohawk / EnviroGen	Think Green!	1.0¢/kWh	—	75% landfill gas, 25% hydro	—
Niagara Mohawk/Green Mountain Energy	Green Mountain Energy Electricity	1.3¢/kWh	—	50% wind, 50% small hydro	Green-e
Niagara Mohawk/Sterling Planet	Sterling Green	1.5¢/kWh	—	40% wind, 30% small hydro, 30% bioenergy	—
NYSEG / Community Energy	Catch The Wind / New Wind Energy	2.0-2.5¢/kWh	—	100-kWh blocks of new wind	Green-e
Rochester Gas & Electric/Community Energy	Catch the Wind	2.0-2.5¢/kWh	—	100-kWh blocks of new wind	Green-e
Select Energy	Non-residential product	N/A	—	Wind	—
Pennsylvania[9]					
ElectricAmerica	50% Hydro	0.39¢/kWh	—	50% large hydro	—
Energy Cooperative of Pennsylvania	Eco Choice 100	1.08¢/kWh	$5/year	90% landfill gas, 10% wind, 0.1% solar	Green-e
	New Wind Energy	2.5¢/kWh	—	Wind	—
Green Mountain Energy Company	Green Mountain Energy Electricity	1.37¢/kWh	$3.95/mo.	10% wind, 90% hydropower	—
	Nature's Choice	1.39¢/kWh	$3.95/mo.	60% biomass, 30% small hydro, 10% wind, < 1% solar	Green-e
PECO Energy/Community Energy	PECO Wind	2.54¢/kWh	—	100-kWh blocks of new wind	—
PEPCO Energy Services	100% Renewable	3.39¢/kWh	—	100% renewable	—
	51% Green Electricity	3.0¢/kWh	—	51% biomass and 1% hydro	—

	10% Green Electricity	2.67¢/kWh	—	10% biomass	—
	100% NewWind Energy	4.5¢/kWh		100% new wind	—
	51% NewWind Energy	3.57¢/kWh		51% new wind	—
Rhode Island					
Constellation New Energy	Commercial Renewable Energy (non-residential)	NA	—	Various	Green-e
Narragansett Electric / Community Energy, Inc.	NewWind Energy 100%	2.0¢/kWh	—	50% small hydro, 50% new* wind	Green-e
	NewWind Energy 50%	1.0¢/kWh	—	25% small hydro, 25% new* wind	Green-e
Narragansett Electric / Conservation Services Group	GreenerWatts New England 100%	1.7¢/kWh	—	75% small hydro, 14% new* landfill gas, 10% wind, 1% new* solar	Green-e
Narragansett Electric / People's Power & Light	New England GreenStart RI 100%	1.5¢/kWh	—	69% small hydro, 30% new* wind, 1% new* solar	Green-e
	New England GreenStart RI 50%	0.75¢/kWh	—	34.5% small hydro, 15% new* wind, 0.5% new* solar	Green-e
Narragansett Electric / Sterling Planet	Sterling Supreme 100%	1.98¢/kWh	—	40% small hydro, 25% biomass, 25% new* solar, 10% wind,	—
Texas[10]					
Green Mountain Energy Company	100% Wind Power	0.66¢/kWh	$4.95/mo.	100% wind	—
	Reliable Rate Plan	0.46¢/kWh	$4.95/mo.	Wind and hydro	—
	Month-to-Month Plan	0.26¢/kWh	$4.95/mo.	Wind and hydro	—
Reliant Energy	Renewable Plan	0.0¢/kWh	$5.34/mo.	100% renewable energy	—
Strategic Energy	Non-residential product	N/A	—	Wind	—
TXU Energy	Non-residential product	N/A	—	Wind	—

Virginia					
Washington Gas Energy Services/Community Energy	New Wind Energy	2.5¢/kWh	—	100 kWh blocks of new wind	—
PEPCO Energy Services[11]	100% Green Electricity	4.367¢/kWh	—	100% biomass	—
	51% Green Electricity	3.997¢/kWh	—	51% biomass and less than 1% hydro	—
	10% Green Electricity	3.687¢/kWh	—	10% biomass	—
	100% NewWind Energy	5.027¢/kWh	—	100% new wind	—
	51% NewWind Energy	4.147¢/kWh	—	51% new wind	—

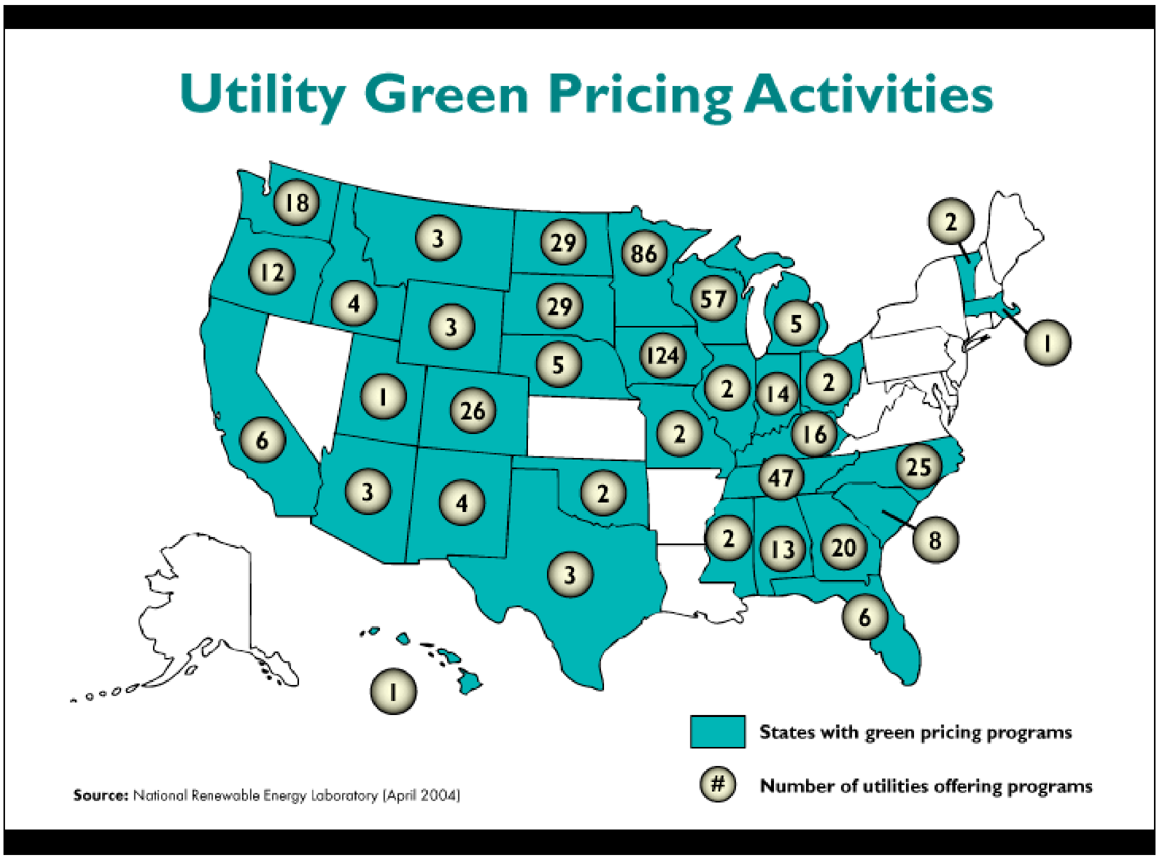
Source: National Renewable Energy Laboratory.

Notes:
N/A= Not applicable.
[1] Prices may vary by service territory. Prices may also differ for commercial/industrial customers.
[2] New is defined as operating or repowered after January 1, 1999 based on the Green-e TRC certification standards. New power sources denoted with an asterisk (*) are new as of January 1, 1998.
[3] Offered in PEPCO service territory. Product prices are based on annual average costs for customers in PEPCO's service territory (5.04¢/kWh). http://www.dcpsc.org/customerchoice/whatis/electric/electric.shtm
[4] Price premium is for Central Maine Power service territory.
[5] Product offered in Baltimore Gas and Electric and PEPCO service territories. Price is for PEPCO service territory based on price to compare of 5.01¢/kWh. http://www.oag.state.md.us/energy/
[6] Green Mountain Energy offers products in Conectiv, GPU, and PSE&G service territories. Product prices are for Conectiv service territory (price to compare of 6.75¢/kWh).
[7] Price premium is based on a comparison to ConEdison Solutions' standard electricity product.
[8] Price premium is for Niagara Mohawk service territory. Premium varies depending on energy taxes.
[9] Product prices are for PECO service territory (price to compare of 6.17¢/kWh). http://www.oca.state.pa.us/elecomp/pricecharts.html
[10] Product prices are based on price to beat of 10.4¢/kWh for TXU service territory (ONCOR). http://www.powertochoose.org/
[11] Products are only available in Dominion Virginia Power service territory. Price is based on price to compare of 3.983¢/kWh

References:
Green power marketer and utility Web sites.
District of Columbia Public Service Commission http://www.dcpsc.org/customerchoice/whatis/electric/electric.shtm
Maryland Attorney General Electricity Supplier Rate and Service Information http://www.oag.state.md.us/energy/
Pennsylvania Office of Consumer Advocate Residential Price Comparison Charts http://www.oca.state.pa.us/elecomp/pricecharts.html
Virginia's State Corporation Commission http://www.yesvachoice.com/howtochoose/howtoccompare.asp
Texas Public Utility Commission http://www.powertochoose.org/

3.8 – States with Utility Green Pricing Programs

Green pricing is an optional utility service that allows customers an opportunity to support a greater level of utility company investment in renewable energy technologies. Participating customers pay a premium on their electric bill to cover the extra cost of the renewable energy. Many utilities are offering green pricing to build customer loyalty, as well as expand business lines and expertise prior to electric market competition. To date, more than 500 investor-owned, municipal, and cooperative utilities in 34 states have either implemented or announced plans to offer a green pricing option.



Source: L. Bird and B. Swezey, National Renewable Energy Laboratory. Updated April 2004.
http://www.eere.energy.gov/greenpower/markets/pricing.shtml?page=4

Figure 3.8.1. Number of Utilities Offering Green Pricing Programs by State

Table 3.8.1. New Renewables Capacity Supported through Utility Green Pricing Programs, as of December 2003 (in MW)

Source	MW in Place	%	MW Planned	%
Wind	425.4	81.7	133.4	78.6
Biomass	75.7	14.5	10.0	5.9
Solar	4.9	0.9	1.3	0.8
Geothermal	5.5	1.1	25.0	14.7
Small Hydro	9.3	1.8	0.0	0.0
Total	520.8	100.0	169.7	100.0

Source: L.Bird and B. Swezey, Estimates of Renewable Energy Capacity Serving U.S. Green Power Markets, National Renewable Energy Laboratory, June 2004. http://www.eere.energy.gov/greenpower/resources/tables/new_gp_cap.shtml

Table 3.8.2. Utility Green Pricing Programs, April 2004

State	Utility Name	Program Name	Resource Type	Start Date	Premium
AL	Alabama Power	Renewable Energy Rate	biomass co-firing	2003/ 2000	6.0¢/ kWh
AL	TVA: City of Athens Electric Department, Cullman Electric Coop, Cullman Power Board, Decatur Utilities, Florence Utilities, Hartselle Utilities, Huntsville Utilities, Joe Wheeler EMC, Muscle Shoals Electric Board, Scottsboro Electric Power Board, Sheffield Utilities, Tuscumbia Electric Department	Green Power Switch	wind, landfill gas, solar	2000	2.67¢/ kWh
AZ	Arizona Public Service	Solar Partners Program	central PV	1997	$2.64/ 15kWh
AZ	Salt River Project	EarthWise Energy	central PV, landfill gas, small hydro	1998/ 2001	3.0¢/kWh
AZ	Tucson Electric	GreenWatts	landfill gas, PV, wind	2000	7.5-10¢/ kWh
CA	City of Alameda	Clean Future Fund	various, electric vehicles	1999	1.0¢/kWh
CA	City of Palo Alto Utilities/3 Phases Energy Services	Palo Alto Green	wind, solar	2003/ 2000	1.5¢/kWh
CA	Los Angeles Dept. of Water and Power	Green Power for a Green LA	wind, landfill gas	1999	3.0¢/kWh
CA	Pasadena Water & Power	Green Power	wind	2003	2.5¢/kWh
CA	Roseville Electric	RE Green Energy Program	geothermal, hydro, PV	2000	1.0¢/kWh

CA	Sacramento Municipal Utility District	Greenergy	wind, landfill gas, hydro	1997	1.0¢/kWh
CA	Sacramento Municipal Utility District	PV Pioneers I	PV	1993	$4/month
CO	Colorado Springs Utilities	Green Power	wind	1997	3.0¢/kWh
CO	Holy Cross Energy	Local Renewable Energy Pool	small hydro, PV	2002	3.3¢/kWh
CO	Holy Cross Energy	Wind Power Pioneers	wind	1998	2.5¢/kWh
CO	Platte River Power Authority (Estes Park, Fort Collins Utilities, Longmont Power & Communications, Loveland Water & Light)	Wind Power Program	wind	1996	2.5¢/kWh
CO	Tri-State Generation & Transmission (18 of 44 coops): Carbon Power, Chimney Rock, Gunnison County Electric, Kit Carson, La Plata Electric, Mountain Parks Electric, Mountain View Electric, New Mexico, Northwest Rural, Poudre Valley Rural Electric Association, Public Power District, Sangre, San Isabel Electric, San Luis Valley Rural Electric Coop, San Miguel Power, Springer Electric, United Power, White River	Renewable Resource Power Service	wind, landfill gas	1999	2.5¢/kWh
CO	Xcel Energy	WindSource	wind	1997	2.5¢/kWh
CO	Xcel Energy	Renewable Energy Trust	PV	1993	Contribution
CO	Yampa Valley Electric Association	Green Power	wind	1999	3.0¢/kWh
FL	City of Tallahassee/Sterling Planet	Green for You	biomass, solar	2002	1.6¢/kWh
FL	City of Tallahassee/Sterling Planet	Green for You	solar only	2002	11.6¢/kWh
FL	Florida Power & Light/Green Mountain Energy	Sunshine Energy	biomass, wind, solar	2004	0.975¢/kWh
FL	Gainesville Regional Utilities	GRUgreen Energy	landfill gas, wind, solar	2003	2.0¢/kWh
FL	Southern Company: Gulf Power Company	EarthCents Solar	PV in schools; central PV	1996/ 1999	Contribution; $6.00/ 100 watts
FL	Tampa Electric Company (TECO)	Tampa Electric's Renewable Energy Program	PV, landfill gas	2000	10.0¢/kWh
FL	Utilities Commission City of New Smyrna Beach	Green Fund	local PV projects	1999	Contribution
GA	Georgia Electric Membership Corporation (16 of 42 coops offer program): Carroll EMC, Coastal Electric, Cobb EMC, Coweta-Fayette EMC, Flint Energies, GreyStone Power, Habersham EMC, Irwin EMC, Jackson EMC, Jefferson Energy, Lamar EMC, Ocmulgee EMC, Sawnee EMC, Snapping Shoals EMC, Tri-County EMC, Walton EMC of Monroe	Green Power EMC	landfill gas	2001	TBD
GA	Georgia Power	Green Energy	landfill gas, wind, solar	TBD	5.5¢/kWh
GA	Savannah Electric	Green Energy	landfill gas, wind, solar	TBD	6.0¢/kWh

GA	TVA: Blue Ridge Mountain Electric Membership Corporation, North Georgia Electric Membership Corporation	Green Power Switch	wind, landfill gas, solar	2000	2.67¢/ kWh
HI	Hawaiian Electric	Sun Power for Schools	PV in schools	1996	Contribution
IA	Alliant Energy	Second Nature	wind, landfill gas	2001	2.0¢/kWh
IA	Basin Electric Power Cooperative: Lyon Rural, Harrison County, Nishnabotna Valley Cooperative, Northwest Rural Electric Cooperative, Western Iowa	Prairie Winds	wind	2000	1.0¢/kWh
IA	Cedar Falls Utilities	Wind Energy Electric Project	wind	1999	Contribution
IA	Corn Belt Power Cooperatives: (11 co-ops and 1 municipal cooperative) Boone Valley Electric Cooperative, Butler County REC, Calhoun County REC, Franklin REC, Glidden REC, Grundy County REC, Humboldt County REC, Iowa Lakes Electric Cooperative, Midland Power Cooperative, Prairie Energy Cooperative, Sac County REC, North Iowa Municipal Electric Cooperative Association	Varies by Utility	wind	2004	Contribution
IA	Dairyland Power Cooperative: Allamakee-Clayton/Postville, Hawkeye Tri-County/Cresco, Heartland Power/Thompson & St. Ansgar	Evergreen Renewable Energy Program	wind	1997	3.0¢/kWh
IA	Farmers Electric Cooperative	Green Power Project	biodiesel, wind	2004	Contribution
IA	Iowa Association of Municipal Utilities (80 of 137 participating) Afton, Algona, Alta Vista, Aplington, Auburn, Bancroft, Bellevue, Bloomfield, Breda, Brooklyn, Buffalo, Burt, Callender, Carlisle, Cascade, Coggon, Coon Rapids, Corning, Corwith, Danville, Dayton, Durant, Dysart, Earlville, Eldridge, Ellsworth, Estherville, Fairbank, Farnhamville, Fontanelle, Forest City, Gowrie, Grafton, Grand Junction, Greenfield, Grundy Center, Guttenberg, Hopkinton, Hudson, Independence, Keosauqua, La Porte City, Lake Mills, Lake View, Laurens, Lenox, Livermore, Maquoketa, Marathon, McGregor, Milford, Montezuma, Mount Pleasant, Neola, New Hampton, Ogden, Orient, Osage, Panora, Pella, Pocahontas, Preston, Readlyn, Rockford, Sabula, Sergeant Bluff, Sibley, Spencer, Stanhope, State Center, Stratford, Strawberry Point, Stuart, Tipton, Villisca, Vinton, Webster City, West Bend, West Liberty, West Point, Westfield, Whittemore, Wilton, Winterset	Green City Energy	wind, biomass, solar	2003	Varies by utility
IA	MidAmerican Energy	Renewable Advantage	wind	2004	Contribution

IA	Missouri River Energy Services (MRES): Alton, Atlantic, Denison, Fontanelle, Hartley, Hawarden, Kimballton, Lake Park, Manilla, Orange City, Paullina, Primghar, Remsen, Rock Rapids, Sanborn, Shelby, Sioux Center, Woodbine	RiverWinds	wind	2003	2.0 - 2.5¢/kWh
IA	Muscatine Power and Water	Solar Muscatine	solar	2004	Contribution
IA	Waverly Light & Power	Iowa Energy Tags	wind	2001	2.0¢/kWh
ID	Avista Utilities	Buck-A-Block	wind	2002	1.8¢/kWh
ID	Idaho Power	Green Power Program	various	2001	Contribution
ID	PacifiCorp: Utah Power	Blue Sky	wind	2003	1.95¢/kWh
ID	Vigilante Electric Cooperative	Alternative Renewable Energy Program	wind, solar, hydro	2003	1.1¢/kWh
IL	City of St. Charles/ComEd and Community Energy, Inc.	TBD	wind, landfill gas	2003	Contribution
IL	Dairyland Power Cooperative: Jo-Carroll Energy/Elizabeth	Evergreen Renewable Energy Program	wind	1997	3.0¢/kWh
IN	Hoosier Energy (5 of 17 coops): Southeastern Indiana REMC, South Central Indiana REMC, Utilities District of Western Indiana REMC, Decatur County REMC, Daviess-Martin County REMC	EnviroWatts	landfill gas	2001	2.0¢/kWh - 4.0¢/kWh
IN	Indianapolis Power & Light	Elect PlanSM Green Power Program	geothermal	1998	0.9¢/kWh
IN	PSI Energy/Cinergy	Green Power Rider	wind, solar, landfill gas, digester gas	2001	Contribution
IN	Wabash Valley Power Association (7 of 27 coops offer program): Boone REMC, Hendricks Power Cooperative, Kankakee Valley REMC, Miami-Cass REMC, Tipmont REMC, White County REMC, Northeastern REMC	EnviroWatts	landfill gas	2000	0.9-1.0¢/kWh
KY	East Kentucky Power Cooperative: Bluegrass, Clark, Inter County Energy Cooperative, Owen, Nolin, Salt River, Grayson, South Kentucky, Shelby, Cumberland, Licking, Jackson, Mason, Fleming	EnviroWatts	landfill gas	2002	2.75¢/kWh
KY	TVA: Bowling Green Municipal Utilities, Franklin Electric Plant Board	Green Power Switch	landfill gas, solar, wind	2000	2.67¢/kWh
MA	Concord Municipal Light Plant (CMLP)	Green Power	hydro	2004	3.0¢/kWh
MI	Consumers Energy	Green Power Pilot Program	wind	2001	3.2¢/kWh
MI	DTE Energy	Solar Currents	central PV	1996	$6.94/100 watts
MI	Lansing Board of Water and Light	GreenWise Electric Power	landfill gas, small hydro	2001	3.0¢/kWh
MI	Traverse City Light and Power	Green Rate	wind	1996	1.58¢/kWh
MI	We Energies	Energy for Tomorrow	wind, landfill gas, hydro	2000	2.04¢/kWh

MN	Alliant Energy	Second Nature	wind, landfill gas	2002	2.0¢/kWh
MN	Basin Electric Power Cooperative: Minnesota Valley Electric Coop, Sioux Valley Southwestern	Prairie Winds	wind	2000	1.0¢/kWh
MN	Dairyland Power Cooperative: Freeborn-Mower Cooperative/Albert Lea, People's/Rochester, Tri-County/Rushford	Evergreen Renewable Energy Program	wind	1997	3.0¢/kWh
MN	Great River Energy (28) : Agralite Electric Cooperative, Arrowhead Electric Cooperative, BENCO Electric, Brown County Rural Electric, Connexus Energy, Co-op Light & Power, Crow Wing Power, Dakota Electric Association, East Central Electric Association, Federated Rural Electric, Goodhue County, Itasca Mantrap Cooperative, Kandiyohi Power Cooperative, Lake Country Power, Lake Region Electric Cooperative, McLeod Cooperative Power, Meeker Cooperative Light & Power, Mille Lacs Electric Cooperative, Minnesota Valley Electric Cooperative, Nobles Cooperative Electric, North Itasca, Redwood Electric Cooperative, Runestone Electric, South Central Electric Association, Stearns Electric, Steele-Waseca, Todd-Wadena, Wright-Hennepin Electric	Wellspring	wind	1997	1.45-2.0¢/kWh
MN	Minnesota Power	WindSense	wind	2002	2.5¢/kWh
MN	Minnkota Power Cooperative: Beltrami, Clearwater Polk, North Star, PKM, Red Lake, Red River, Roseau, Wild Rice, Thief River Falls	Infinity Wind Energy	wind	1999	1.5¢/kWh
MN	Missouri River Energy Services (39 of 55): Adrian, Alexandria, Barnesville, Benson, Breckenridge, Detroit Lakes, Elbow Lake, Henning, Jackson, Lakefield, Lake Park, Luverne, Madison, Moorhead, Ortonville, St. James, Sauk Centre, Staples, Wadena, Westbrook, Worthington	RiverWinds	wind	2002	2.0-2.5¢/kWh
MN	Moorhead Public Service	Capture the Wind	wind	1998	1.5¢/kWh
MN	Otter Tail Power	TailWinds	wind	2002	2.6¢/kWh
MN	Southern Minnesota Municipal Power Agency (all 18 munis offer program): Fairmont Public Utilities, Wells Public Utilities, Austin Utilities, Preston Public Utilities, Spring Valley Utilities, Blooming Prairie Public Utilities, Rochester Public Utilities, Owatonna Public Utilities, Waseca Utilities, St. Peter Municipal Utilities, Lake City Utilities, New Prague Utilities Commission, Redwood Falls Public Utilities, Litchfield Public Utilities, Princeton Public Utilities, North Branch Water and Light, Mora Municipal Utilities, Grand Marais Public Utilities	Wind Power	wind	2000	1.0¢/kWh
MN	Xcel Energy	WindSource	wind	2003	2.0¢/kWh

MO	Boone Electric Cooperative	Renewable Choice	wind	2003	2.0¢/kWh
MO	City Utilities of Springfield	WindCurrent	wind	2000	5.0¢/kWh
MS	TVA: City of Oxford, North East Mississippi Electric Power Association, Starkville Electric System	Green Power Switch	wind, landfill gas, solar	2000	2.67¢/kWh
MT	Basin Electric Power Cooperative: Lower Yellowstone	Prairie Winds	wind	2000	1.0¢/kWh
MT	Northwestern Energy	E+ Green	wind, solar	2003	2.0¢/kWh
MT	Vigilante Electric Cooperative	Alternative Renewable Energy Program	wind, solar, hydro	2003	1.1¢/kWh
NC	Dominion North Carolina Power, Duke Power, Progress Energy/CP&L ElectriCities (7 of 57) City of High Point, City of Laurinburg, City of Newton, City of Shelby, City of Statesville,Town of Apex, Town of Granite Falls NC Electric Cooperatives (14 of 27 cooperatives offer the program): Blue Ridge Electric Membership Corp., Brunswick Electric Membership Corp., Carteret Craven Electric Coop., Edgecombe-Martin County Electric Membership Corp., EnergyUnited, Four County Electric Membership Corp., Haywood Electric Membership Corp., Jones-Onslow Electric Membership Corp., Pee Dee Electric Membership Corp., Piedmont Electric Membership Corp., Randolph Electric Membership Corp., Roanoke Electric Membership Corp., Tri-County Electric Membership Corp., Wake Electric Membership Corp.	NC GreenPower	biomass, wind, solar	2003	4.0¢/kWh
NC	TVA: Mountain Electric Cooperative	Green Power Switch	landfill gas, solar, wind	2000	2.67¢/kWh
ND	Basin Electric Power Cooperative (49 coops offer program in 5 states): Oliver Mercer Electric Coop, Mor-gran-sou Electric Coop, KEM Electric Coop, North Central Electric Coop, Verendrye, Capital , Northern Plains, Dakota Valley, Burke Divide, Montrail Williams, McKenzie Electric Coop, West Plains, Slope Electric Coop	PrairieWinds	wind	2000	1.0¢/kWh
ND	Minnkota Power Cooperative: Cass County Electric, Cavalier Rural Electric, Nodak Electric, Northern Municipal Power Agency (12 municipals)	Infinity Wind Energy	wind	1999	1.5¢/kWh
ND	Missouri River Energy Services: City of Lakota	RiverWinds	wind	2002	2.0-2.5¢/kWh
NE	Lincoln Electric System	Renewable Energy Program	wind	1998	4.3¢/kWh
NE	Nebraska Public Power District	Prairie Power Program	TBD	1999	Contribution
NE	Omaha Public Power District	Green Power Program	landfill gas, wind	2002	3.0¢/kWh

NE	Tri-State: Chimney Rock Public Power District, Northwest Rural Public Power District	Renewable Resource Power Service	wind, landfill gas	2001	2.5¢/kWh
NM	El Paso Electric	Renewable Energy Tariff	wind	2003	3.19¢/kWh
NM	Public Service of New Mexico	PNM Sky Blue	wind	2003	1.8¢/kWh
NM	Tri-State: Kit Carson Electric Cooperative	Renewable Resource Power Service	wind, landfill gas	2001	2.5¢/kWh
NM	Xcel Energy	WindSource	wind	1999	3.0¢/kWh
OH	AMP Ohio/Green Mountain Energy: Cuyahoga Falls	Nature's Energy	small hydro, wind, landfill gas	2003	1.3¢/kWh
OH	City of Bowling Green	Bowling Green Power	small hydro, wind, landfill gas	1999	1.35¢/kWh
OK	Edmond Electric	Pure & Simple	wind	2004	1.8¢/kWh
OK	OG&E Electric Services	Wind Power	wind	2003	0.63¢/kWh
OR	City of Ashland/Bonneville Environmental Foundation	Renewable Pioneers	solar	2003	2.0¢/kWh
OR	Emerald People's Utility District/Green Mountain Energy	Choose Renewable Electricity	wind, geothermal	2003	0.78-1.2¢/kWh
OR	Eugene Water & Electric Board	EWEB Wind Power	wind	1999	1.3¢/kWh
OR	Midstate Electric Cooperative	Environmentally Preferred Power	wind, small hydro	1999	2.5¢/kWh
OR	Oregon Trail Electric Cooperative	Green Power	wind	2002	1.5¢/kWh
OR	Pacific Northwest Generating Cooperative (5 of 16 coops offer program): Central Electric Cooperative, Clearwater Power, Consumers Power, Douglas Electric Cooperative, Umatilla Electric Cooperative	Green Power	landfill gas	1998	1.8-2.0¢/kWh
OR	PacifiCorp: Pacific Power	Blue Sky Block	wind	2000	1.95¢/kWh
OR	PacifiCorp: Pacific Power/3 Phases Energy Services	Blue Sky Usage	existing geothermal, wind	2002	0.78¢/kWh
OR	PacifiCorp: Pacific Power/3 Phases Energy Services	Blue Sky Habitat	existing geothermal, wind	2002	0.78¢/kWh + $2.50 donation
OR	Portland General Electric/Green Mountain Energy	Green Mountain Renewable Energy Usage	existing geothermal, wind	2002	0.8¢/kWh
OR	Portland General Electric/Green Mountain Energy	Healthy Habitat	existing geothermal, wind	2002	0.99¢/kWh
OR	Portland General Electric Company	Clean Wind for Medium to Large Commercial and Industrial Accounts	wind	2003	1.5-1.7¢/kWh
OR	Portland General Electric Company	Clean Wind Power	wind	2000	3.5¢/kWh

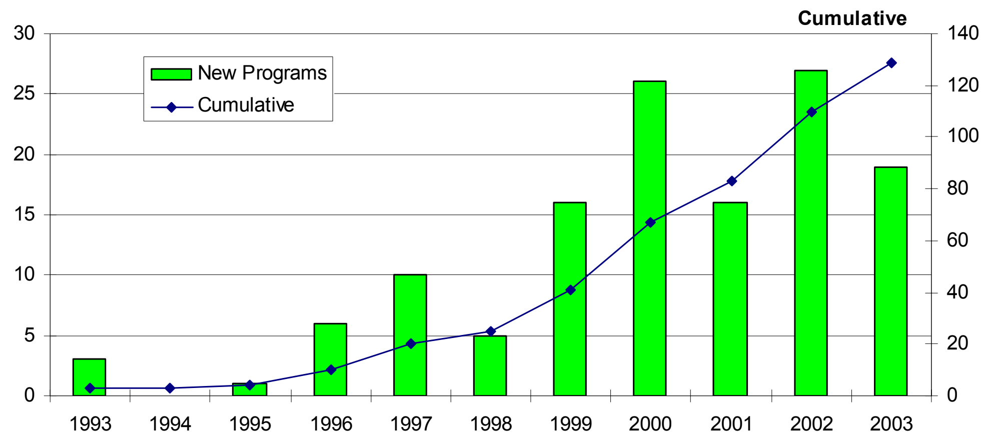
SC	Santee Cooper, Aiken Electric Cooperative, Berkeley Electric Cooperative, Horry Electric Cooperative, Mid-Carolina Electric Cooperative, Palmetto Electric Cooperative, Santee Electric Cooperative, Tri-County Electric Cooperative	Green Power Program	landfill gas	2001	3.0¢/kWh
SD	Basin Electric Power Cooperative: Bon Homme-Yankton Electric Assn., Central Electric Cooperative Association, Charles Mix Electric Association, City of Elk Point, Clay-Union Electric Corporation, Codington-Clark Electric Cooperative, Dakota Energy Cooperative, Douglas Electric Cooperative, FEM Electric Association, H-D Electric Cooperative, Kingsbury Electric Cooperative, Lyon-Lincoln Electric Cooperative, McCook Electric Cooperative, Northern Electric Cooperative, Oahe Electric Cooperative, Renville-Sibley Coop, Sioux Valley Southwestern Electric Coop, Southeastern Electric Coop, Union County Electric Cooperative, Whetstone Valley Electric Cooperative, Black Hills Electric Coop, LaCreek Electric Coop, West River Power Association, Butte Electric Coop, Cherry Todd Electric Coop, Moreau Grand, Grand Electric Cooperative, Rosebud	Prairie Winds	wind	2000	1.0¢/kWh
SD	Missouri River Energy Services: City of Vermillion	RiverWinds	wind	2002	2.0-2.5¢/kWh

TN	Alcoa Electric Department, Appalachian Electric Cooperative, Athens Utility Board, Bristol Tennessee Electric System, Caney Fork Electric Cooperative, City of Maryville Electric Department, Clarksville Department of Electricity, Cleveland Utilities, Clinton Utilities Board, Cookeville Electric Department, Cumberland Electric Membership Corporation, Dickson Electric Department, Duck River Electric Membership Corporation, Elizabethton Electric System, EPB (Chattanooga), Erwin Utilities, Fayetteville Public Utilities, Gibson Electric Membership Corporation, Greeneville Light and Power System, Harriman Utility Board, Johnson City Power Board, Jackson Energy Authority, Knoxville Utilities Board, Lafollette Utilities Board, Lawrenceburg Power System, Lenoir City Utilities Board, Loudon Utilities, McMinnville Electric System, Meriwhether Lewis Electric Cooperative, Middle Tennessee Electric Membership Corporation, Morristown Power System, Mountain Electric Cooperative, Murfreesboro Electric Department, Nashville Electric Service, Newport Utilities, Oak Ridge Electric Department, Paris Board of Public Utilities, Plateau Electric Cooperative, Powell Valley Electric Cooperative, Pulaski Electric System, Sequachee Valley Electric Cooperative, Sevier County Electric System, Springfield Department of Electricity, Sweetwater Utilities Board, Tullahoma Utilities Board, Upper Cumberland Electric Membership Corporation, Volunteer Energy Cooperative	Green Power Switch	biogas, solar, wind	2000	2.67¢/kWh
TX	Austin Energy	GreenChoice	wind, hydro, landfill gas	2000/ 1997	0.5¢/kWh
TX	City Public Service of San Antonio	Windtricity	wind	2000	3.0¢/kWh
TX	El Paso Electric	Renewable Energy Tariff	wind	2001	1.92¢/kWh
UT	PacifiCorp: Utah Power	Blue Sky	wind	2000	1.95¢/kWh
VT	Central Vermont Public Service	CVPS Cow Power	biogas	TBD	4¢/kWh
VT	Green Mountain Power	CoolHome, CoolBusiness	wind, biomass	2002	Contribution
WA	Avista Utilities	Buck-A-Block	wind	2002	1.82¢/kWh
WA	Benton County Public Utility District	Green Power Program	landfill gas, wind	1999	Contribution
WA	Chelan County PUD	Sustainable Natural Alternative Power (SNAP)	PV, wind, micro hydro	2001	Contribution
WA	Clallam County PUD	Green Power Rate	landfill gas	2001	0.7¢/kWh
WA	Clark Public Utilities	Green Lights	PV, wind	2002	1.5¢/kWh

WA	Cowlitz PUD	Renewable Resource Energy	wind, PV	2002	2.0¢/kWh
WA	Grant County PUD	Alternative Energy Resources Program	wind	2002	2.0¢/kWh
WA	Grays Harbor PUD	Green Power Program	wind	2002	3.0¢/kWh
WA	Lewis County PUD	Green Power Energy Rate	wind	2003	2.0¢/kWh
WA	Mason County PUD No. 3	Mason EverGreen Power	wind	2003	2.0¢/kWh
WA	Orcas Power & Light	Go Green	small hydro, wind, PV	1997	3.5¢/kWh
WA	Pacific County PUD	Green Power	wind, hydro	2002	1.05¢/kWh
WA	PacifiCorp: Pacific Power	Blue Sky	wind	2000	1.95¢/kWh
WA	Peninsula Light	Green by Choice	wind, hydro	2002	2.8¢/kWh
WA	Puget Sound Energy	Green Power	wind, solar	2002	2.0¢/kWh
WA	Seattle City Light	Seattle Green Power Program	solar, wind, biogas	2002	Contribution
WA	Snohomish County PUD	Planet Power	wind	2002	2.0¢/kWh
WA	Tacoma Power	EverGreen Options	small hydro, wind	2000	Contribution
WI	Alliant Energy	Second Nature	wind, landfill gas	2000	2.0¢/kWh
WI	Dairyland Power Cooperative: Barron Electric, Bayfield/Iron River, Chippewa/Cornell Valley, Clark/Greenwood, Dunn/Menomonie, Eau Claire/Fall Creek, Jackson/Black River Falls, Jump River/Ladysmith, Oakdale, Pierce-Pepin/Ellsworth, Polk-Burnett/Centuria, Price/Phillips, Richland, Riverland/Arcadia, St. Croix/Baldwin, Scenic Rivers/Lancaster, Taylor/Medford, Vernon/Westby	Evergreen Renewable Energy Program	wind	1997	3.0¢/kWh
WI	Great River Energy: Head of the Lakes	Wellspring	wind	1997	1.28-2.0¢/kWh
WI	Madison Gas & Electric	Wind Energy Program	wind	1999	3.33¢/kWh
WI	We Energies	Energy for Tomorrow	landfill gas, hydro, wind	1996	2.04¢/kWh
WI	Wisconsin Public Power Inc. (34 of 37 munis offer program): Algoma, Cedarburg, Florence, Kaukauna, Muscoda, Stoughton, Reedsburg, Oconomowoc, Waterloo, Whitehall, Columbus, Hartford, Lake Mills, New Holstein, Richland Center, Boscobel, Cuba City, Hustisford, Sturgeon Bay, Waunakee, Lodi, New London, Plymouth, River Falls, Sun Prairie, Waupun, Eagle River, Jefferson, Menasha, New Richmond, Prairie du Sac, Slinger, Two Rivers, Westby	Renewable Energy Program	small hydro, wind, biogas	2001	2.0¢/kWh
WI	Wisconsin Public Service	NatureWise	Wind, landfill gas, biogas	2002	2.65¢/kWh

WI	Wisconsin Public Service	SolarWise for Schools	PV installations on schools	1997	Contribution
WY	Lower Valley Energy	Green Power	wind	2003	1.67¢/kWh
WY	PacifiCorp: Pacific Power	Blue Sky	wind	2000	1.95¢/kWh
WY	Tri-State: Carbon Power & Light	Renewable Resource Power Service	wind, landfill gas	2001	2.5¢/kWh

Source: L. Bird and B. Swezey, National Renewable Energy Laboratory
http://www.eere.energy.gov/greenpower/markets/pricing.shtml?page=1



Source: L. Bird and B. Swezey, 2004.

Figure 3.8.2. Growth Trend in Utility Green Pricing Programs, 1993-2003

Table 3.8.3. Estimated Cumulative Number of Customers Participating in Utility Green Pricing Programs

Customer Segment	1999	2000	2001	2002	2003
Residential	n/a*	131,000	166,300	224,500	258,700
Nonresidential	n/a*	1,700	2,500	3,900	6,500
Total	66,900	132,700	168,800	228,400	265,000
% Nonresidential	n/a	1.3%	1.5%	1.7%	2.4%

*Information on customer segments was not collected in 1999.
Source: Bird, L., and K. Cardinal, 2004. *Trends in Utility Green Pricing Programs (2003)*, NREL/TP-620-36833. Golden, CO: National Renewable Energy Laboratory, September.
http://www.eere.energy.gov/greenpower/pdfs/36833.pdf

Table 3.8.4. Customer Participation Rates in Utility Green Pricing Programs

Participation Rate	1999	2000	2001	2002	2003
Average	0.9%	1.2%	1.3%	1.2%	1.2%
Median	0.8%	0.7%	0.7%	0.8%	0.9%
Top 10 programs	2.1%-4.7%*	2.6%-7.3%	3.0%-7.0%	3.0%-5.8%	3.9%-11.1%

*Data for April 2000
Source: Bird and Cardinal, 2004.

Table 3.8.5. Annual Sales of Green Energy through Utility Green Pricing Programs (millions of kWh)

Segment	2000	2001	2002	2003
Residential customers	---	399.7	661.3	874.1
Nonresidential customers	---	172.8	233.7	410.3
All customers	453.7	572.5	895.0	1,284.4
% Nonresidential	---	30%	26%	32%

*Sales information for customer segments not available for 2000.
Source: Bird and Cardinal, 2004.

3.9 – Renewable Energy Certificates

Renewable energy certificates (RECs)—also known as green tags, renewable energy credits, or tradeable renewable certificates—represent the environmental attributes of power generated from renewable electric plants. A number of organizations offer green energy certificates separate from electricity service (i.e., customers do not need to switch from their current electricity supplier to purchase these certificates). Organizations that offer green certificate products are listed below.

Table 3.9.1. Renewable Energy Certificate Product Offerings, July 2004

Certificate Marketer	Product Name	Renewable Resources	Location of Renewable Resources	Residential Price Premium*	Certification
3 Phases Energy Services	Green Certificates	100%new wind	Nationwide	2.0¢/kWh	Green-e
Aquila, Inc.	Aquila Green Credits (non-residential only)	100% new wind	Kansas	N/A	Green-e
Bonneville Environmental Foundation	Green Tags	≥98% new wind, ≤ 1% new solar, ≤ 1% new biomass	Washington, Oregon, Wyoming, Montana, Nevada	2.0¢/kWh	Green-e
Community Energy	New Wind Energy	100% new wind	Pennsylvania, West Virginia	2.5¢/kWh	Green-e
EAD Environmental	100% Wind Renewable Energy Certificates	100% new wind	Nationwide	1.5¢/kWh	(Green-e for non-residential only)
	Home Grown Hydro Certificates	100% small hydro (<5MW)	New England	1.2¢/kWh	(Green-e for non-residential only)
Green Mountain Energy	TRCs (non-residential only)	100% renewable	Nationwide	N/A	Green-e
Maine Interfaith Power & Light/BEF	Green Tags (supplied by BEF)	≥98% new wind, ≤ 1% new solar, ≤ 1% new biomass	Washington, Oregon, Wyoming, Montana, Nevada	2.0¢/kWh	Green-e
Maine Interfaith Power & Light	First Wind of Maine	100% wind	Maine	4.0¢/kwh	—
Maine Power Options	MPO MaineMade Certificates (non-residential only)	50% hydro, 50% biomass	Maine	NA	—

Mass Energy/People's Power and Light	New England Wind	100% new wind	Massachusetts	5.0¢/kWh	—
Mainstay Energy	Fossil Free 100% Renewable	100% renewable	Nationwide	2.0¢/kWh	Green-e
	Fossil Free 100% Wind	100% wind	Nationwide	2.5¢/kWh	Green-e
	Fossil Free 100% Solar	100% solar	Nationwide	20¢/kWh	Green-e
NativeEnergy	WindBuilders	100% new wind	South Dakota	1.0¢/kWh $10 per ton of CO2 avoided	**
	CoolHome	New biogas and new wind	Vermont and Pennsylvania (biomass), South Dakota (wind)	1.0¢/kWh $10 per ton of CO2 avoided	**
	WindBuilders Business Partners (non-residential only)	100% new wind	South Dakota Minnesota	<1.0¢/kWh <$10 per ton of CO2 avoided	**
NUON Renewables Ventures	PVUSA Solar TRCs (non-residential)	100% solar	California	NA	Green-e
Pacific Renewables, Inc	Green Tags	100% new biomass	Nebraska	~3¢/kWh ($25/month for avg. consumer)	Green-e
PG&E National Energy Group	PureWind Certificates	100% new wind	New York	4.0¢/kWh	—
Pepco Energy Services	PES Green TRC (non-residential only)	100% new renewables	Nationwide	NA	Green-e
PPM Energy	Green Tags from Wind Energy (non-residential only)	100% new wind	Nationwide	NA	Green-e
Renewable Choice Energy	American Wind	100% new wind	Nationwide	2.0-4.0¢/kWh	Green-e

Sterling Planet	Green America	45% new wind 50% new biomass 5% new solar	Nationwide	1.6¢/kWh	Green-e
Sun Power Electric	ReGen (available in New England)	99% new landfill gas, 1% new solar	New York, Massachusetts, Rhode Island	3.6¢/kWh	Green-e
Waverly Light & Power	Iowa Energy Tags	100% wind	Iowa	2.0¢/kWh	—
WindCurrent	Chesapeake Windcurrent	100% new wind	West Virginia	2.5¢/kWh - 3.0¢/kWh	Green-e
Viking Wind	Green Energy Tags (non-residential only)	100% new wind	Minnesota	NA	Green-e
Vision Quest	Green Energy (non-residential only)	100% new wind	Alberta, Canada	NA	Green-e

*Large users may be able to negotiate price premiums.
** The Climate Neutral Network certifies the methodology used to calculate the CO2 emissions offset.
NA = Not applicable.
Source: L. Bird and B. Swezey, National Renewable Energy Laboratory
http://www.eere.energy.gov/greenpower/markets/certificates.shtml?page=1

Table 3.9.2. Estimated Wholesale RECs Supplying Voluntary Markets, 2003

Segment	Retail Sales Millions of MWh	Estimated RECs Sales Millions of MWh
Utility Green Pricing	1.3	0.4
Competitive Markets	1.9	1.9
Unbundled RECs	0.7	0.7
Total Green Power Market	3.9	3.0

Source: L. Bird, NREL, 2004

Table 3.9.3. Voluntary Market REC Retirements in Texas and NEPOOL

Year	Texas Voluntary REC Retirements (MWh)	NEPOOL Voluntary REC Retirements (MWh)*
2001	N/a	0
2002	241,000	112,973
2003	797,000	56,905

Sources: ERCOT 2004; NEPOOL GIS

Table 3.9.4. Voluntary Market Wholesale REC Prices for New Sources by Type and Region ($/MWh)

Region	Wind	Solar	Biomass	Small Hydro
CA	1.75-2.00		1.50	
WECC	1.25-7.50	30.00-150.00	1.50-3.50	
Central	2.00-5.50		1.50	
PJM	15.00-17.00	80.00-200.00	4:00-5.00	
New York	15.00-16.00		6.00	
NEPOOL	35.00		45.00	5.00
SPP	2.50-5.00			
Southeast			3.50	
Sources: Evolution Markets (data for July 2003 through October 2004) and GT Energy.				

Table 3.9.5. Voluntary Market Wholesale REC Prices for Existing Sources by Type and Region ($/MWh)

Region	Biomass	Geothermal	Hydro	Small Hydro	LIHI Hydro
WECC	0.25-2.50	1.00-3.50			
Central					
PJM					
New York	2.00-5.00		2.00-3.00	1.00-3.50	
NEPOOL				2.00-4.00	6.00
Southeast					
Source: Evolution Markets. Data for July 2003 through October 2004.					

3.10 – State Incentive Programs

Many states have policies or programs in place to support renewable energy resources, such as tax incentives; industry recruitment incentives; or grant, loan, or rebate programs. The following table lists the incentives currently available by state.

Table 3.10.1. Financial Incentives for Renewable Energy Resources by State

State	Tax Incentives	Grants, Loans, Rebates and Other Incentives
AL	Wood-Burning Heating System Deduction (Personal)	Renewable Fuels Development Program (Biomass, Municipal Solid Waste)
AK		Power Project Loan Fund
AZ	Qualifying Wood Stove Deduction; Solar and Wind Energy Systems Credit (Personal); Solar and Wind Equipment Sales Tax Exemption (Personal)	APS – EPS Credit Purchase Program; TEP – SunShare PV Buydown
AR		
CA	Solar or Wind Energy System Credit – Personal; Tax Deduction for Interest on Loans for Energy Efficiency; Solar or Wind Energy System Credit – Corporate; California Property Tax Exemption for Solar Systems	Emerging Renewable (Rebate) Program; SELFGEN – SELF-Generation Program; Solar Schools Program; San Diego - Residential Solar Electric Incentive for Homes Destroyed in Wildfires; Anaheim Public Utilities – PV Buydown Program; Burbank Water & Power – Residential & Commercial Solar Support; City of Palo Alto Utilities – PV Partners; Glendale Water & Power – Solar Solutions Program; LADWP – Solar Incentive Program; Redding Electric – Vantage Renewable Energy Rebate Program; Roseville Electric – PV Buy Down Program; SMUD – Solar Water Heater Program Rebate; SMUD – PV Pioneer II Loan; SMUD – Solar Water Heater Program Loan Geothermal and PV leasing; Solar water heating; Energy technology export program; Agricultural Biomass to Energy Program; Supplemental Energy Payments (SEPs)
CO		Aspen Solar Pioneer Program - Solar Hot Water Rebate; Gunnison County Electric - Renewable Energy Resource Loan; Aspen Solar Pioneer Program - Zero-Interest Loan Colorado - Aspen - Grid-Tied Micro Hydro Production Incentive; Colorado - Aspen Solar Pioneer Program - PV Production Incentive;
CT	Local Option for Property Tax	Residential PV Rebate Program; Mainstay Energy Rewards Program - Green Tag Purchase Program; Connecticut - Commercial, Industrial, Institutional PV Grant Program; Connecticut - Fuel Cell Initiative; Connecticut - New Energy Technology Program; Energy Conservation Loan
DE		Green Energy Program Rebates;
DC		
FL	Solar Energy Equipment Exemption	Florida - Gainesville Regional Utilities - Solar Rebate Program; Florida - JEA - Solar Incentive Program
GA		

State	Tax Incentives	Grants, Loans, Rebates and Other Incentives
HI	Residential Solar and Wind Energy Credit; Corporate Solar and Wind Energy Credit	HECO, MECO, HELCO - Energy $olutions Solar Water Heater Rebate; Kauai Electric - Residential Solar Water Heating Program; Kaua'i Island Utility Cooperative - Commercial Solar Water Heating Program; Oahu - Energy $olutions Honolulu Solar Roofs Initiative Loan Program; Kauai County - Solar Water Heating Loan Program; Maui County - Maui Solar Roofs Initiative Loan Program for Solar Water Heating
ID	Solar, Wind, and Geothermal Deduction (Personal)	BEF - Renewable Energy Grant; Low-Interest Loans for Renewable Energy Resource Program
IL	Special Assessment for Renewable Energy Systems	Renewable Energy Resources Program Rebates; Chicago Photovoltaic Incentive Program (PIP); Renewable Energy Resources Program (RERP) Grants; Illinois Clean Energy Community Foundation Grants
IN	Renewable Energy Systems Exemption	Alternative Power & Energy Grant Program; Distributed Generation Grant Program (DGGP); Energy Education and Demonstration Grant Program; Energy Efficiency and Renewable Energy (EERE) Set-Aside
IA	Wind Energy Equipment Exemption; Local Option Special Assessment of Wind Energy Devices; Methane Gas Conversion Property Tax Exemption; Property Tax Exemption for Renewable Energy Systems	Grants for Energy Efficiency and Renewable Energy Research; Alternate Energy Revolving Loan Program; Iowa Building Energy Management Program (Iowa Energy Bank)
KS	Renewable Energy Property Tax Exemption	State Energy Program Grants
KY		
LA	Solar Energy System Exemption	
ME		Mainstay Energy Rewards Program - Green Tag Purchase Program; Renewable Resources Matching Fund Program
MD	Clean Energy Incentive Act (Personal Credit); Personal Income Tax Credit for Green Buildings; Clean Energy Incentive Act (Corporate Credit); Corporate Income Tax Credit for Green Buildings; Sales Tax Exemption - Fuel Cells; Wood Heating Fuel Exemption; Local Option - Corporate Property Tax Credit; Special Property Assessment	Solar Energy Grant Program; Community Energy Loan Program; State Agency Loan Program

State	Tax Incentives	Grants, Loans, Rebates and Other Incentives
MA	Alternative Energy and Energy Conservation Patent Exemption (Personal); Renewable Energy State Income Tax Credit; Alternative Energy and Energy Conservation Patent Exemption (Corporate); Solar and Wind Energy System Deduction; Solar and Wind Power Systems Excise Tax Exemption; Renewable Energy Equipment Sales Tax Exemption; Local Property Tax Exemption	Clustered PV Installation Program; Open PV Installation Program; Mainstay Energy Rewards Program - Green Tag Purchase Program; Commercial, Industrial, & Institutional Initiative Grants
MI		Community Energy Project Grants; Energy Efficiency Grants; Large-Scale PV Demonstration Project Grants; Michigan Biomass Energy Program Grants; NextEnergy Curriculum Development Grants
MN	Solar-Electric (PV) Sales Tax Exemption; Wind Sales Tax Exemption; Wind and Solar-Electric (PV) Systems Exemption	Solar-Electric (PV) Rebate Program; Solar-Electric (PV) Rebate Program; Renewable Development Fund Grants; Agricultural Improvement Loan Program for Wind Energy; Value-Added Stock Loan Participation Program Renewable Energy Production Incentives;
MS		Energy Investment Program
MO	Wood Energy Production Credit	Missouri Schools Going Solar; Energy Loan Program
MT	Residential Alternative Energy System Tax Credit; Residential Geothermal Systems Credit; Alternative Energy Investment Corporate Tax Credit; Corporate Property Tax Reduction for New/Expanded Generating Facilities; Generation Facility Corporate Tax Exemption; Renewable Energy Systems Exemption	NorthWestern Energy - PV Rebate Program; NorthWestern Energy - PV Systems for Fire Stations; NorthWestern Energy - Sun4Communities; NorthWestern Energy - USB Renewable Energy Fund; BEF - Renewable Energy Grant; Alternative Energy Revolving Loan Program
NE		Dollar and Energy Savings Loans
NV	Renewable Energy/Solar Sales Tax Exemption; Renewable Energy Producers Property Tax Exemption; Renewable Energy Systems Exemption	Solar Energy Systems Demonstration Program; Boulder City Public Works - Energy Efficient Appliance Program; Nevada Power - PV Rebate Program; Sierra Pacific Power - PV Rebate Program
NH	Local Option Property Tax Exemption for Renewable Energy	Mainstay Energy Rewards Program - Green Tag Purchase Program
NJ	Solar and Wind Energy Systems Exemption	New Jersey Clean Energy Rebate Program; Renewable Energy Advanced Power Program; Renewable Energy Economic Development Program (REED); Reduced Energy Demand Options for Local Governments and Schools (REDO)

State	Tax Incentives	Grants, Loans, Rebates and Other Incentives
NM	Renewable Energy Production Tax Credit	Clean Energy Grants Program
NY	Solar and Fuel Cell Electric Generating Equipment Tax Credit; Green Building Tax Credit Program; Solar and Wind Energy Systems Exemption	Energy $mart New Construction Program; PV Incentive Program; Wind Incentive Program; LIPA - Solar Pioneer Program; Renewables R&D Grant Program; Energy $mart Loan Fund
NC	Renewable Energy Tax Credit – Personal; Renewable Energy Tax Credit – Corporate; Active Solar Heating and Cooling Systems Exemption	Energy Improvement Loan Program
ND	Geothermal, Solar and Wind Personal Credit; Geothermal, Solar, and Wind Corporate Credit; Large Wind Sales Tax Exemption; Geothermal, Solar, and Wind Property Exemption; Large Wind Property Tax Reduction	
OH	Conversion Facilities Corporate Tax Exemption; Conversion Facilities Sales Tax Exemption; Conversion Facilities Property Tax Exemp.	Renewable Energy Loans
OK	Zero-Emission Facilities Production Tax Credit	
OR	Residential Energy Tax Credit; Business Energy Tax Credit; Renewable Energy Systems Exemption	Solar Electric Buy-down Program; Solar Water Heating Buy-down Program; Ashland - Solar Electric Program; Ashland Electric Utility - The Bright Way to Heat Water Rebate; EPUD - Solar Water Heater Program Rebate; EWEB - Energy Management Services Rebate; EWEB - The Bright Way To Heat Water Rebate; OTEC - Photovoltaic Rebate Program; New Renewable Energy Resources Grants; BEF - Renewable Energy Grant; Small Scale Energy Loan Program (SELP); Ashland Electric Utility - The Bright Way to Heat Water Loan; EPUD - Solar Water Heater Program Loan; EWEB - Energy Management Services Loan; EWEB - The Bright Way To Heat Water Loan
PA		Sustainable Development Fund Solar PV Grant Program (PECO Territory); Pennsylvania Energy Harvest Grant Program; Metropolitan Edison Company SEF Grants (FirstEnergy Territory); Penelec SEF of the Community Foundation for the Alleghenies Grant Program (FirstEnergy Territory); SEF of Central Eastern Pennsylvania Grant Program (PP&L Territory); Sustainable Development Fund Grant Program (PECO Territory); West Penn Power SEF Grant Program; Metropolitan Edison Company SEF Loans (FirstEnergy Territory); Penelec SEF of the Community Foundation for the Alleghenies Loan Program (FirstEnergy Territory); SEF of Central Eastern Pennsylvania Loan Program (PP&L Territory); Sustainable Development Fund Commercial Financing Program (PECO Territory); West Penn Power SEF Commercial Loan Program

State	Tax Incentives	Grants, Loans, Rebates and Other Incentives
RI	Renewable Energy Personal Tax Credit; Renewable Energy Sales Tax Refund; Renewable Energy Property Tax Exemption	PV & Wind Rebate Program; Small Customer Incentive Program for Green Power Marketers; Mainstay Energy Rewards Program - Green Tag Purchase Program; PV Grant for Commercial, Industrial and Institutional Buildings; RFP for Purchase/Sale of Renewable Electricity to Large Customers Renewable Generation Supply Incentive
SC		
SD	Renewable Energy Systems Exemption; Wind Energy Property Tax Exemption	
TN	Wind Energy Systems Exemption	Small Business Energy Loan Program
TX	Solar Energy Device Franchise Tax Deduction; Solar and Wind-Powered Energy Systems Exemption	Austin Energy - Home Energy Air Conditioning and Appliance Rebates; Austin Energy - Solar Rebate Program
UT	Renewable Energy Systems Tax Credit – Personal; Renewable Energy Systems Tax Credit – Corporate; Renewable Energy Sales Tax Exemption	
VT	Sales Tax Exemption	Solar & Wind Incentive Program; Mainstay Energy Rewards Program - Green Tag Purchase Program
VA	Local Option Property Tax Exemption for Solar	Virginia Small Wind Incentives Program (VSWIP);
WA	Sales and Use Tax Exemption	Clallam County PUD - Solar Rebate Program; Grays Harbor PUD - Solar Water Heating Rebate; Orcas Power & Light - Photovoltaic Rebate; Pacific County PUD - Solar Water Heater Rebate; Puget Sound Energy - Solar PV System Rebate; BEF - Renewable Energy Grant; Franklin PUD - Solar Water Heating Loan; Grays Harbor PUD - Solar Water Heating Loan
WV	Tax Exemption for Wind Energy Generation; Special Assessment for Wind Energy Systems	
WI	Solar and Wind Energy Equipment Exemption	Focus on Energy - Cash-Back Reward; Wisconsin Municipal Utility Solar Energy Cash Allowance; Focus on Energy - Grant Programs; Focus on Energy - Loan Program
WY	Renewable Energy Sales Tax Exemption	Photovoltaic Grant Program
Source: North Carolina Solar Center, Database of State Incentives for Renewable Energy, http://www.dsireusa.org/summarytables/financial.cfm?&CurrentPageID=7, July, 2004		

3.11 – Federal Agency Purchases of Green Power

In March 2004, federal agency purchases of green power reached 527 million kWh, an increase of 70% from July 2003, according to the Federal Energy Management Program (FEMP). Including renewable energy generated from on-site systems, the federal government uses 1,067 million kWh of renewable energy annually, which puts it more than three-quarters of the way toward meeting the 2.5% federal renewable energy usage goal for 2005. The federal goal was established by DOE pursuant to Executive Order 13123, which directed federal agencies to increase their use of renewable energy.

Table 4.1 – Projections of Renewable Electricity Net Capacity

(Gigawatts)

Renewable Energy	Data Sources	Projections 2005	2010	2015	2020	2025
Geothermal	AEO2005 - Reference Case	2.19	2.21	2.66	3.45	4.62
	AEO2005 - High Renewables		2.21		5.63	7.30
	EERE GPRA FY05		6.50	8.20	10.00	12.20
Wind	AEO2005 - Reference Case	8.18	8.88	9.29	10.45	11.25
	AEO2005 - High Renewables		8.88		11.63	13.97
	EERE GPRA FY05		14.60	32.30	63.90	67.70
Solar[1]	AEO2005 - Reference Case	0.61	0.98	1.14	1.60	2.72
	AEO2005 - High Renewables		0.99		1.80	3.23
	EERE GPRA FY05		2.20	5.20	13.60	26.50
Hydroelectric	AEO2005 - Reference Case	79.10	79.21	79.21	79.21	79.21
	AEO2005 - High Renewables		79.21		79.21	79.21
	EERE GPRA FY05		78.90	78.90	78.90	78.90
Biomass/Wood (excludes cogen)	AEO2005 - Reference Case	1.78	1.83	2.06	2.75	4.50
	AEO2005 - High Renewables		1.78		2.62	5.18
	EERE GPRA FY05		2.10	2.10	2.20	2.70
MSW and LFG	AEO2005 - Reference Case	3.68	3.83	3.89	3.92	3.93
	AEO2005 - High Renewables		3.83		3.96	3.97
	EERE GPRA FY05[2]		4.00	4.20	4.40	4.40
Total Renewable Energy	AEO2005 - Reference Case	100.18	102.09	103.80	107.56	112.99
	AEO2005 - High Renewables		102.42		112.37	121.57
	EERE GPRA FY05[3]		105.40	116.00	133.90	147.70

Sources: EIA *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February), Tables A16 and E7. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Projected Benefits of Federal Energy Efficiency Programs: FY2005 Budget Request,* prepared by the National Renewable Energy Laboratory, NREL/TP-620-36407 (May 2004).
Notes: OnLocation GPRA05 benefits estimates do not estimate any programmatic influence on biomass power since the biomass program has been redirected away from biomass power to integrated biorefinery technologies. Total represents portfolio case values, while individual program values represent each program case. The portfolio case accounts for program interactions and micro-price feedback effects.

[1] Solar thermal and photovoltaic energy.

[2] EERE does not have an R&D program for Biomass, LFG/MSW and thus are not included in GPRA projections
[3] Biomass, MSW and LFG are not included in the portfolio value. The portfolio values do not equal the summed values of the individual programs, as the portfolio analysis accounts for program interactions and micro-price feedback effects. Total includes biomass combined heat and power and on-site electricity-only plants for industrial and commercial sectors not detailed above.

Table 4.2 – Projections of Renewable Electricity Net Generation

(Billion Kilowatthours)

Renewable Energy	Data Sources	Projections 2005	2010	2015	2020	2025
Geothermal	AEO2005 - Reference Case	12.07	12.33	16.09	22.83	32.78
	AEO2005 - High Renewables		12.33		41.33	55.65
	EERE GPRA FY05		43.00	57.40	71.80	89.20
Wind	AEO2005 - Reference Case	23.55	25.89	27.34	31.61	34.52
	AEO2005 - High Renewables		25.89		36.15	44.60
	EERE GPRA FY05		47.10	110.70	234.40	249.80
Solar[1]	AEO2005 - Reference Case	1.08	1.94	2.32	3.35	5.70
	AEO2005 - High Renewables		1.95		3.74	6.73
	EERE GPRA FY05		2.20	8.20	22.20	33.80
Hydroelectric	AEO2005 - Reference Case	294.17	306.21	306.36	306.62	306.91
	AEO2005 - High Renewables		306.21		306.63	306.91
	EERE GPRA FY05		302.70	303.70	306.90	307.20
Biomass/Wood (without cogeneration)	AEO2005 - Reference Case	20.64	27.61	30.01	32.35	37.35
	AEO2005 - High Renewables		29.58		33.63	44.08
	EERE GPRA FY05		21.40	22.30	22.40	24.50
MSW and LFG	AEO2005 - Reference Case	26.58	27.82	28.31	28.60	28.73
	AEO2005 - High Renewables		27.82		28.96	29.11
	EERE GPRA FY05[2]		28.90	30.30	31.30	31.50
Total Renewable Energy	AEO2005 - Reference Case	408.94	435.54	446.64	465.21	489.19
	AEO2005 - High Renewables		439.72		498.09	541.58
	EERE GPRA FY05[3]		436.20	483.10	563.30	626.10

Sources: EIA Annual Energy Outlook 2005, DOE/EIA-0383 (2005) (Washington, D.C., February), Tables A16 and E7. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Projected Benefits of Federal Energy Efficiency Programs: FY2005 Budget Request, prepared by the National Renewable Energy Laboratory, NREL/TP-620-36407 (May 2004).
Notes: OnLocation GPRA05 benefits estimates do not estimate any programmatic influence on biomass power since the biomass program has been redirected away from biomass power to integrated biorefinery technologies. Total represents portfolio case values, while individual program values represent each program case. The portfolio case accounts for program interactions and micro-price feedback effects.

[1] Solar thermal and photovoltaic energy.

[2] EERE does not have an R&D program for LFG/MSW and thus are not included in GPRA projections

[3] Biomass, MSW and LFG are not included in the portfolio value. The portfolio values do not equal the summed values of the individual programs, as the porfolio analysis accounts for program interactions and micro-price feedback effects.

Table 4.3 – Projections of Renewable Electricity Carbon Dioxide Emissions Savings

(Million Metric Tons Carbon Equivalent per Year)

	Data Sources	Projections				
		2005	2010	2015	2020	2025
Renewable Energy						
Geothermal	AEO2005 - Reference Case	2.32	2.45	2.97	3.75	5.03
	AEO2005 - High Renewables		2.45		6.79	8.54
	EERE GPRA FY05		8.54	10.60	11.80	13.68
Wind	AEO2005 - Reference Case	4.53	5.14	5.05	5.19	5.30
	AEO2005 - High Renewables		5.14		5.94	6.84
	EERE GPRA FY05		9.35	20.45	38.52	38.32
Solar[1]	AEO2005 - Reference Case	0.21	0.39	0.43	0.55	0.87
	AEO2005 - High Renewables		0.39		0.61	1.03
	EERE GPRA FY05		0.44	1.51	3.65	5.18
Hydroelectric	AEO2005 - Reference Case	56.63	60.82	56.59	50.39	47.08
	AEO2005 - High Renewables		60.82		50.39	47.08
	EERE GPRA FY05		60.12	56.10	50.43	47.12
Biomass/Wood (without cogeneration)	AEO2005 - Reference Case	3.97	5.48	5.54	5.32	5.73
	AEO2005 - High Renewables		5.88		5.53	6.76
	EERE GPRA FY05		4.25	4.12	3.68	3.76
MSW and LFG	AEO2005 - Reference Case	5.12	5.53	5.23	4.70	4.41
	AEO2005 - High Renewables		5.53		4.76	4.47
	EERE GPRA FY05[2]		5.74	5.60	5.14	4.83
Total Renewable Energy	AEO2005 - Reference Case	78.72	86.51	82.50	76.45	75.04
	AEO2005 - High Renewables		87.34		81.85	83.08
	EERE GPRA FY05[3]		86.64	89.23	92.57	96.04
Heat Rate	Btu/kWh	10,796	10,593	9,019	8,266	7,891
Carbon Coefficient	MMTCE/Tbtu	0.01783	0.01875	0.02048	0.01988	0.01944

Sources: Generation data: *EIA Annual Energy Outlook 2005,* DOE/EIA-0383 (04) (Washington, D.C., February 2005), Tables A16 and F8. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Projected Benefits of Federal Energy Efficiency Programs: FY2005 Budget Request*, prepared by the National Renewable Energy Laboratory, NREL/TP-620-36407 (May 2004).

Carbon emission coefficients and heat rates: U.S. Department of Energy, GPRA2003 Data Call, Appendix B, pages B-13 and B-16, (September 14, 2001).

Notes:

Carbon Emissions Savings based on calculation: (10^9 kWh) * (Btu/kWh) * (TBtu/10^12 Btu) * (MMTCE/TBtu)

[1] Solar thermal and photovoltaic energy.

[2] EERE does not have an R&D program for LFG/MSW and thus are not included in GPRA projections

[3] Biomass, MSW and LFG are not included in the portfolio value. The portfolio values do not equal the summed values of the individual programs, as the portfolio analysis accounts for program interactions and micro-price feedback effects.

Table 5.1 – U.S. Primary and Delivered Energy – Overview

(Quadrillion Btu per year)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Primary Consumption by Source [1]									
Petroleum [2]	34.20	33.55	38.40	38.33	38.40	39.07	44.84	51.30	54.42
Natural Gas	20.39	19.74	23.91	22.90	23.65	22.51	26.11	30.73	31.47
Coal[3]	15.39	19.18	22.65	21.98	22.04	22.76	24.95	27.27	30.48
Nuclear	2.74	6.10	7.86	8.03	8.14	7.97	8.49	8.67	8.67
Renewable[4]	5.49	6.13	6.16	5.29	5.96	6.15	6.85	7.57	8.10
Other [5]	0.07	-0.03	0.06	-0.01	-0.01	-0.07	0.00	0.00	0.00
Total Primary	78.29	84.68	98.90	96.37	98.01	98.16	111.27	125.60	133.18
Primary Consumption by Sector									
Residential	15.85	17.04	20.51	20.25	20.94	21.23	23.47	25.56	26.62
Commercial	10.59	13.32	17.16	17.32	17.57	17.55	20.29	24.24	26.74
Industrial	32.15	31.89	34.68	32.53	32.86	32.52	35.47	38.19	39.53
Transportation	19.70	22.42	26.55	26.28	26.65	26.86	32.04	37.61	40.28
Total Primary[6]	78.29	84.67	98.90	96.38	98.03	98.16	111.27	125.60	133.18
Delivered Consumption by Sector									
Residential	7.50	6.60	7.20	6.91	6.95	7.24	12.67	13.80	14.26
Commercial	4.10	3.85	4.22	4.04	4.12	4.18	9.53	11.38	12.49
Industrial	22.67	21.21	22.80	21.83	22.13	21.69	27.35	29.66	30.76
Transportation	19.66	22.37	26.49	26.22	26.60	26.80	31.85	37.39	40.04
Total Delivered[6]	53.93	54.03	60.71	59.00	59.79	59.91	81.39	92.23	97.56

Sources: EIA, *Annual Energy Outlook 2005,* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A2; EIA, *Annual Energy Review 2003,* DOE/EIA-0384(2003) (Washington, D.C., September 2004), Tables 2.1a-f.

Notes:

[1] For historical figures, these values include the electric-power sector's consumption

[2] Includes natural gas plant liquids, crude oil consumed as a fuel, and non-petroleum-based liquids for blending, such as ethanol.

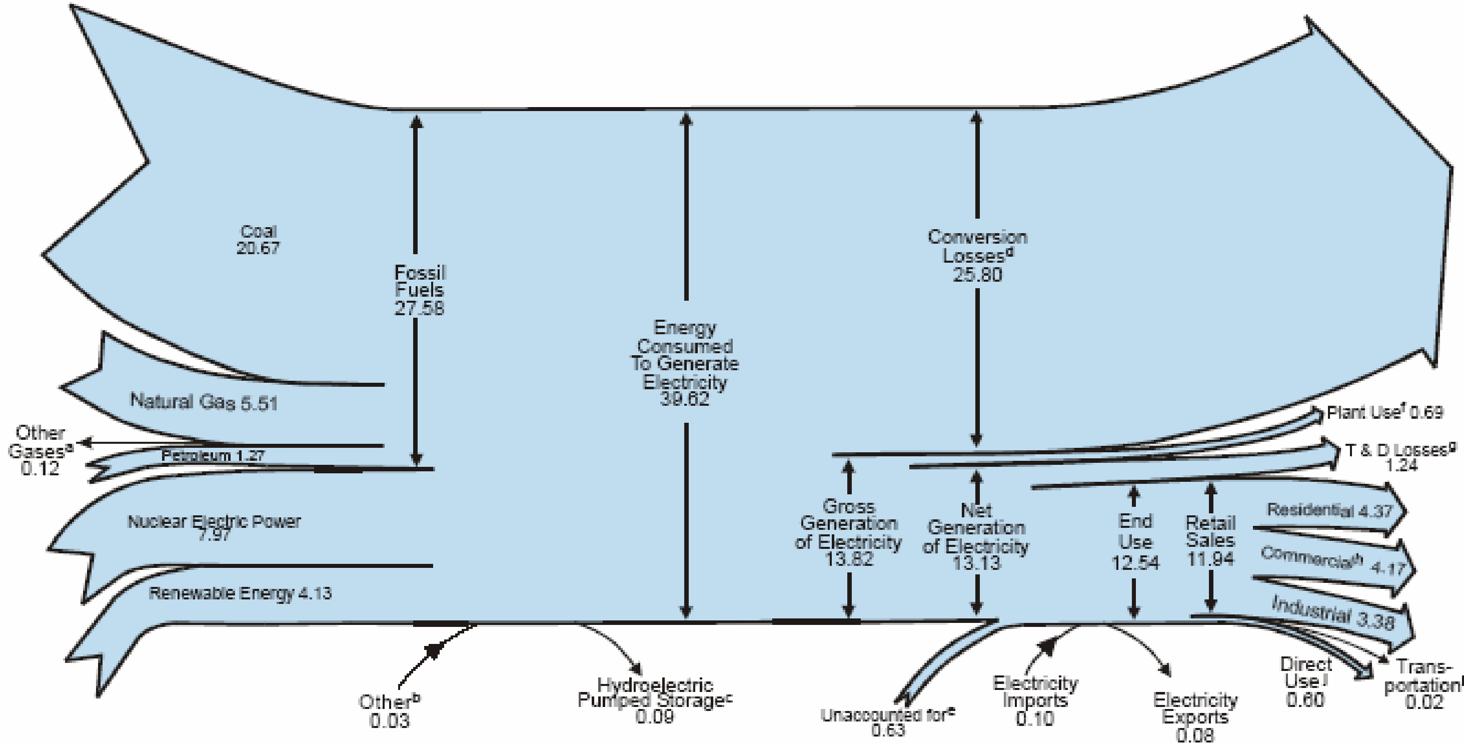
[3] Includes coal in all sectors as well as net imports of coal coke in the industrial sector

[4] Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; municipal solid waste; other biomass; wind; photovoltaic and solar thermal sources; nonelectric energy from renewable sources, such as active and passive solar systems, and wood; and both the ethanol and gasoline components of E85, but not the ethanol components of blends less than 85 percent. Excludes electricity imports using renewable sources and nonmarketed renewable energy.

[5] For historical figures, this value includes hydroelectric pumped storage and electricity net imports. For forecasted figures, this value includes only liquid hydrogen.

[6] For historical figures, this value does not include the electric-power sector's consumption

Table 5.2 – Electricity Flow Diagram (Quadrillion Btu)



Source: EIA*, Annual Energy Review,* DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Diagram 5.

Notes:

a Blast furnace gas, propane gas, and other manufactured waste gases derived from fossil fuels.

b Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

c Pumped storage facility production minus energy used for pumping.

d Approximately two-thirds of all energy used to generate electricity. See note "Electrical System Energy Losses," at end of Section 2.

e Data collection frame differences and nonsampling error.

f Electric energy used in the operation of power plants, estimated as 5 percent of gross generation. See note "Electrical System Energy Losses," at end of Section 2.

g Transmission and distribution losses (electricity losses that occur between the point of generation and delivery to the customer) are estimated as 9 percent of gross generation. See note "Electrical System Energy Losses," at end of Section 2.

h Commercial retail sales plus approximately 95 percent of "Other" retail sales from Table 8.9.

I Approximately 5 percent of "Other" retail sales from Table 8.9.

j Commercial and industrial facility use of onsite net electricity generation; and electricity sales among adjacent or co-located facilities for which revenue information is not available.

Table 5.3 – Electricity Overview

(Billion Kilowatthours, unless otherwise noted)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Electric Power Sector Generation [1]	2,286	2,901	3,638	3,580	3,698	3,691	4,273	5,011	5,432
End-Use Sector Generation	3	137	165	157	160	157	48	74	91
Total Generation	2,290	3,038	3,802	3,737	3,858	3,848	4,322	5,085	5,522
Capability (gigawatts)									
Electric Power Sector [2]	579	710	782	819	876	923	955	1,050	1,145
End Use Sector [3]	NA	24	30	29	29	30	32	39	45
Total Capability	579	734	812	848	905	953	987	1,089	1,190
Imports from Canada/Mexico	25	18	49	39	36	30	31	31	25
Exports to Canada/Mexico	4	16	15	16	14	24	22	16	14
Loss and Unaccounted for [4]	216	214	231	215	241	179	NA	NA	NA
Retail Sales [5]	2,094	2,713	3,421	3,370	3,463	3,500	4,070	4,811	5,220
Direct Use [6]	NA	114	183	174	178	175	204	229	248
Total Use	2,094	2,827	3,605	3,544	3,641	3,675	4,274	5,040	5,467

Sources: EIA, *Annual Energy Outlook 2005,* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Tables A8, A9 and A10; EIA, *Annual Energy Review 2003,* DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Tables 8.1, 8.11a, 8.11b, and 8.11d.

Notes:

[1] Electricity-only and combined-heat-and-power (CHP) plants within the NAICS 22 category whose primary business is to sell electricity, or electricity and heat, to the public. Through 1988, data are for electric utilities only; beginning in 1989, data are for electric utilities and independent power producers.

[2] Through 1988, data are for net summer capacity at electric utilities only. Beginning in 1989, data also include net summer capacity at independent power producers, commercial plants, and industrial plants. All data include electric sector combined-heat-and-power (CHP) plants beginning after 1989.

[3] Commercial and industrial combined-heat-and-power (CHP) and electricity-only plants. Data begins in 1989.

[4] Electricity losses that occur between the point of generation and delivery to the customer, and data collection frame differences and nonsampling error.

[5] Electricity retail sales to ultimate customers reported by electric utilities and other energy service providers.

[6] Commercial and industrial facility use of onsite net electricity generation; and electricity sales among adjacent or co-located facilities for which revenue information is not available.

Table 5.4 - Consumption of Fossil Fuels by Electric Generators

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Coal (million short tons) [1]	569	781	983	962	975	1,002	1,139	1,267	1,425
Distillate Fuel Oil (million barrels) [2]	29	16	30	29	22	28	68	72	77
Residual Fuel Oil (million barrels) [3]	391	183	138	159	105	137	138	156	157
Petroleum Coke (million short tons)	0.2	1.0	3.2	3.3	5.7	5.7	NA	NA	NA
Other Liquids (million barrels) [4]	NA	0.02	0.4	0.4	1.2	1.9	NA	NA	NA
Total Petroleum (million barrels) [5]	421	205	184	205	156	196	206	228	233
Natural Gas (billion cubic feet)	3,682	3,147	5,014	5,142	5,408	4,688	6,740	9,451	9,426
Stocks of Coal and Petroleum (end of year)									
Coal (million short tons)	183	156	102	138	142	121	NA	NA	NA
Petroleum (million barrels) [7]	136	84	41	57	52	52	NA	NA	NA

Sources: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Tables A2, A13 and A15; EIA, *Annual Energy Review 2003,* DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.5b and 8.8.

Notes:
Data is for electric power sector consumption only. Data include fuel consumption to produce electricity by combined heat and power plants. Through 1988, consumption data are for electric utilities only. Beginning in 1989, consumption data also include independent power producers.

[1] Anthracite, bituminous coal, subbituminous coal, lignite, waste coal, and synthetic coal.

[2] Light fuel oil (nos. 1, 2, and 4). For 1949-1979, data are for gas turbine and internal combustion plant use of petroleum. For 1980-2000, electric utility data also include small amounts of kerosene and jet fuel. Forecast values calculated from quadrillion Btu using conversion factor 5.825 MMBtu/barrel.

[3] Heavy fuel oil (nos. 5 and 6). For 1949-1979, data are for steam plant use of petroleum. For 1980-2000, electric utility data also include a small amount of fuel oil no. 4. Forecast values calculated from quadrillion Btu using conversion factor 6.287 MMBtu/barrel.

[4] Jet fuel, kerosene, other petroleum liquids, and waste oil.

[5] Petroleum coke is converted from short tons to barrels by multiplying by 5. In forecasted values, total petroleum is calculated sum.

[6] Through 1998, data are for electric utilities only. Beginning in 1999, data are for electric utilities and independent power producers.

[7] Includes distillate fuel oil, residual fuel oil, other liquids and petroleum coke.

Table 5.5 – Electric Power Sector Energy Consumption

(Trillion Btu)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Coal	12,123	16,235	20,185	19,494	19,733	20,419	22,812	25,279	28,544
Natural Gas	3,810	3,224	5,120	5,271	5,522	4,805	6,874	9,640	9,615
Petroleum	2,634	1,281	1,145	1,270	955	1,200	1,263	1,400	1,432
Other Gas [1]	NA	6	19	9	25	13	NA	NA	NA
Total Fossil Fuels	18,567	20,746	26,470	26,044	26,235	26,437	30,949	36,320	39,591
Nuclear Electric Power	2,739	6,104	7,862	8,033	8,143	7,973	8,490	8,666	8,666
Hydroelectric Pumped Storage [2]	---	-36	-57	-90	-88	-88	NA	NA	NA
Conventional Hydroelectric	2,867	3,014	2,768	2,169	2,636	2,722	3,084	3,083	3,083
Wood	3	106	126	116	141	152	323	365	399
Waste	2	180	294	314	353	336	344	353	354
Geothermal	110	326	296	289	305	276	271	607	925
Solar [3]	NA	4	5	6	6	5	11	17	20
Wind	NA	29	57	68	105	108	266	325	355
Total Renewable Energy	2,982	3,658	3,547	2,962	3,545	3,600	4,299	4,750	5,136
Electricity Imports	71	8	115	75	78	22	31	52	38
Other [4]	NA	0.08	1.28	0.00	6.96	1.37	NA	NA	NA
Total Primary Consumption	24,359	30,481	37,939	37,024	37,919	37,945	43,769	49,789	53,431

Sources: EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.4b and EIA, *Annual Energy Outlook 2005,* DOE/EIA-0383 (20045 (Washington, D.C., February 2005), Tables A2 and A17.

Notes:

Data are for fuels consumed to produce electricity at both electricity-only and at combined heat and power plants. Through 1988, data are for consumption at electric utilities only. Beginning in 1989, data also include consumption at independent power producers.

[1] Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels.
[2] Pumped storage facility production minus energy used for pumping. 1980 data included in Conventional Hydroelectric.
[3] Solar thermal and photovoltaic energy.
[4] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.
NA = Not Available

Table 5.6 – Fossil Fuel Generation by Age of Generating Units

(Megawatts)

	1980	1990	2000	2001	2002	2003	2004
<5 years	91,001	39,870	54,274	90,877	155,534	204,504	218,854
6-10 years	136,236	54,270	44,042	42,164	37,735	33,121	33,234
11-20 years	145,618	224,879	92,854	87,057	82,977	83,140	81,085
21-30 years	99,223	143,868	221,690	210,982	196,464	175,461	156,694
31-40 years	21,042	93,450	141,055	155,292	172,139	188,274	205,136
41-50 years	4,023	14,701	86,582	91,321	94,204	95,560	93,156
>50 years	4,232	2,566	11,634	15,259	18,161	24,487	33,967
Total	501,376	573,603	652,129	692,952	757,214	804,546	822,128

Source: *PowerDat*, © 2005, Platts, a division of the McGraw-Hill companies. Query by NREL 3/05.
Notes:
Total MW does not equal fossil fuel-generation capacity cited in Table 6.1.
Capacity reported in this table is nameplate capacity

Table 5.7 – Nuclear Generation by Age of Generating Units

(Megawatts)

	1980	1990	2000	2001	2002	2003	2004
<5 years	16,289	30,408	1,270	0	0	0	0
6-10 years	33,989	25,628	1,215	2,485	2,485	1,270	1,270
11-20 years	6,413	48,929	56,036	51,537	49,189	47,200	40,278
21-30 years	309	6,073	44,597	46,859	43,105	41,420	39,315
31-40 years	0	0	4,095	6,332	12,435	17,324	26,351
Total	57,000	111,039	107,214	107,214	107,214	107,214	107,214

Source: *PowerDat*, © 2005, Platts, a division of the McGraw-Hill companies. Query by NREL 3/05.

Notes:

Total MW does not equal nuclear generation capacity cited in Table 6.1.

Capacity reported in this table is nameplate capacity

Table 5.8 – Operational Renewable Energy Generating Capacity

(Megawatts)

	1980	1990	2000	2001	2002	2003 [1]
Agricultural Residues[2]	40	165	373	373	373	373
BioGas[3]	18	361	933	999	1,030	1,053
Municipal Solid Waste[4]	263	2,172	2,970	2,970	2,970	3,000
Timber Residues[5]	3,576	6,305	7,447	7,458	7,497	7,497
Bioenergy Total [6]	3,897	9,003	11,722	11,800	11,869	11,922
Geothermal	802	2,540	2,779	2,779	2,779	2,779
Photovoltaic [7]	0.025	4.170	27.645	38.452	59.703	67.710
Solar Thermal	0	274	354	354	354	354
Hydro [8]	80,491	90,955	94,324	94,335	94,335	94,356
Wind	0.06	1,569	2,780	4,623	5,078	5,090
Total	85,190	104,344	111,987	113,930	114,475	114,569

Source: Renewable Electric Plant Information System (REPiS Database), Version 7, National Renewable Energy Laboratory, 2003, http://www.nrel.gov/analysis/repis/.

Notes:

Totals do not equal renewable generation capacity cited in Table 6.1.

[1]2003 data is preliminary; it is not verified at time of Data Book release

[2]Agricultural residues, cannery wastes, nut hulls, fruit pits, nut shells

[3]Biogas, alcohol (includes butahol, ethanol, and methanol), bagasse, hydrogen, landfill gas, livestock manure, wood gas (from wood gasifier)

[4]Municipal solid waste (includes industrial and medical), hazardous waste, scrap tires, wastewater sludge, refused-derived fuel

[5]Timber and logging residues (Includes tree bark, wood chips, saw dust, pulping liquor, peat, tree pitch, wood or wood waste)

[6] There are an additional 65.45 MW of ag waste, 5.445 MW of bio gas, and 483.31 MW of wood residues that are not accounted for here because they have no specific online date.

[7] There are an additional 3.4 MW of photovoltaic capacity that are not accounted for here because they have no specific online date.

[8] There are an additional 24 MW of hydroelectric capacity that are not accounted for here because they have no specific online date.

Table 5.9 – Number of Utilities by Class of Ownership and Nonutilities

	1980	1990	1999	2000	2002	2003
Investor Owned Utilties	240	266	239	240	217	219
Federally Owned Utilities	41	10	9	9	12	12
Cooperatively Owned Utilities[1]	936	951	900	894	889	895
Other Publicly Owned Utilities	1,753	2,010	2,012	2,009	1,870	1,886
Total Number of Utilities	2,970	3,237	3,160	3,152	2,988	3,012
Nonutilities			1,930		511	617

Source: EIA, *The Changing Structure of the Electric Power Industry 2000: An Update*; UDI/Platts Energy, *Platts directory of electric power producers and distributors 109th edition*, The McGraw-Hill Companies.

Notes:
[1] Co-ops operate in all states except Connecticut, Hawaii, Rhode Island, and the District of Columbia

Note: 2001 data is not reported, but is available from the publishers (Platts)

Table 5.10 – Top 10 Investor-Owned Utilities

Utility by Sales (Million kWh)	1990		2000		2001		2002		2003	
	Rank	Million kWh	Rank	Million kWh	Rank	Million kWh	Rank	Million kWh	Rank	Million kWh
Florida Power & Light Co.	5	65,222	2	88,128	2	90,495	1	95,543	1	99,339
TXU Electric Co.	1	78,340	1	100,885	1	102,526	2	90,522	2	79,050
Georgia Power Co.	8	53,953	4	74,434	5	72,545	3	75,432	3	75,018
Duke Energy Corp	7	58,359	9	53,726	4	72,977	4	75,362	4	73,763
Virginia Electric & Power Co.	9	52,122	8	65,294	7	67,858	6	71,477	5	72,197
Commonwealth Edison Co.	2	70,852	3	77,176	3	76,918	5	73,835	6	68,384
Southern California Edison Co.	4	70,063	6	73,686	8	52,034	7	54,391	7	52,229
Alabama Power Co.	12	38,081	10	52,068	9	49,338	8	52,073	8	52,208
PacifiCorp	10	40,288	43	18,859	11	47,708	11	47,030	9	48,339
Pacific Gas & Electric Co.	3	70,597	7	72,121	12	46,680	9	49,830	10	47,881
Detroit Edison Co	11	39,674	11	50,131	10	48,089	10	48,346	11	43,672
Reliant Energy HL&P	6	58,583	5	73,716	6	69,839	16	35,423	17	34,694

Utility by Revenue (Million $)	1990		2000		2001		2002		2003	
	Rank	Million $	Rank	Million $	Rank	Million $	Rank	Million $	Rank	Million $
Florida Power & Light Co.	4	4,803	4	6,065	3	7,302	2	7,028	1	7,952
Southern California Edison Co.	1	6,767	1	7,416	1	7,782	1	7,848	2	6,845
TXU Electric Co.	6	4,200	3	6,433	2	7,748	4	6,520	3	6,437
Pacific Gas & Electric Co.	2	6,513	2	6,988	4	7,171	3	6,821	4	6,369
Consolidated Edison Co-NY Inc.	5	4,385	6	5,286	6	5,622	6	4,874	5	5,380
Commonwealth Edison Co.	3	5,668	5	5,723	5	5,703	5	5,457	6	5,123
Virginia Electric & Power Co.	10	3,299	9	4,022	7	4,340	7	4,611	7	4,665

Duke Energy Corp	7	3,681	12	3,151	9	4,159	8	4,345	8	4,335
Georgia Power Co.	9	3,426	8	4,283	8	4,305	9	4,288	9	4,310
Public Service Electric&Gas Co.	11	3,262	11	3,247	11	3,563	10	3,639	10	3,518
Reliant Energy HL&P	8	3,436	7	4,743	10	5,622	14	2,898	11	3,437
Detroit Edison Co.	12	3,187	10	3,834	12	3,511	11	3,494	13	3,193

Source: EIA, *Electric Sales and Revenue*, DOE/EIA -0540 (00) (Washington, D.C., December 2003), Table 17.

Table 5.11 – Top 10 Independent Power Producers Worldwide

(Megawatts)

Company	2002 Capacity (MW)	2003 Capacity (MW)
Tractebel Electricity & Gas Int'l	50,000	48,317
ENEL SpA.	46,456	45,744
AES	55,660	44,917
Entergy Wholesale Operations	21,323	30,000
Calpine	19,319	29,891
Dominion Generation	23,830	24,408
Mirant	22,100	23,254
NRG Energy	20,954	21,200
Reliant	22,349	19,442
Edison Mission Energy	18,688	18,733

Source: Company 10K SEC filings at http://www.sec.gov/ accessed 7/04

Table 5.12 – Utility Mergers and Acquisitions

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Pending
Mergers/Acquisitions																		
IOU-IOU	4	1	2	1	7	4	1	3	1	5	10	4	10	3	7	2	2	2
Co-op-Co-op	4	3	2	2	7	2	1	4	2	13	15	15	3	3		2		
IOU-Co-op				1	2			1		1					1			
IOU-Gas [1]									1	5	4	3	6	1				
Muni-Muni								1				2				1	1	
Muni-Co-op										1			1					
Power Authority-IOU											1							
Nonutility-IOU													6	1		3		1
Nonutility-Muni																1		
Foreign-IOU [2]												2	1	3	1			
Total	8	4	4	4	16	6	2	9	4	25	30	26	27					
Related Activities																		
Name Changes									5	2	7	11	1	4	6	3	3	
New Holding Company										1	5	4	2	3		2	2	
Moved Headquarters						1												
Ceased Operations											1					1		

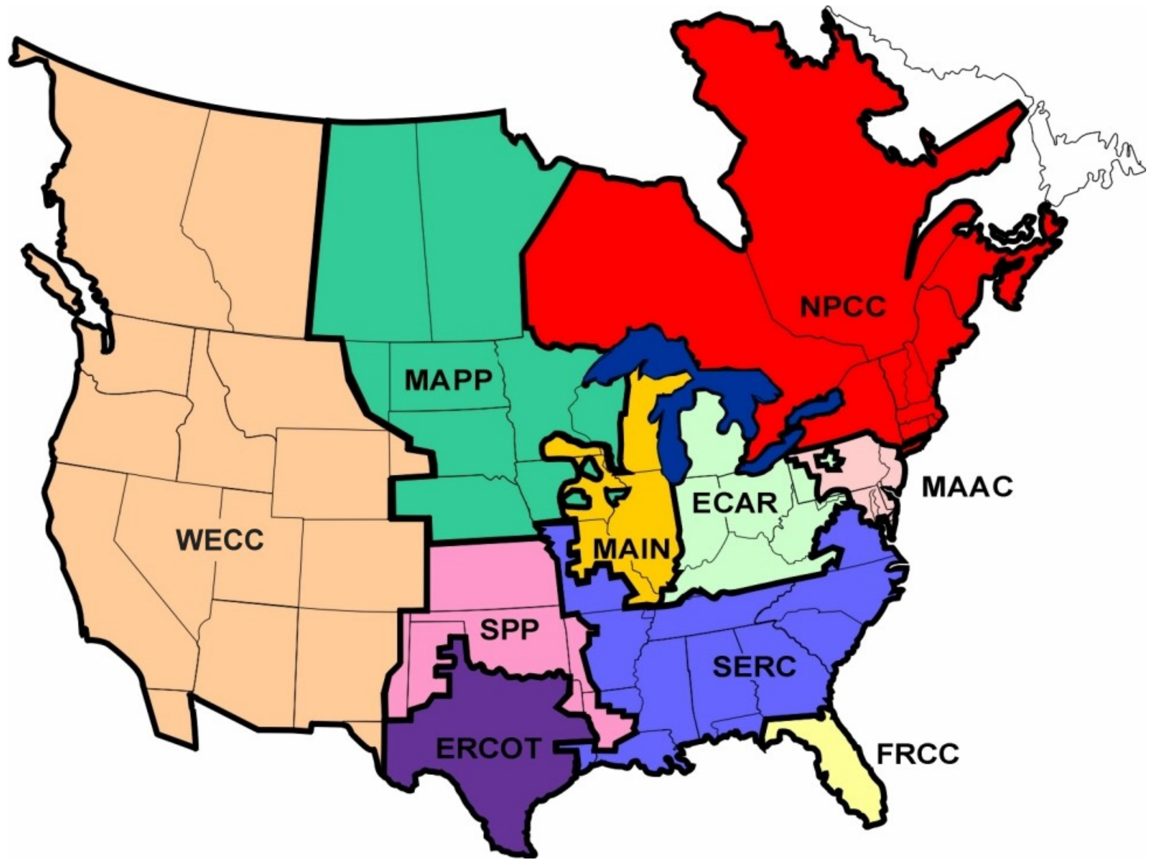
Source: Calculated from UDI/Platts Energy, *Platts directory of electric power producers and distributors 109th edition*, The McGraw-Hill Companies

Notes:

[1] Gas local distribution company, pipeline, or developer

[2] Excludes Canadian mergers and acquisitions. Includes foreign acquisition of U.S. companies

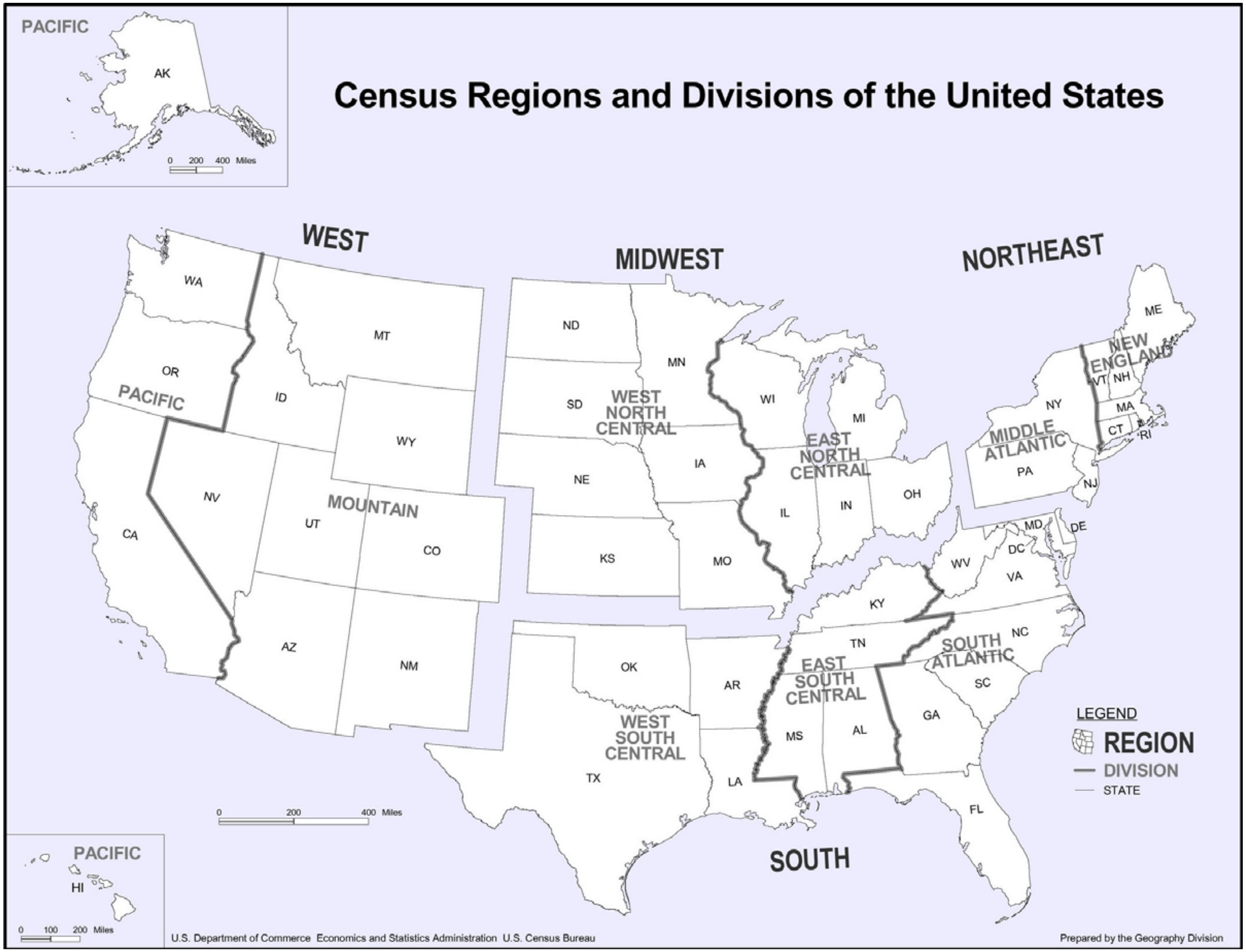
Table 5.13a – North American Electric Reliability Council Map for the United States



ECAR	**ECAR East Central Area Reliability Coordination Agreement**	**NPCC**	**Northeast Power Coordinating Council**
ERCOT	**Electric Reliability Council of Texas**	**SERC**	**Southeastern Electric Reliability Council**
FRCC	**Florida Reliability Coordinating Council**	**SPP**	**Southwest Power Pool**
MAAC	**Mid-Atlantic Area Council**	**WECC**	**Western Electricity Coordinating Council**
MAIN	**Mid-Atlantic Interconnected Network**	**ASCC**	**Alaskan Systems Coordinating Council**
MAPP	**Mid-Continent Area Power Pool**		

Source: North American Electric Reliability Council, www.nerc.com

Table 5.13b – Census Regions



Source: U.S. Department of Commerce, Bureau of the Census, www.census.gov

Table 6.1 – Electric Net Summer Capability (All Sectors)

(Gigawatts)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Coal [1]	NA	307.4	315.1	314.2	315.4	315.4	313.8	343.8	398.4
Petroleum/Natural Gas [2]	NA	220.4	283.8	320.7	374.2	421.3	448.5	510.6	547.2
Total Fossil Energy	444.1	527.8	598.9	634.9	689.5	736.7	762.3	854.4	945.6
Nuclear	51.8	99.6	97.9	98.2	98.7	98.8	100.6	102.7	102.7
Hydroelectric Pumped Storage [3]	NA	19.5	19.5	19.1	20.4	20.4	20.9	20.9	20.9
Conventional Hydroelectric	81.7	73.9	79.4	79.5	79.4	79.4	79.2	79.2	79.2
Geothermal	0.9	2.7	2.8	2.2	2.3	2.3	2.2	3.4	4.6
Wood [4]	0.1	5.5	6.1	5.9	5.8	5.9	7.0	8.9	11.3
Waste [5]	NA	2.5	3.9	3.8	3.8	3.9	3.8	3.9	3.9
Solar Thermal and Photovoltaic	NA	0.3	0.4	0.4	0.4	0.4	1.0	1.6	2.7
Wind	NA	1.8	2.4	3.9	4.4	4.9	8.9	10.4	11.3
Total Renewable Energy	82.7	86.8	94.9	95.7	96.1	96.7	102.1	107.6	113.0
Other [6]	NA	0.5	0.5	0.4	0.6	0.6	0.7	0.7	0.7
Total Electric Capability	578.6	734.1	811.7	848.3	905.3	953.2	986.6	1086.2	1182.8

Sources: EIA, *Annual Energy Outlook 2005* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Tables A9, A16; EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.11a.

Notes:
Data include electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Through 1988, data are for net summer capacity at electric utilities only. Beginning in 1989, data also include net summer capacity at independent power producers and the commercial and industrial (end-use) sectors.

[1] Anthracite, bituminous coal, subbituminous coal, lignite, waste coal, and synthetic coal.

[2] Petroleum, natural gas, distillate fuel oil, residual fuel oil, petroleum coke, jet fuel, kerosene, other petroleum, waste oil, supplemental gaseous fuels, blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels. Includes natural gas fired distributed generation.

[3] Pumped storage included in Conventional Hydro prior to 1989.

[4] Wood, black liquor, and other wood waste. Includes projections for energy crops after 2010. Includes other biomass in projections.

[5] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass. Waste included in Wood prior to 1985.

[6] Includes batteries, chemicals, hydrogen, pitch, sulfur, purchased steam, fuel cells, and miscellaneous technologies.

NA = Not Available

Table 6.2 – Electricity-Only Plant Net Summer Capability

(Gigawatts)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Coal [2]	NA	299.9	305.2	305.2	305.8	305.5	304.6	334.6	389.2
Petroleum/Natural Gas [3]	NA	198.7	243.9	279.4	324.6	370.3	388.8	447.8	484.4
Total Fossil Energy	NA	498.6	549.0	584.5	630.4	675.8	693.4	782.5	873.6
Nuclear	NA	99.6	97.9	98.2	98.7	98.8	100.6	102.7	102.7
Hydroelectric Pumped Storage [4]	NA	19.5	19.5	19.1	20.4	20.4	20.9	20.9	20.9
Conventional Hydroelectric	NA	73.3	78.2	78.4	78.3	78.3	78.2	78.2	78.2
Geothermal	NA	2.7	2.8	2.2	2.3	2.3	2.2	3.4	4.6
Wood [5]	NA	1.0	1.5	1.5	1.4	1.4	1.8	2.8	4.5
Waste [6]	NA	1.9	2.8	3.0	2.9	3.0	3.6	3.7	3.7
Solar Thermal and Photovoltaic	NA	0.3	0.4	0.4	0.4	0.4	0.6	0.8	0.9
Wind	NA	1.8	2.4	3.6	4.4	4.9	8.9	10.4	11.3
Total Renewable Energy	NA	80.9	88.1	89.1	89.7	90.2	95.3	99.3	103.1
Other	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Electric Capability [7]	NA	698.6	754.5	790.8	839.2	885.2	910.1	1005.3	1100.2

Sources: EIA, *Annual Energy Outlook 2005* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Tables A9, A16; EIA, *Annual Energy* Review 2003, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.11c.

Notes:

Data are for electricity-only plants in the electric power sector whose primary business is to sell electricity to the public. Through 1988, data are for net summer capacity at electric utilities only. Beginning in 1989, data also include net summer capacity at independent power producers.

[1] Anthracite, bituminous coal, subbituminous coal, lignite, waste coal, and synthetic coal.

[2] Petroleum, natural gas, distillate fuel oil, residual fuel oil, petroleum coke, jet fuel, kerosene, other petroleum, waste oil, supplemental gaseous fuels, blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels. Includes natural gas fired distributed generation.

[3] Pumped storage included in Conventional Hydro prior to 1989.

[4] Wood, black liquor, and other wood waste. Includes projections for energy crops after 2010. Includes other biomass in projections.

[5] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass. Waste included in Wood prior to 1985.

[6] Includes batteries, chemicals, hydrogen, pitch, sulfur, purchased steam, fuel cells, and miscellaneous technologies.

NA = Not Available

Table 6.3 – Combined-Heat-and-Power Plant Net Summer Capability

(Gigawatts)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Coal [2]	NA	2.4	5.0	4.6	5.2	5.7	5.1	5.0	5.0
Petroleum/Natural Gas [3]	NA	8.3	21.9	22.5	30.8	31.5	39.7	39.7	39.7
Total Fossil Energy	NA	10.7	26.9	27.1	36.1	37.2	44.8	44.7	44.7
Nuclear	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hydroelectric Pumped Storage	NA	NA	NA	NA	NA	NA	NA	NA	NA
Conventional Hydroelectric	NA	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Geothermal	NA	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00
Wood [4]	NA	0.2	0.2	0.1	0.1	0.2	0.00	0.00	0.00
Waste [5]	NA	0.2	0.5	0.4	0.4	0.4	0.00	0.00	0.00
Solar Thermal and Photovoltaic	NA	NA	NA	NA	NA	NA	0.00	0.00	0.00
Wind	NA	0.0	0.0	0.3	0.0	0.0	NA	NA	NA
Total Renewable Energy	NA	0.5	0.7	0.8	0.6	0.6	0.3	0.3	0.3
Other	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Electric Capability [6]	NA	11.2	27.7	27.9	36.6	37.8	45.1	45.0	45.0

Sources: EIA, *Annual Energy Outlook 2005* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Tables A9, A16; EIA, *Annual Energy* Review 2003, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.11c.

Notes:

Includes combined-heat-and-power (CHP) plants whose primary business is to sell electricity and heat to the public. For 1989-2001, does not include electric utility CHP plants—these are included in "Electricity-Only Plant Capability " in Table 6.2. Also includes commercial and industrial CHP and a small number of commercial electricity-only plants.

[1] Anthracite, bituminous coal, subbituminous coal, lignite, waste coal, and synthetic coal.

[2] Petroleum, natural gas, distillate fuel oil, residual fuel oil, petroleum coke, jet fuel, kerosene, other petroleum, waste oil, supplemental gaseous fuels, blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels. Includes natural gas fired distributed generation.

[3] Pumped storage included in Conventional Hydro prior to 1989.

[4] Wood, black liquor, and other wood waste. Includes projections for energy crops after 2010. Includes other biomass in projections.

[5] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass. Waste included in Wood prior to 1985.

[6] Includes batteries, chemicals, hydrogen, pitch, sulfur, purchased steam, fuel cells, and miscellaneous technologies.

NA = Not Available

Table 6.4 – Regional Noncoincident [1] Peak Loads

(Megawatts, except as noted)

North American Electric Reliability Council Regions	1990	2000	2001	2002	2003	1990	2000	2001	2002	2003
	Summer Peak					Winter Peak				
ECAR	79,258	92,033	100,235	102,996	100,714	67,097	84,546	85,485	87,300	86,120
ERCOT	42,737	57,606	55,201	56,248	57,639	35,815	44,641	44,015	45,414	46,538
FRCC	NA	37,194	39,062	40,696	41,618	NA	38,606	40,922	45,635	44,266
MAAC	42,613	49,477	54,015	55,569	56,257	36,551	43,256	39,458	46,551	44,748
MAIN	40,740	52,552	56,344	56,396	57,169	32,461	41,943	40,529	42,412	42,332
MAPP (U.S.)	24,994	28,605	28,321	29,119	29,957	21,113	24,536	21,815	23,645	24,148
NPCC (U.S.)	44,116	50,057	55,949	56,012	56,550	40,545	43,852	42,670	46,009	46,903
SERC	121,943	156,088	149,293	158,767	157,864	117,448	139,146	135,182	141,882	138,291
SPP	52,541	40,199	40,273	39,688	40,564	38,949	30,576	29,614	30,187	29,891
WECC[2] (U.S.)	97,389	114,602	109,119	119,074	119,320	94,252	97,324	96,622	95,951	105,492
Contiguous U.S.	546,331	678,413	687,812	714,565	717,652	484,231	588,426	576,312	604,986	608,729
ASCC (Alaska)	463	NF	NF	NF	NF	613	NF	NF	NF	NF
Hawaii	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
U.S. Total	546,794	678,413	687,812	714,565	717,652	484,844	588,426	576,312	604,986	608,729
Capacity Margin (%) [3]	21.6	15.7	14.5	16.4	19.8	NA	29.5	28.9	29.4	32.8

Source: EIA, *Annual Energy Review 2003,* DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.12.

Notes:

NF = data not filed

NA = Not Applicable

2003 data are forecast estimates.

[1] Noncoincident peak load is the sum of two or more peak loads on individual systems that do not occur at the same time interval.

[2] Renamed from WSCC in 2002

[3] The percent by which planned generating capacity resources are expected to be greater (or less) than estimated net internal demand at the time of expected peak summer (or winter) demand. Net internal demand does not include estimated demand for direct control load management and customers with interruptible service agreements.

Table 6.5 – Electric Generator Cumulative Additions and Retirements

(Gigawatts) [1]

	2010	2020	2025
Cumulative Planned Additions			
Coal Steam	1.8	1.8	1.8
Other Fossil Steam [2]	0.0	0.0	0.0
Combined Cycle	28.3	28.3	28.3
Combustion Turbine/Diesel	3.9	3.9	3.9
Nuclear	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0
Renewable Sources [3]	2.7	2.9	3.0
Distributed Generation [4]	0.0	0.0	0.0
Total Planned Additions	36.7	36.9	37.0
Cumulative Unplanned Additions			
Coal Steam	0.0	30.6	85.1
Other Fossil Steam [2]	0.0	0.0	0.0
Combined Cycle	3.5	44.2	56.8
Combustion Turbine/Diesel	5.9	47.4	69.9
Nuclear	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0
Renewable Sources [3]	0.2	4.0	7.7
Distributed Generation [4]	0.4	3.1	6.9
Total Unplanned Additions	9.9	129.1	226.4
Cumulative Retirements			
Coal Steam	2.4	3.0	3.0
Other Fossil Steam [2]	9.3	28.6	29.2
Combined Cycle	0.1	0.4	0.4
Combustion Turbine/Diesel	1.9	8.1	9.9
Nuclear	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0
Renewable Sources [3]	0.1	0.1	0.1
Total Retirements	13.8	40.1	42.6

Sources: EIA, *Annual Energy Outlook 2005,* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A9.

Notes:

[1] Additions and retirements since December 31, 2001.

[2] Includes oil-, gas-, and dual-fired capability.

[3] Includes conventional hydroelectric, geothermal, wood, wood waste, municipal solid waste, landfill gas, other
biomass, solar, and wind power.

[4] Primarily peak load capacity fueled by natural gas.

Table 6.6 – Transmission and Distribution Circuit Miles

(Miles) [1]

Voltage (kilovolts)	1980	1990	1999	2000 [2]	2001 [2]	2002 [2]	2003 [2]
230	NA	70,511	76,762	76,437	80,515	81,252	82,238
345	NA	47,948	49,250	51,025	53,855	54,827	54,195
500	NA	23,958	26,038	25,000	27,343	27,587	27,407
765	NA	2,428	2,453	2,426	2,518	2,560	2,560
Total	NA	144,845	154,503	154,888	164,231	166,226	166,400

Sources: EIA, *Electricity Transmission Fact Sheets*, http://www.eia.doe.gov/cneaf/electricity/page/fact_sheets/transmission.html; NERC, *Electricity Supply and Demand Database*, 2003, http://www.nerc.com/~esd/Brochure.pdf

Notes:

[1] Circuit miles of AC lines 230 kV and above.

[2] Data includes both existing and planned transmission lines

Table 7.1 – Electricity Net Generation

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Coal [1]	1,162	1,594	1,966	1,904	1,933	1,970	2,223	2,494	2,890
Petroleum [2]	246	127	111	125	95	118	126	143	148
Natural Gas [3]	346	373	601	639	691	629	922	1,374	1,403
Other Gases [4]	N/A	10	14	9	11	11	4	5	5
Total Fossil Energy	1,754	2,104	2,692	2,677	2,730	2,729	3,276	4,016	4,446
Nuclear	251	577	754	769	780	764	813	830	830
Hydroelectric Pumped Storage[5]	N/A	-4	-6	-9	-9	-9	-9	-9	-9
Conventional Hydroelectric [6]	279	293	276	217	264	275	306	307	307
Geothermal	5	15	14	14	14	13	12	23	33
Wood [7]	0	33	38	35	39	37	61	72	81
Waste [8]	0	13	23	22	23	23	28	29	29
Solar Thermal and Photovoltaic	N/A	0	0	1	1	1	2	3	6
Wind	N/A	3	6	7	10	11	26	32	35
Total Renewable Energy	285	357	356	295	351	359	436	465	489
Generation for Own Use [9]	N/A	N/A	N/A	N/A	N/A	N/A	-204	-229	-248
Other [10]	N/A	4	5	5	6	5	10	10	10
Total Electricity Generation	2,290	3,038	3,802	3,737	3,858	3,848	4,526	5,313	5,767

Sources: EIA, Annual Energy Review 2003, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.2a, and EIA, Annual Energy Outlook 2005, DOE/EIA-0383(2005) (Washington, D.C., February 2005), Tables A8 and A16.

Notes:

Data include electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Through 1988, data are for generation at electric utilities only. Beginning in 1989, data also include generation at independent power producers and the commercial and industrial (end-use) sectors.

[1] Anthracite, bituminous coal, subbituminous coal, lignite, waste coal, and synthetic coal.

[2] Distillate fuel oil, residual fuel oil, petroleum coke, jet fuel, kerosene, other petroleum, and waste oil.

[3] Natural gas, including a small amount of supplemental gaseous fuels. Forecast data Include electricity generation from fuel cells.

[4] Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels, including refinery and still gas.

[5] Pumped storage facility production minus energy used for pumping. Data for 1980 included in conventional hydroelectric power.

[6] Hydroelectric data through 1988 are for generation at electric utilities and industrial plants only; beginning in 1989, data also include generation at independent power producers and commercial plants.

[7] Wood, black liquor, and other wood waste.

[8] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass.

[9] Includes nonutility and end-use sector generation for own use.

[10] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Table 7.2 – Net Generation at Electricity-Only Plants

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Coal [1]	1,162	1,560	1,911	1,852	1,881	1,916	2,169	2,440	2,836
Petroleum [2]	246	118	98	113	83	106	112	124	128
Natural Gas [3]	346	265	399	427	457	406	634	1,038	1,048
Other Gases [4]	N/A	0	0	0	0	0	N/A	N/A	N/A
Total Fossil Energy	1,754	1,942	2,408	2,392	2,422	2,428	2,915	3,602	4,012
Nuclear	251	577	754	769	780	764	813	830	830
Hydroelectric Pumped Storage[5]	N/A	-4	-6	-9	-9	-9	-9	-9	-9
Conventional Hydroelectric [6]	276	290	271	214	260	269	300	301	301
Geothermal	5.1	15	14	14	14	13	12	23	33
Wood [7]	0.3	6	7	7	7	7	28	32	37
Waste [8]	0	10	18	17	17	17	26	26	26
Solar Thermal and Photovoltaic	N/A	0	0	1	1	1	1	2	2
Wind	N/A	3	6	7	10	11	26	32	35
Total Renewable Energy	282	324	316	259	311	318	393	416	434
Other [9]	N/A	0	0	0	1	0	N/A	N/A	N/A
Total Electricity Generation	2,286	2,840	3,473	3,411	3,505	3,501	4,112	4,839	5,267

Sources: EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.2c, and EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383(2005) (Washington, D.C., February 2005), Tables A8 and A16.

Notes:
Data are for electricity-only plants in the electric power sector whose primary business is to sell electricity to the public. Through 1988, data are for generation at electric utilities only. Beginning in 1989, data also include generation at independent power producers.

[1] Anthracite, bituminous coal, subbituminous coal, lignite, waste coal, and synthetic coal.

[2] Distillate fuel oil, residual fuel oil, petroleum coke, jet fuel, kerosene, other petroleum, and waste oil.

[3] Natural gas, including a small amount of supplemental gaseous fuels. Forecast data Include electricity generation from fuel cells.

[4] Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels, including refinery and still gas.

[5] Pumped storage facility production minus energy used for pumping. Data for 1980 included in conventional hydroelectric power.

[6] Hydroelectric data through 1988 are for generation at electric utilities and industrial plants only; beginning in 1989, data also include generation at independent power producers and commercial plants.

[7] Wood, black liquor, and other wood waste.

[8] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass.

[9] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Table 7.3 – Electricity Generation at Combined-Heat-and-Power Plants

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Coal [1]	N/A	33	55	51	51	53	54	54	54
Petroleum [2]	N/A	8	13	11	11	12	15	19	20
Natural Gas [3]	N/A	105	197	208	230	219	288	337	355
Other Gases [4]	N/A	10	14	9	11	11	4	5	5
Total Fossil Energy	N/A	157	279	279	303	295	361	415	434
Nuclear	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hydroelectric Pumped Storage[5]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Conventional Hydroelectric [6]	N/A	3	4	3	4	6	6	6	6
Geothermal	N/A	N/A	N/A	N/A	N/A	N/A	0	0	0
Wood [7]	N/A	27	30	29	31	30	34	40	43
Waste [8]	N/A	1	3	2	3	3	2	2	2
Solar Thermal and Photovoltaic	N/A	N/A	N/A	N/A	N/A	N/A	1	2	4
Wind	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total Renewable Energy	N/A	32	38	35	39	39	43	50	55
Other [9]	N/A	4	5	5	4	5	10	10	10
Total Electricity Generation	N/A	192	321	319	346	339	413	475	500

Sources: EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.2c, and EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383(2005) (Washington, D.C., February 2005), Tables A8 and A16.

Notes: Includes combined-heat-and-power (CHP) plants whose primary business is to sell electricity and heat to the public.
For 1989-2002, does not include electric utility CHP plants—these are included in "Net Generation at Electricity-Only Plants " in Table 7.2. Also includes commercial and industrial CHP and a small number of commercial and industrial (end-use sectors) electricity-only plants.
[1] Anthracite, bituminous coal, subbituminous coal, lignite, waste coal, and synthetic coal.
[2] Distillate fuel oil, residual fuel oil, petroleum coke, jet fuel, kerosene, other petroleum, and waste oil.
[3] Natural gas, including a small amount of supplemental gaseous fuels. Forecast data Include electricity generation from fuel cells.
[4] Blast furnace gas, propane gas, and other manufactured and waste gases derived from fossil fuels, including refinery and still gas.
[5] Pumped storage facility production minus energy used for pumping. Data for 1980 included in conventional hydroelectric power.
[6] Hydroelectric data through 1988 are for generation at electric utilities and industrial plants only; beginning in 1989, data also include generation at independent power producers and commercial plants.
[7] Wood, black liquor, and other wood waste.
[8] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass.
[9] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

Table 7.4 – Generation and Transmission/Distribution Losses

(Billion kWh)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Net Generation Delivered	2,290	3,038	3,802	3,737	3,858	3,848	4,322	5,085	5,522
Generation Losses [1]	4,859	6,305	7,793	7,578	7,767	7,769	8,506	9,507	10,137
Transmission and Distribution Losses [2]	N/A	224	238	224	247	195	260	289	311

Sources: Calculated from EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Tables 8.1, 8.2a and 8.4a, and EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383(2005) (Washington, D.C., February 2005), Tables A2 and A8.

Notes:

[1] Generation Losses for all years are calculated by calculating a Gross Generation value in billion kWh by multiplying the energy input in trillion Btu by (1000/3412) and subtracting the Net Generation in billion kWh from the Gross Generation estimate.

[2] Transmission and Distribution Losses = Electricity Needed to be Transmitted - Electricity Sales, where Electricity Needed to be Transmitted = Total Generation from Electric Generators + Cogenerators + Net Imports - Generation for Own Use. Represents energy losses that occur between the point of generation and delivery to the customer, and data collection frame differences and nonsampling error.

Table 7.5 – Electricity Trade

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Interregional Electricity Trade									
Gross Domestic Firm Power Trade	N/A	N/A	N/A	143	139	137	106	51	38
Gross Domestic Economy Trade	N/A	N/A	N/A	182	210	199	207	133	102
Gross Domestic Trade	N/A	N/A	N/A	325	349	335	312	184	140
International Electricity Trade									
Firm Power Imports from Mexico and Canada	N/A	N/A	N/A	12	10	11	2	1	0
Economy Imports from Mexico and Canada	N/A	N/A	N/A	26	27	18	29	31	25
Gross Imports from Mexico and Canada	25	18	49	39	36	31	31	32	25
Firm Power Exports to Mexico and Canada	N/A	N/A	N/A	7	6	6	1	0	0
Economy Exports to Mexico and Canada	N/A	N/A	N/A	10	9	20	21	16	14
Gross Exports to Canada and Mexico	4	16	15	16	14	24	22	16	14

Sources: EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.1, and EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383(2005) (Washington, D.C., February 2005), Table A10.

Notes:

All data are from EIA AEO except Gross Imports and Exports for 1980-2003.

Table 8.1 – Electricity Sales

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Electricity Sales by Sector[1]									
Residential	717	924	1,192	1,203	1,267	1,280	1,471	1,696	1,810
Commercial	488	751	1,055	1,089	1,116	1,119	1,466	1,854	2,088
Industrial	815	946	1,064	964	972	991	1,107	1,229	1,286
Transportation/Other [2]	74	92	109	114	107	109	26	32	35
Total Sales	2,094	2,713	3,421	3,370	3,463	3,500	4,070	4,811	5,220
Direct Use [3]	N/A	114	183	184	178	175	204	229	248
Total	2,094	2,827	3,605	3,554	3,641	3,675	4,274	5,040	5,467

Sources: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383(2005) (Washington, D.C., February 2005), Table A8; EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2002) (Washington, D.C., September 2004), Table 8.9.

Notes:

[1] Electricity retail sales to ultimate customers reported by electric utilities and other energy service providers.

[2] Other includes public street and highway lighting, other sales to public authorities, sales to railroads and railways, and interdepartmental sales through 2002. Transportation sector sales reported starting in 2010.

[3] Commercial and industrial facility use of onsite net electricity generation; and electricity sales among adjacent or colocated facilities for which revenue information is not available.

Table 8.2 – Demand-Side Management

	1980	1990	2000	2001	2002	2003
Load Management Peak Load Reductions (MW)[1]	NA	7,911	10,027	11,928	9,516	9,323
Energy Efficiency Peak Load Reductions (MW)[2]	NA	5,793	12,873	13,027	13,420	13,581
Total Peak Load Reductions (MW)	NA	13,704	22,901	24,955	22,936	22,904
Energy Savings (Million kWh)	NA	20,458	53,701	54,762	54,075	50,265
Costs (Million 2000 $)[3]	NA	1,506	1,620	1,649	1,564	1,228

Sources: Sources: EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.13; EIA, *Electric Power Annual 2003*, DOE/EIA-0348(2003) (Washington, D.C., December 2004), table 9.1, 9.4 and 9.7

Notes:
The actual reduction in peak load reflects the change in demand for electricity that results from a utility demand-side management program that is in effect at the time that the utility experiences its actual peak load as opposed to the potential installed peak load reduction capability. Differences between actual and potential peak reduction result from changes in weather, economic activity, and other variable conditions.

[1] Load management includes programs such as direct load control and interruptible load control, and beginning in 1997, "other types" of demand-side management programs. "Other types" are programs that limit or shift peak loads from on-peak to off-peak time periods, such as space heating and water heating storage systems.

[2] Energy efficiency refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided. From 1989 to 1996, energy efficiency includes "other types" of demand-side management programs. Beginning in 1997, these programs are included under load management.

[3] Historical data converted to 2000 dollars using EIA *Annual Energy Review 2003*, Appendix D.

Table 8.3 - Electricity Sales, Revenue, and Consumption by Census Division and State, 2003

Census Division and State	Sales (MWh)	Revenue (million $)	Average Revenue (¢/kWh)	Electricity Consumption (kWh/person)	Census Division and State	Sales (MWh)	Revenue (million $)	Average Revenue (¢/kWh)	Electricity Consumption (kWh/person)
New England	**122,641,448**	**12,816**	**10.4**	**8,636**	**East South Central**	**312,064,000**	**17,320**	**5.6**	**21,637**
Connecticut	31,783,319	3,231	10.2	9,115	Alabama	83,844,220	4,929	5.9	18,617
Maine	11,971,837	1,172	9.8	9,144	Kentucky	85,219,631	3,763	4.4	20,693
Massachusetts	54,728,455	5,820	10.6	8,524	Mississippi	45,543,881	2,940	6.5	37,771
New Hampshire	11,005,912	1,188	10.8	8,540	Tennessee	97,455,808	5,687	5.8	16,673
Rhode Island	7,799,496	816	10.5	7,248	**West South Central**	**93,991,704**	**35,198**	**7.1**	**15,046**
Vermont	5,352,429	588	11.0	8,642	Arkansas	43,108,259	2,399	5.6	15,803
Middle Atlantic	**361,813,094**	**36,437**	**10.1**	**8,995**	Louisiana	77,769,322	5,387	6.9	17,306
New Jersey	76,589,333	7,245	9.5	8,862	Oklahoma	50,428,168	3,201	6.3	14,381
New York	144,222,104	17,936	12.4	7,507	Texas	322,685,955	24,211	7.5	14,599
Pennsylvania	141,001,657	11,256	8.0	11,398	**Mountain**	**231,061,000**	**15,513**	**6.7**	10,837
East North Central	**563,972,401**	**36,894**	**6.5**	**12,302**	Arizona	64,079,560	4,706	7.3	7,727
Illinois	135,973,629	9,359	6.9	10,750	Colorado	46,494,645	3,146	6.8	10,224
Indiana	100,467,779	5,393	5.4	16,206	Idaho	21,218,685	1,107	5.2	15,522
Michigan	108,877,193	7,461	6.9	10,799	Montana	12,691,252	782	6.2	13,823
Ohio	151,412,306	10,213	6.7	13,238	Nevada	30,131,660	2,499	8.3	13,438
Wisconsin	67,241,494	4,468	6.6	12,283	New Mexico	19,330,491	1,354	7.0	10,290
West North Central	**260,667,000**	**15,720**	**6.0**	**15,647**	Utah	23,860,350	1,290	5.4	10,144
Iowa	41,207,284	2,519	6.1	14,007	Wyoming	13,253,836	630	4.8	26,396
Kansas	36,735,390	2,333	6.3	13,482	**Pacific Contiguous**	**362,037,959**	**35,117**	**9.7**	**8,017**
Minnesota	63,087,339	3,791	6.0	21,500	California	238,709,728	27,741	11.6	6,731
Missouri	74,239,888	4,470	6.0	12,981	Oregon	45,194,730	2,795	6.2	12,680
Nebraska	25,856,566	1,458	5.6	14,882	Washington	78,133,501	4,580	5.9	12,743
North Dakota	10,461,108	572	5.5	16,516	**Pacific Noncontiguous**	**15,954,518**	**2,088**	**13.1**	**8,410**
South Dakota	9,079,990	577	6.4	11,871	Alaska	5,563,682	584	10.5	8,582

South Atlantic	**763,991,000**	**51,697**	**6.8**	**14,067**
Delaware	12,599,590	877	7.0	15,400
District of Columbia	10,879,622	808	7.4	19,511
Florida	217,378,622	16,774	7.7	12,788
Georgia	123,676,657	7,816	6.3	14,254
Maryland	71,258,583	4,594	6.4	12,927
North Carolina	121,335,121	8,329	6.9	14,408
South Carolina	77,054,098	4,684	6.1	18,573
Virginia	101,509,984	6,364	6.3	13,782
West Virginia	28,296,993	1,450	5.1	15,621
Hawaii	10,390,836	1,504	14.5	8,321
U.S. Total	**3,488,191,978**	**258,798**	**7.4**	**11,576**

Sources: EIA, Electric Sales and Revenue 2003 Spreadsheets, Data Tables, http://www.eia.doe.gov/cneaf/electricity/esr/esr_tabs.html, Tables 1b, 1c, 1d, and U.S. Census Bureau, Annual Estimates of the Population for the United States and States, and for Puerto Rico: April 1, 2000, to July 1, 2004 (NST-EST2004-01) - State Population Estimates: 2003, http://www.census.gov/popest/national/files/NST_EST2004_ALLDATA.csv

Notes:

Revenue in 2003 dollars.

Includes bundled and unbundled consumers

Table 9.1 – Price of Fuels Delivered to Electric Generators

(2003 Dollars per Million Btu) [1]

	1980	1992	2000	2001	2002	2003	2010	2020	2025
Distillate Fuel	NA	NA	NA	NA	NA	NA	5.36	6.01	6.33
Residual Fuel [2]	NA	3.08	4.42	3.81	3.40	4.45	4.19	4.71	5.00
Natural Gas [3]	NA	2.85	4.55	4.63	3.62	5.37	4.27	5.20	5.44
Steam Coal [4]	NA	1.73	1.27	1.27	1.28	1.28	1.25	1.25	1.31
Fossil Fuel Average [5]	NA	1.94	1.83	1.79	1.54	2.19	2.06	2.45	2.46

Sources: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383(2005) (Washington, D.C., February 2005), Table A3, and EIA, *Electric Power Annual 2003*, DOE/EIA-0348(2003) (Washington, D.C., December 2004), Table 4.5.

Notes:

Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

Data are for steam-electric plants with a generator nameplate capacity of 50 or more megawatts.
Beginning in 2002, data from the Form EIA-423, "Monthly Cost and Quality of Fuels for Electric Plants Report" for independent power producers and combined heat and power producers are included in this data dissemination. Prior to 2002, these data were not collected; the data for 2001 and previous years include only data collected from electric utilities via the FERC Form 423.

[1] Historical Data converted to 2003$/MMBtu using EIA Annual Energy Review 2003 Appendix D.

[2] 1990-2003 data are for distillate fuel oil (all diesel and No. 1, No. 2, and No. 4 fuel oils), residual fuel oil (No. 5 and No. 6 fuel oils and bunker C fuel oil), jet fuel, kerosene, petroleum coke (converted to liquid petroleum), and waste oil.

[3] Natural gas, including a small amount of supplemental gaseous fuels that cannot be identified separately.

[4] Anthracite, bituminous coal, subbituminous coal, lignite, waste coal, and synthetic coal.
[5] Weighted average price.

Table 9.2 – Electricity Retail Sales

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Retail Sales[1]									
Residential	717	924	1,192	1,203	1,267	1,280	1,471	1,696	1,810
Commercial	488	751	1,055	1,089	1,116	1,119	1,466	1,854	2,088
Industrial	815	946	1,064	964	972	991	1,107	1,229	1,286
Transportation / Other[3]	74	92	109	114	107	109	26	32	35
Total	2,094	2,713	3,421	3,370	3,463	3,500	4,070	4,811	5,220

Sources: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005), (Washington, D.C., February 2005), Table A8 and EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Table 8.9.

Notes:

[1] Electricity retail sales to ultimate customers by electric utilities and, beginning in 1996, other energy service providers.

[2] Other includes public street and highway lighting, other sales to public authorities, sales to railroads and railways, and interdepartmental sales through 2003. Transportation sector sales reported starting in 2010.

Table 9.3 – Prices of Electricity Sold

(2003 cents per Kilowatthour) [1]

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Price by End-Use Sector[2]									
Residential	10.6	10.1	8.7	8.9	8.6	8.7	7.8	8.2	8.3
Commercial	10.8	9.5	7.9	8.2	8.0	8.1	6.8	7.5	7.6
Industrial	7.2	6.1	4.9	5.2	5.0	5.0	4.7	5.3	5.4
Transportation / Other[3]	9.4	8.3	6.9	7.3	6.8	7.0	6.4	6.8	6.8
End-Use Sector Average	9.2	8.5	7.2	7.6	7.3	7.4	6.6	7.2	7.3
Price by Service Category[2]									
Generation	N/A	N/A	N/A	N/A	4.7	4.8	4.1	4.7	4.9
Transmission	N/A	N/A	N/A	N/A	0.6	0.5	0.6	0.7	0.7
Distribution	N/A	N/A	N/A	N/A	2.1	2.1	2.0	1.8	1.8

Sources: EIA, Annual Energy Outlook 2005, DOE/EIA-0383 (2005), (Washington, D.C., February 2005), Table A8 and EIA, Annual Energy Review 2003, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.10.

Notes:

For 1980, data are for selected Class A utilities whose electric operating revenues were $100 million or more during the previous year. For 1990, data are for a census of electric utilities. For 2000 onward, data also include energy service providers selling to retail customers.

[1] Historical Data real prices expressed in chained (2003) dollars, calculated by using gross domestic product implicit price deflators using EIA Annual Energy Review 2003 Appendix D.

[2] Prices represent average revenue per kilowatthour.

[3] Public street and highway lighting, other sales to public authorities, sales to railroads and railways and interdepartmental sales.

Table 9.4 – Revenue from Electric Utility Retail Sales by Sector

(Millions of 2003 Dollars)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
Residential	71,750	88,706	98,258	101,263	103,130	105,464	115,251	139,584	149,710
Commercial	49,792	67,592	78,404	84,409	84,388	86,070	99,691	139,850	159,617
Industrial	55,425	54,935	49,381	47,440	45,595	46,396	52,282	64,843	69,121
Transportation/Other [1]	6,562	7,212	7,183	7,815	6,932	7,202	1,682	2,170	2,391
All Sectors [2]	182,217	218,361	232,998	240,939	240,299	244,998	268,906	346,448	380,838

Sources: Calculated from EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005), (Washington, D.C., February 2005), Table A8; EIA, *Annual Energy Review 20*03, DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Tables 8.9 and 8.10.

Notes:

[1] Other includes public street and highway lighting, other sales to public authorities, sales to railroads and railways, and interdepartmental sales through 2003. Transportation sector revenue reported starting in 2010.
[2] For 1980, data are for selected Class A utilities whose electric operating revenues were $100 million or more during the previous year. For 1990, data are for a census of electric utilities. For 2000 onward, data also include energy service providers selling to retail customers

Table 9.5 – Revenue from Sales to Ultimate Consumers by Sector, Census Division, and State, 2003

(Millions of 2003 Dollars)

Census Division/ State	Residen- tial	Commer- cial	Industrial	Other[1]	All Sectors [2]
New England	**5,382**	**5,395**	**2,012**	**27**	**12,816**
Connecticut	1,492	1,292	433	15	3,231
Maine	522	409	241	0	1,172
Massachusetts	2,253	2,684	871	12	5,820
New Hampshire	509	445	234	0	1,188
Rhode Island	348	352	116	0	816
Vermont	258	212	117	0	588
Middle Atlantic	**14,424**	**16,431**	**5,243**	**338**	**36,437**
New Jersey	2,921	3,335	976	13	7,245
New York	6,743	9,372	1,552	269	17,936
Pennsylvania	4,760	3,724	2,715	57	11,256
East North Central	**14,541**	**12,483**	**9,839**	**30**	**36,894**
Illinois	3,616	3,690	2,025	28	9,359
Indiana	2,162	1,374	1,855	1	5,393
Michigan	2,813	2,672	1,976	0	7,461
Ohio	4,097	3,349	2,766	0	10,213
Wisconsin	1,853	1,397	1,217	0	4,468
West North Central	**6,958**	**5,420**	**3,342**	**0**	**15,720**
Iowa	1,094	726	699	0	2,519
Kansas	971	882	479	0	2,333
Minnesota	1,579	1,257	955	0	3,791
Missouri	2,186	1,618	667	0	4,470
Nebraska	608	499	352	0	1,458

Census Division/ State	Residen- tial	Commer- cial	Industrial	Other[1]	All Sectors [2]
East South Central	**7,420**	**5,111**	**4,788**	**0**	**17,320**
Alabama	2,175	1,399	1,355	0	4,929
Kentucky	1,435	963	1,365	0	3,763
Mississippi	1,343	913	684	0	2,940
Tennessee	2,467	1,836	1,384	0	5,687
West South Central	**15,989**	**10,877**	**8,326**	**6**	**35,198**
Arkansas	1,130	585	685	0	2,399
Louisiana	2,241	1,628	1,518	0	5,387
Oklahoma	1,507	1,083	611	0	3,201
Texas	11,111	7,581	5,512	6	24,211
Mountain	**6,409**	**5,700**	**3,400**	**4**	**15,513**
Arizona	2,316	1,803	587	0	4,706
Colorado	1,280	1,298	565	3	3,146
Idaho	443	304	360	0	1,107
Montana	311	292	179	0	782
Nevada	932	718	849	0	2,499
New Mexico	471	593	290	0	1,354
Utah	494	504	290	1	1,290
Wyoming	161	189	281	0	630
Pacific Contiguous	**12,949**	**15,856**	**6,261**	**51**	**35,117**
California	9,686	13,167	4,840	48	27,741
Oregon	1,252	988	554	1	2,795
Washington	2,010	1,701	866	3	4,580

North Dakota	241	214	117	0	572
South Dakota	280	224	73	0	577
South Atlantic	**25,963**	**17,711**	**7,949**	**74**	**51,697**
Delaware	360	284	233	0	877
District of Columbia	144	627	14	22	808
Florida	9,636	6,083	1,048	7	16,774
Georgia	3,711	2,699	1,397	9	7,816
Maryland	2,060	1,178	1,329	27	4,594
North Carolina	4,106	2,770	1,453	0	8,329
South Carolina	2,117	1,316	1,251	0	4,684
Virginia	3,174	2,365	815	9	6,364
West Virginia	654	389	408	0	1,450
Pacific Noncontiguous	**745**	**788**	**556**	**0**	**2,088**
Alaska	238	259	87	0	584
Hawaii	507	528	469	0	1,504
U.S. Total	**110,779**	**95,772**	**51,716**	**531**	**258,798**

Source: EIA, *Electric Sales and Revenue 2003 Spreadsheets,* Data Tables, http://www.eia.doe.gov/cneaf/electricity/esr/esr_tabs.html, Table 1c.

Notes:

[1] Includes sales for public street and highway lighting, to public authorities, railroads and railways, and interdepartmental sales

[2] Includes bundled and unbundled Consumers

Table 9.6 – Production, Operation, and Maintenance Expenses for Major U.S. Investor-Owned and Publicly Owned Utilities

(Million of Nominal Dollars)

	Investor-Owned Utilities					Publicly Owned Utilities[1]				
	1990	1995	2000	2002	2003	1990	1995	2000	2002	2003
Production Expenses										
Cost of Fuel	32,635	29,122	32,555	24,132	26,476	5,276	5,664	7,702	9,348	10,378
Purchased Power	20,341	29,981	61,969	58,828	62,173	10,542	11,988	16,481	24,446	26,078
Other Production Expenses	9,526	9,880	12,828	7,688	7,532	155	212	225	1,647	1,285
Total Production Expenses[2]	62,502	68,983	107,352	90,649	96,181	15,973	17,863	24,398	36,188	38,526
Operation and Maintenance Expenses										
Transmission Expenses	1,130	1,425	2,699	3,494	3,585	604	663	845	951	977
Distribution Expenses	2,444	2,561	3,115	3,113	3,185	950	630	854	1,000	1,044
Customer Accounts Expenses	3,247	3,613	4,246	4,165	4,180	375	448	662	700	754
Customer Service and Information Expenses	1,181	1,922	1,839	1,821	1,893	75	120	233	354	311
Sales Expenses	212	348	403	261	234	29	30	82	84	95
Administrative and General Expenses	10,371	13,028	13,009	12,872	13,466	1,619	2,127	2,097	2,594	2,742
Total Electric Operation and Maintenance Expenses	18,585	22,897	25,311	25,726	26,543	3,653	4,018	4,772	5,683	5,923

Source: EIA, *Electric Power Annual 2003,* DOE/EIA-0348(2003) (Washington, D.C., December 2004), Tables 8.1, 8.3 and 8.4; and EIA, *Electric Power Annual 2001*, DOE/EIA-0348(2001) (Washington, D.C., December 2002), Table 8.1; EIA, *Financial Statistics of Major US Publicly Owned Electric Utilities 1994,* DOE/EIA-0437(94)/2 (Washington, D.C., December 1995), Table 8 and Table 17; EIA, *Financial Statistics of Major US Publicly Owned Electric Utilities 1999*, DOE/EIA-0437(99)/2 (Washington, D.C., November 2000), Table 10 & Table 21; EIA, *Financial Statistics of Major US Publicly Owned Electric Utilities 2000*, DOE/EIA-0437(00)/2 (Washington, D.C., November 2001), Table 10 & Table 21.; EIA, Public Electric Utility Database (Form EIA-412) 2002 and 2003.

Notes:

[1] Publicly Owned Utilities include generator and nongenerator electric utilities.

[2] Totals may not equal sum of components because of independent rounding.

Table 9.6a – Operation and Maintenance Expenses for Major U.S. Investor-Owned Electric Utilities

(Million of Nominal Dollars, unless otherwise indicated)

	1990	1995	2000	2002	2003
Utility Operating Expenses	142,471	165,321	210,324	188,745	197,459
Electric Utility	127,901	150,599	191,329	171,291	175,473
Operation	81,086	91,881	132,662	116,374	122,723
Production	62,501	68,983	107,352	90,649	96,181
Cost of Fuel	32,635	29,122	32,555	24,132	26,476
Purchased Power	20,341	29,981	61,969	58,828	62,173
Other	9,526	9,880	12,828	7,688	7,532
Transmission	1,130	1,425	2,699	3,494	3,585
Distribution	2,444	2,561	3,115	3,113	3,185
Customer Accounts	3,247	3,613	4,246	4,165	4,180
Customer Service	1,181	1,922	1,839	1,821	1,893
Sales	212	348	403	261	234
Administrative and General	10,371	13,028	13,009	12,872	13,466
Maintenance	11,779	11,767	12,185	10,843	11,141
Depreciation	14,889	19,885	22,761	17,319	16,962
Taxes and Other	20,146	27,065	23,721	26,755	24,648
Other Utility	14,571	14,722	18,995	17,454	21,986
Operation (Mills per Kilowatthour) [1]					
Nuclear	10.04	9.43	8.41	8.54	8.86
Fossil Steam	2.21	2.38	2.31	2.54	2.50
Hydroelectric & Pumped Storage	3.35	3.69	4.74	5.07	4.50
Gas Turbine and Small Scale [2]	8.76	3.57	4.57	2.72	2.76
Maintenance (Mills per Kilowatthour) [1]					
Nuclear	5.68	5.21	4.93	5.04	5.23
Fossil Steam	2.97	2.65	2.45	2.68	2.73
Hydroelectric & Pumped Storage	2.58	2.19	2.99	3.58	3.01
Gas Turbine and Small Scale [2]	12.23	4.28	3.50	2.38	2.26

Source: EIA, *Electric Power Annual 2003*, DOE/EIA-0348(2003) (Washington, D.C., December 2004), Tables 8.1 and 8.2, and EIA, Electric Power Annual 2001, Tables 8.1 and 8.2.

Notes:

[1] Operation and maintenance expenses are averages, weighed by net generation.

[2] Includes gas turbine, internal combustion, photovoltaic, and wind plants.

Table 9.6b – Operation and Maintenance Expenses for Major U.S. Publicly Owned Generator and Nongenerator Electric Utilities

(Million of Nominal Dollars, except employees)

	1990	1995	2000	2002	2003
Production Expenses					
Steam Power Generation	3,742	3,895	5,420	6,558	7,539
Nuclear Power Generation	1,133	1,277	1,347	1,646	1,739
Hydraulic Power Generation	205	261	332	746	785
Other Power Generation	196	231	603	1,144	1,100
Purchased Power	10,542	11,988	16,481	24,446	26,078
Other Production Expenses	155	212	225	1,647	1,285
Total Production Expenses[1]	15,973	17,863	24,398	36,188	38,526
Operation and Maintenance Expenses					
Transmission Expenses	604	663	845	951	977
Distribution Expenses	950	630	854	1,000	1,044
Customer Accounts Expenses	375	448	662	700	754
Customer Service and Information Expenses	75	120	233	354	311
Sales Expenses	29	30	82	84	95
Administrative and General Expenses	1,619	2,127	2,097	2,594	2,742
Total Electric Operation and Maintenance Expenses	3,653	4,018	4,772	5,683	5,923
Total Production and Operation and Maintenance Expenses	19,626	22,651	30,100	44,813	47,165
Fuel Expenses in Operation					
Steam Power Generation	2,395	2,163	4,150	4,818	5,624
Nuclear Power Generation	242	222	316	433	398
Other Power Generation	113	101	373	754	771
Total Electric Department Employees[2]	N/A	73,172	71,353	93,520	92,752

Source: EIA, *Financial Statistics of Major US Publicly Owned Electric Utilities* 1994, DOE/EIA-0437(94)/2 (Washington, D.C., December 1995), Table 8 and Table 17; EIA, Financial *Statistics of Major U.S. Publicly Owned Electric Utilities 1999*, DOE/EIA-0437(99)/2 (Washington, D.C., November 2000), Table 10 & Table 21; EIA, *Financial Statistics of Major US Publicly Owned Electric Utilities 2000*, DOE/EIA-0437(00)/2 (Washington, D.C., November 2001), Table 10 & Table 21; EIA, Public Electric Utility Database (Form EIA-412) 2002 and 2003; EIA, *Electric Power Annual 2003*, DOE/EIA-0348(2003) (Washington, D.C., December 2004), Tables 8.3 and 8.4

Notes:
[1] Totals may not equal sum of components because of independent rounding.
[2] Number of employees were not submitted by some publicly owned electric utilities because the number of electric utility employees could not be separated from the other municipal employees or the electric utility outsourced much of the work.

Table 9.7 – Environmental Compliance Equipment Costs

(Nominal Dollars)

	1990	1995	2000	2001	2002	2003	2010	2020	2025
Average Flue Gas Desulfurization Costs at Utilities									
Average Operation & Maintenance Costs (mills/kWh)	1.35	1.16	0.96	1.27	1.11	1.23	N/A	N/A	N/A
Average Installed Costs ($/kW)	118	126	124	131	124	124	N/A	N/A	N/A

Source: EIA, *Electric Power Annual 2001*, DOE/EIA-0348 (01) (March 2003), Table 5.3, Electric Power Annual 2003, Table 5.3.

Notes:

Includes plants under the Clean Air Act that were monitored by the Environmental Protection Agency even if sold to an unregulated entity.

These data are for plants with a fossil-fueled steam-electric capacity of 100 megawatts or more.

Table 10.1 – Consumer Price Estimates for Energy Purchases

(2003 Dollars, per Million Btu)[1]

	1970	1980	1990	2000	2002	2003	2010	2020	2025
Coal	1.38	2.70	1.84	1.27	1.29	1.30	1.27	1.27	1.32
Natural Gas	2.14	5.29	4.72	5.68	5.15	6.86	5.52	6.30	6.59
Distillate Fuel	4.21	12.40	9.44	9.90	8.71	9.90	9.53	9.79	10.03
Jet Fuel	2.65	11.77	6.96	6.60	6.05	6.46	6.25	6.58	6.93
Liquified Petroleum Gases	5.30	10.44	8.27	10.19	9.52	13.04	10.99	11.74	12.34
Motor Gasoline	10.35	18.21	11.18	12.01	11.32	12.93	12.31	12.51	12.80
Residual Fuel	1.53	7.18	3.87	4.74	3.93	4.66	3.99	4.52	4.81
Other [2]	5.01	12.99	7.11	6.98	N/A	N/A	N/A	N/A	N/A
Petroleum Total	6.25	13.69	9.16	9.94	9.09	10.51	9.91	10.29	10.66
Nuclear Fuel	0.65	0.80	0.82	0.45	N/A	N/A	N/A	N/A	N/A
Wood and Waste	4.69	4.18	2.08	1.90	N/A	N/A	N/A	N/A	N/A
Primary Energy Total [3]	3.92	8.46	5.50	5.78	7.78	9.01	8.61	9.18	9.55
Electric Utility Fuel	1.16	3.24	1.79	1.43	N/A	N/A	N/A	N/A	N/A
Electricity Purchased by End Users	18.09	25.81	23.69	20.04	21.60	21.74	19.36	21.11	21.38
Total Energy [3]	5.99	12.75	10.11	9.85	10.26	11.50	10.56	11.42	11.83

Sources: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005), (Washington, D.C., February 2005), Table A3 and EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Table 3.3.

Notes:

[1] Historical Data converted to 2003$/MMBtu using EIA Annual Energy Review 2003 Appendix D.
[2] Consumption-weighted average price for asphalt and road oil, aviation gasoline, kerosene, lubricants, petrochemical feedstocks, petroleum coke, special naphthas, waxes, and miscellaneous petroleum products.
[3] The "Primary Energy Total" and "Total Energy" prices include consumption-weighted average prices for coal coke imports and coal coke exports that are not shown in the other columns.

Table 10.2 – Economy-Wide Indicators

(Billions of 2000 Chain Weighted Dollars, unless otherwise noted)

	1980	1990	2000	2001	2002	2003	2010	2020	2025
GDP Chain Type Price Index (2000 = 1.000)	0.541	0.816	1.000	1.024	1.041	1.060	1.218	1.563	1.814
Real Gross Domestic Product	5,162	7,113	9,817	9,891	10,075	10,381	13,084	17,634	20,292
Real Consumption	3,374	4,770	6,739	6,910	7,123	7,356	9,031	11,826	13,352
Real Investment	645	895	1,736	1,598	1,561	1,629	2,324	3,805	4,868
Real Government Spending	1,115	1,530	1,722	1,780	1,858	1,909	2,135	2,486	2,647
Real Exports	324	553	1,096	1,037	1,012	1,032	1,917	3,633	4,956
Real Imports	311	607	1,476	1,436	1,484	1,550	2,287	3,883	5,094
Real Disposable Personal Income	3,858	5,324	7,194	7,333	7,560	7734	9,594	12,783	14,990
Consumer Price Index (2002 = 1.000)	0.824	1.307	1.722	1.771	1.799	1.840	2.12	2.78	3.26
Unemployment Rate (percent)	7.1	5.6	4.0	4.7	5.8	6.0	5.57	4.48	4.55
Housing Starts (millions)	1.3	1.2	1.6	1.6	1.7	1.8	1.89	1.88	1.89
Gross Output									
Total Industrial					5,067	5,105	6,165	7,633	8,469
Non-Manufacturing					1,240	1,254	1,329	1,587	1,736
Manufacturing					3,826	3,851	4,836	6,046	6,733
Energy-Intensive Manufacturing					1,057	1,048	1,219	1,384	1,462
Non-Energy-Intensive Manufacturing									
Population (all ages, millions)	226.5	248.8	281.4	285.1	288.0	290.8	310.1	337.0	350.6
Employment Non-Agriculture (millions)	95.9	115.6	134.4	134.6	134.2	135.5	140.7	159.7	169.1
Employment Manufacturing (millions)	20.4	19.2	17.5	16.5	15.3	14.6	14.0	13.0	12.7

Sources: EIA, Annual Energy Outlook 2005, DOE/EIA-0383(2005) (Washington, D.C., February 2005), Table A19, EIA, Annual Energy Review 2002, DOE/EIA-0384(2002) (Washington, D.C., October 2003), Table D1, Bureau Of Economic Analysis, National Income and Products Accounts Tables (NIPA), Tables 1.1.4, 1.1.6, 2.1, and 6.4 B-D, http://www.bea.doc.gov/bea/dn/nipaweb/NIPATableIndex.asp, Department of Labor, Bureau of Labor Statistics, Current Population Survey, Current Population Survey, Household Data Annual Averages, http://www.bls.gov/cps/cpsa2003.pdf, National Association of Home Builders, http://www.nahb.org/generic.aspx?sectionID=130&genericContentID=554.

Table 10.3 – Composite Statements of Income for Major U.S. Publicly Owned Generator and Investor-Owned Electric Utilities, 2003

(Million 2003 Dollars)

	Publicly Owned Generator Electric Utilities [1]	Investor-Owned Electric Utilities
Operating Revenue - Electric	33,906	202,369
Operating Expenses - Electric	29,637	175,473
Operation Including Fuel	22,642	122,723
Production	17,948	96,181
Transmission	872	3,585
Distribution	696	3,185
Customer Accounts	582	4,180
Customer Service	280	1,893
Sales	84	234
Administrative and General	2,180	13,466
Maintenance	2,086	11,141
Depreciation and Amortization	3,844	16,962
Taxes and Tax Equivalents	1,066	24,648
Net Electric Operating Income	4,268	28,768

Source: EIA, *Electric Power Annual 2003*, DOE/EIA-0348(2003), (Washington, D.C., December 2004), Tables 8.1 and 8.3.

Note:

[1] The data represent those utilities meeting a threshold of 150 million kilowatthours of customer sales or resale for the two previous years.

Table 11.1 – Emissions from Electricity Generators, 2003

(Thousand short tons of gas)

	1990	2000	2001	2002	2003	2010	2020	2025
Coal Fired								
Carbon Dioxide	1,672,757	2,083,038	2,016,017	2,059,779	2,099,132	2,358,682	2,614,183	2,950,672
Sulfur Dioxide	15,220	10,623	10,004	9,732	N/A	N/A	N/A	N/A
Nitrogen Oxide	5,642	4,563	4,208	4,094	N/A	N/A	N/A	N/A
Methane	11	13	13	13	N/A	N/A	N/A	N/A
Nitrous Oxide	25	31	31	31	32	N/A	N/A	N/A
Petroleum Fired								
Carbon Dioxide	108,467	98,106	108,798	78,374	106,373	106,147	117,840	120,415
Sulfur Dioxide	639	482	529	343	N/A	N/A	N/A	N/A
Nitrogen Oxide	221	166	170	130	N/A	N/A	N/A	N/A
Methane	1	1	1	0	0	N/A	N/A	N/A
Nitrous Oxide	1	1	1	1	1	N/A	N/A	N/A
Gas Fired								
Carbon Dioxide	188,275	298,065	305,230	315,812	303,466	399,152	559,935	558,343
Sulfur Dioxide	1	232	262	8	N/A	N/A	N/A	N/A
Nitrogen Oxide	565	422	359	270	N/A	N/A	N/A	N/A
Methane	0	1	1	1	0	N/A	N/A	N/A
Nitrous Oxide	0	1	1	1	0	N/A	N/A	N/A
Other [1]								
Carbon Dioxide	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sulfur Dioxide 2	49	59	55	210	N/A	N/A	N/A	N/A
Nitrogen Oxide 2	235	180	180	206	N/A	N/A	N/A	N/A
Methane	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nitrous Oxide 3	1	1	0	1	1	N/A	N/A	N/A
Total								
Carbon Dioxide	1,969,610	2,479,319	2,430,156	2,453,966	2,512,498	2,886,482	3,315,362	3,653,182
Sulfur Dioxide	15,909	11,396	10,850	10,293	N/A	9,290	8,950	8,950

Nitrogen Oxide	6,663	5,330	4,917	4,699	N/A	3,989	4,175	4,286
Mercury	N/A	N/A	N/A	50,081	49,699	54,076	55,452	55,966
Methane	12	14	14	14	14	N/A	N/A	N/A
Nitrous Oxide	26	33	33	33	34	N/A	N/A	N/A
Sulfur Hexafluoride [4]	2	1	1	1	1	N/A	N/A	N/A

Sources: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Tables A8 and A18, EIA, *Emissions of Greenhouse Gases in the United States 2003*, DOE/EIA-0573(2003) (Washington, D.C., December 2004) Tables 10, 17, 25, 29, and EPA, *National Emission Inventory - Air Pollutant Emission Trends*, "Average Annual Emissions, All Criteria Pollutants," August 2003, http://www.epa.gov/ttn/chief/trends/index.html.

Notes:

Emissions from electric-power sector only.

[1] Emissions total less than 500 tons.

[2] Emissions from plants fired by other fuels; includes internal combustion generators.

[3] Emissions from wood-burning plants.

[4] Sulfur hexafluoride (SF6) is a colorless, odorless, nontoxic, and nonflammable gas used as an insulator in electric T&D equipment. SF6 has a 100-year global warming potential that is 22,200 times that of carbon dioxide and has an atmospheric lifetime of 3,200 years.

Table 11.2 – Installed Nameplate Capacity of Utility Steam-Electric Generators With Environmental Equipment

(Megawatts)

	1990	2000	2001	2002
Coal Fired				
Particulate Collectors	315,681	321,636	329,187	329,459
Cooling Towers	134,199	146,093	154,747	154,750
Scrubbers	69,057	89,675	97,804	98,363
Total[1]	317,522	328,741	329,187	329,459
Petroleum and Gas Fired				
Particulate Collectors	33,639	31,090	31,575	29,879
Cooling Towers	28,359	29,427	34,649	45,747
Scrubbers	65	0	184	310
Total[1]	59,372	57,697	61,634	71,709
Total				
Particulate Collectors	349,319	352,727	360,762	359,338
Cooling Towers	162,557	175,520	189,396	200,497
Scrubbers	69,122	89,675	97,988	98,673
Total[1]	376,894	386,438	390,821	401,168

Source: EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Table 12.8.

Notes:

[1]Components are not additive because some generators are included in more than one category.

Through 2000, data are for electric utilities with fossil-fueled steam-electric capacity of 100 megawatts or greater. Beginning in 2001, data are for electric utilities and unregulated generating plants (independent power producers, commercial plants, and industrial plants) with fossil-fueled or combustible renewable steam-electric capacity of 100 megawatts or greater.

Table 11.3 – EPA-Forecasted Nitrogen Oxide, Sulfur Dioxide, and Mercury Emissions from Electric Generators

	EPA Base Case 2000				Clear Skies Case			
	2005	**2010**	**2015**	**2020**	**2005**	**2010**	**2015**	**2020**
SO_2 (Thousand Tons)	10,267	9,861	9,227	8,961	8,424	6,242	5,475	4,403
NOx (Thousand Tons)	3,896	3,951	4,017	4,066	3,647	2,186	2,162	1,796
CO2 (Thousand Tons)	2,428,503	2,632,377	2,795,022	2,960,312	2,412,371	2,599,277	2,758,912	2,899,061
Mercury (Tons)	52	53	52	52	49	35	34	30

Source: Environmental Protection Agency (EPA), Clear Skies Initiative Analysis, Runs Table for EPA Modeling Applications 2003 Using IPM http://www.epa.gov/airmarkets/epa-ipm/results2003.html, EPA Base Case for 2003 Analyses http://www.epa.gov/airmarkets/epa-ipm/EPA216a9c.zip, and 2003 Clear Skies Act Case http://www.epa.gov/airmarkets/epa-ipm/EPA216c3.zip

Notes:

The proposed Clear Skies legislation would create a mandatory program that would dramatically reduce power plant emissions of sulfur dioxide (SO2), nitrogen oxides (NOx), and mercury by setting a national cap on each pollutant. http://www.epa.gov/air/clearskies/
Clear Skies would:
Cut sulfur dioxide (SO2) emissions by 73 percent, from year 2000 emissions of 11 million tons to a cap of 4.5 million tons in 2010 and to a cap of 3 million tons in 2018.
Cut emissions of nitrogen oxides (NOx) by 67 percent, from year 2000 emissions of 5 million tons to a cap of 2.1 million tons in 2008 and to a cap of 1.7 million tons in 2018.
Cut mercury emissions by 69 percent - the first-ever national cap on mercury emissions. Emissions would be cut from 1999 emissions of 48 tons to a cap of 26 tons in 2010 and to a cap of 15 tons in 2018.
Analytical Framework of IPM • EPA uses the Integrated Planning Model (IPM) to analyze the projected impact of environmental policies on the electric power sector in the 48 contiguous states and the District of Columbia. Developed by ICF Resources Incorporated and used to support public and private sector clients, IPM is a multi-regional, dynamic, deterministic linear programming model of the U.S. electric power sector. • The model provides forecasts of least-cost capacity expansion, electricity dispatch, and emission control strategies for meeting energy demand and environmental, transmission, dispatch, and reliability constraints. IPM can be used to evaluate the cost and emissions impacts of proposed policies to limit emissions of sulfur dioxide (SO2), nitrogen oxides (NOx), carbon dioxide (CO2), and mercury (Hg) from the electric power sector. • IPM was a key analytical tool in developing the President's Clear Skies proposal.

Table 11.4 – Market Price Indices for Emissions Trading in the South Coast Air-Quality Management District

	1996	1997	1998	1999	2000	2001	2002	2003	2005	2010
Market Price Indices [1]										
RECLAIM Trading Credit ($/lb) [2]										
Nitrogen Oxide	0.05	0.08	0.20	0.90	42.69	11.11	0.70	0.62	3.00	3.00
Sulfur Dioxide	0.15	0.08	0.34	0.29	1.14	6.82	4.00	2.25	3.04	2.84
Emission Reduction Credit ($/lb/day) [3]										
Nitrogen Oxide	2,070	2,908	4,515	4,560	7,675	16,809	8,000	8,458	NA	NA
Sulfur Dioxide	1,367	1,740	1,687	1,687	3,721	7,184	7,500	7000	NA	NA
Particulate Matter (<10 microns)	2,418	1,947	1,981	3,175	6,942	19,030	22,000	25000	NA	NA
Reactive Organic Gas	1,075	754	744	735	1,904	1,869	1,475	1100	NA	NA
Carbon Monoxide	NA	NA	NA	NA	1,000	7,259	7,000	7000	NA	NA

Source: Cantor Fitzgerald EBS, SCAQMD RTC/ERC MPI History, http://www.emissionstrading.com.

Notes:

[1] Market Price Indices (MPIs) reflect current market conditions for a particular date. Dates used here are end of year: 11/12/96, 12/29/97, 12/21/98, 12/27/99, 12/28/00, 12/7/01, 12/19/02 and 12/19/03. 2005 and 2010 prices as of 12/30/03 for all NOx products, 7/29/03 for 2005 SOx RTCs, and 07/02/03 for 2010 SOx RTCs. Prices are an average of the most recent price, lowest bid, and highest bid for RTC and ERC transactions executed by Cantor Fitzgerald and/or reported by the South Coast Air Quality Management District (SCAQMD) for 2,000 pounds or more of RTCs or 10 lbs/day or more of ERCs. SCAQMD was chosen because it is the region with the greatest number of emissions traded.

[2] In the RECLAIM program, the RECLAIM Trading Credit (RTC) is a limited authorization to emit a RECLAIM pollutant in accordance with the restrictions and requirements of the RECLAIM rules. Each RTC has a denomination of one pound of RECLAIM pollutant and a term of one year, and can be held as part of a facility's Allocation or alternatively may be evidenced by an RTC Certificate.

[3] Emissions Reduction Credits (ERCs) are reductions in emissions that have been recognized by the relevant local or state government air agency as being real, permanent, surplus, and enforceable. ERCs are usually measured as a weight over time (e.g., pounds per day or tons per year). Such rate-based ERCs can be used to satisfy emission offset requirements of new major sources and new major modifications of existing major sources.

Table 11.5 – Origin of 2003 Allowable SO_2 Emissions Levels

Type of Allowance Allocation	Number of Allowances	Explanation of Allowance Allocation Type
Initial Allocation	9,191,897	Initial Allocation is the number of allowances granted to units based on the product of their historic utilization and emissions rates (performance standards) specified in the Clean Air Act and other provisions of the Act.
Allowance Auctions	250,000	Allowance Auctions provide allowances to the market that were set aside in a Special Allowance Reserve when the initial allowance allocation was made.
Opt-in Allowances	99,188	Opt-in Allowances are provided to units entering the program voluntarily. There were 11 opt-in units in 2003.
TOTAL 2003 ALLOCATION	**9,541,085**	
Banked Allowances	8,646,818	Banked Allowances are those held over from 1995 through 2002, which can be used for compliance in 2003 or any future year.
TOTAL 2002 ALLOWABLE	**18,187,903**	

Source: EPA, *Acid Rain Program 2003 Progress Report*, Document EPA-430-R-04-011, November 2004, Figure 3.

Table 12.1 – Renewable Energy Impacts Calculation

Conversion Formula:

Step 1 *Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
Step 2 *Annual Electricity Generation (D) x Competing Heat Rate (E) = Annual Output (F)*
Step 3 *Annual Output (F) x Emissions Coefficient (G) = Annual Emissions Displaced (H)*

Technology	**Wind**	**Geothermal**	**Biomass**	**Hydropower**	**PV**	**Solar Thermal**
(A) Capacity (kW)	8,181,033	2,189,957	6,417,795	79,103,834	168,977	440,800
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	25,799,706,093	17,265,620,227	44,975,908,630	306,239,675,812	333,053,696	705,355,200
(E) Competing Heat Rate (Btu/kWh)	10,107	10,107	10,107	10,107	10,107	10,107
(F) Annual Output (Trillion Btu)	261	175	455	3,095	3	7
(G) Carbon Coefficient (MMTCB/Trillion Btu)	0.01783	0.01783	0.01783	0.01783	0.01783	0.01783
(H) Annual Carbon Displaced (MMTC)	4.649	3.111	8.105	55.187	0.060	0.128

Sources: Capacity: EIA, *Annual Energy Outlook 2005,* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16, 2005.
Capacity factors: Hydropower calculated from EIA, *Annual Energy Outlook 2005,* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16. All others based on DOE, *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997, and program data.

Heat Rate: EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table A6.

Carbon Coefficient: DOE, GPRA2003 Data Call, Appendix B, page B-16, 2003.

Notes:

Capacity values exclude combined-heat-and-power (CHP) data but include end-use sector (industrial and commercial) non-CHP data.

Competing heat rate from Fossil-Fueled Steam-Electric Plants heat rate.

Table 12.2 – Number of Home Electricity Needs Met Calculation

Conversion Formula: *Step 1* *Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
Step 2 *Annual Electricity Generation (D) / Average Consumption (E) = Number of Households (F)*

Technology	**Wind**	**Geothermal**	**Biomass**	**Hydropower**	**PV**	**Solar Thermal**
(A) Capacity (kW)	8,181,033	2,189,957	6,417,795	79,103,834	168,977	440,800
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	25,799,706,093	17,265,620,227	44,975,908,630	306,239,675,812	333,053,696	942,183,512
(E) Average Annual Household Electricity Consumption (kWh)	11,586	11,586	11,586	11,586	11,586	11,586
(F) Number of Households	2,226,809	1,490,220	3,881,935	26,431,984	28,746	81,321

Sources: Capacity: EIA, *Annual Energy Outlook 2005,* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16, 2005.

Capacity factors: Hydropower calculated from EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16. All others based on DOE, *Renewable Energy Technology Characterizations*, EPRI TR-109496, 1997, and program data.

Household electricity consumption: EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February), Tables A4 and A8, 2005.

Notes:

Capacity values exclude combined-heat-and-power (CHP) data but include end-use sector (industrial and commercial) non-CHP data.

Table 12.3 – Coal Displacement Calculation

Conversion Formula:	*Step 1*	*Capacity (A) x Capacity Factor (B) x Annual Hours (C) = Annual Electricity Generation (D)*
	Step 2	*Annual Electricity Generation (D) x Conversion Efficiency (E) = Total Output (F)*
	Step 3	*Total Output (F) / Fuel Heat Rate (G) = Quantity Fuel (H)*

Technology	**Wind**	**Geothermal**	**Biomass**	**Hydropower**	**PV**	**Solar Thermal**
(A) Capacity (kW)	8,181,033	2,189,957	6,417,795	79,103,834	168,977	440,800
(B) Capacity Factor (%)	36.0%	90.0%	80.0%	44.2%	22.5%	24.4%
(C) Annual Hours	8,760	8,760	8,760	8,760	8,760	8,760
(D) Annual Electricity Generation (kWh)	25,799,706,093	17,265,620,227	44,975,908,630	306,239,675,812	333,053,696	942,183,512
(E) Competing Heat Rate (Btu/kWh)	10,107	10,107	10,107	10,107	10,107	10,107
(F) Total Output (Btu)	260,757,629,480,278	174,503,623,632,874	454,571,508,527,161	3,095,164,403,427,280	3,366,173,705,613	9,522,648,757,289
(G) Coal Heat Rate (Btu per short ton)	20,381,000	20,381,000	20,381,000	20,381,000	20,381,000	20,381,000
(H) Coal (short tons)	12,794,153	8,562,074	22,303,690	151,865,188	165,162	467,232

Sources: Capacity: EIA, *Annual Energy Outlook 2005,* DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16, 2005.

Capacity factors: Hydropower calculated from EIA, Annual Energy Outlook 2005, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table A16. All others based on DOE, Renewable Energy Technology Characterizations, EPRI TR-109496, 1997 and Program data.

Conversion Efficiency: EIA, Annual Energy Review 2003, DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table A6.

Heat Rate: Annual Energy Outlook 2005, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table H1.

Notes:

Capacity values exclude combined-heat-and-power (CHP) data but include end-use sector (industrial and commercial) non-CHP data.

Table 12.4 – National SO_2 and Heat Input Data

	1980	1985	1990	1995	2000	2003
SO_2 (lbs)	34,523,334,000	32,184,330,000	31,466,566,000	23,667,789,600	22,404,913,800	21,189,064,800
Heat (MMBtu)	17,838,745,941	18,414,433,865	19,684,094,492	21,874,579,916	25,603,420,992	26,000,023,795
SO_2 Heat Factor (lb/MMBtu)	1.935	1.748	1.599	1.082	0.875	0.815

Source: EPA, Clean Air Markets Web site - Data and Maps, Emissions section, http://cfpub.epa.gov/gdm/

Table 12.5 – SO_2, NOx, CO_2 Emission Factors for Coal Fired and Non-Coal Fired Title IV Affected Units

	1996	1997	1998	1999	2000	2001	2002
SO_2 (lbs/mmBtu)							
Coal	1.241	1.245	1.222	1.166	1.036	1.008	0.976
Non-Coal	0.246	0.256	0.318	0.267	0.200	0.220	0.126
Total	1.096	1.093	1.058	0.999	0.875	0.843	0.794
NO_x (lbs/mmBtu)							
Coal	0.568	0.559	0.532	0.487	0.444	0.425	0.408
Non-Coal	0.221	0.234	0.251	0.244	0.210	0.176	0.128
Total	0.518	0.509	0.481	0.442	0.399	0.373	0.348
CO_2 (lbs/mmBtu)							
Coal	206.377	205.537	205.677	205.586	205.646	205.627	205.672
Non-Coal	132.731	130.804	131.685	132.001	133.110	130.159	126.858
Total	195.682	194.056	192.256	191.956	191.672	189.809	188.813

Source: EPA, Acid Rain Program Compliance Report 2001, Emission Scorecard, updated April 2003, Table 1, http://www.epa.gov/airmarkets/emissions/score01/index.html, and EPA, Clean Air Markets Web site - Data and Maps, Emissions section, http://cfpub.epa.gov/gdm/

Table 12.6a – Sulfur Dioxide, Nitrogen Oxide, and Carbon Dioxide Emission Factors, 2003 - Electricity Generators

Fuel	Boiler Type/ Firing Configuration	Emission Factors Sulfur Dioxide [1]	Nitrogen Oxides [2]	Carbon Dioxide [3]
Electricity Generators				
Coal and Other Solid Fuels		lbs per ton	lbs per ton	lbs per 10^6 Btu
Petroleum Coke[4]	fluidized bed[5]	39.0 x S	21	225.13
	all others	39.0 x S	21	225.13
Refuse	all types	3.9	5	199.82
Wood	all types	0.08	1.5	0
Petroleum and Other Liquid Fuels		lbs per 10^3 gal	lbs per 10^3 gal	lbs per 10^6 Btu
Residual Oil[6]	tangential	157.0 x S	32	173.72
	vertical	157.0 x S	47	173.72
	all others	157.0 x S	47	173.72
Distillate Oil[6]	all types	150.0 x S	24	161.27
Methanol	all types	0.05	12.4	138.15
Propane (liquid)	all types	86.5	19	139.04
Coal-Oil Mixture	all types	185.00 x S	50	173.72
Natural Gas and Other Gaseous Fuels		lbs per 10^6 cf	lbs per 10^6 cf	lbs per 10^6 Btu
Natural Gas	tangential	0.6	170	116.97
	all others	0.6	280	116.97
Blast Furnace Gas	all types	950	280	116.97

Source: EIA, Electric Power Annual 2003, DOE/EIA-0348(2003) (Washington, D.C., December 2004) Table A1

Notes:

1 Uncontrolled sulfur dioxide emission factors. "x S" indicates that the constant must be multiplied by the percentage (by weight) of sulfur in the fuel. Sulfur dioxide emission estimates from facilities with flue gas desulfurization equipment are calculated by multiplying uncontrolled emission estimates by one minus the reported sulfur removal efficiencies. Sulfur dioxide emission factors also account for small quantities of sulfur trioxide and gaseous sulfates.

2 Parenthetic values are for wet bottom boilers; otherwise dry bottom boilers. If bottom type is unknown, dry bottom is assumed. Emission factors are for boilers with a gross heat rate of 100 million Btu per hour or greater.

3 Uncontrolled carbon dioxide emission estimates are reduced by 1% to account for unburned carbon.

4 Emission factors for petroleum coke are assumed to be the same as those for anthracite. If the sulfur content of petroleum coke is unknown, a 6 percent sulfur content is assumed.

5 Sulfur dioxide emission estimates from fluidized bed boilers assume a sulfur removal efficiency of 90%.

6 Oil types are categorized by Btu content as follows: heavy (greater than or equal to 144,190 Btu per gallon), and light (less than 144,190 Btu per gallon). cf = Cubic Feet. gal = U.S. Gallons. lbs = Pounds.

Table 12.6b – Sulfur Dioxide, Nitrogen Oxide, and Carbon Dioxide Emission Factors, 2003 - Combined Heat and Power Producers

Fuel	Boiler Type/ Firing Configuration	Emission Factors: Sulfur Dioxide [1]	Nitrogen Oxides [2]	Carbon Dioxide [3]
Coal and Other Solid Fuels		lbs per ton	lbs per ton	lbs per 10^6 Btu
Peat.	all types	30.00 x S	12	0
Agricultural Waste	all types	0.08	1.2	0
Black Liquor	all types	7	1.5	0
Chemicals	all types	7	1.5	0
Closed Loop Biomass	all types	0.08	1.5	0
Internal	all types	0.08	1.5	0
Liquid Acetonitrile Waste	all types	7	1.5	150.76
Liquid Waste	all types	2.8	2.3	163.29
Municipal Solid Waste	all types	1.7	5.9	189.48
Petroleum Coke	all types	39.00 x S	14	225.13
Pitch	all types	30.00 x S	11.1	0
RailRoad Ties	all types	0.08	1.5	0
Red Liquor.	all types	7	1.5	0
Sludge	all types	2.8	5	0
Sludge Waste	all types	2.8	5	0
Sludge Wood	all types	2.8	5	0
Spent Sulfite Liquor	all types	7	1.5	0
Straw	all types	0.08	1.5	0
Sulfur	all types	7	0	0
Tar Coal	all types	30.00 x S	11.1	0
Tires	all types	38.00 x S	21.7	0
Waste Byproducts	all types	1.7	2.3	163.29
Waste Coal	all types	38.00 x S	21.7	0
Wood/Wood Waste	all types	0.08	1.5	0
Petroleum and Other Liquid Fuels		lbs per 10^3 gal	lbs per 10^3 gal	lbs per 10^6 Btu
Heavy Oil[4]	all types	157.00 x S	47	173.72
Light Oil[4]	all types	142.00 x S	20	159.41
Diesel	all types	142.00 x S	20	161.27
Kerosene	all types	142.00 x S	20	159.41
Butane (liquid)	all types	0.09	21	143.2
Fish Oil	all types	0.5	12.4	0
Methanol	all types	0.5	12.4	138.15
Oil Waste	all types	147.00 x S	19	163.61
Propane (liquid)	all types	0.5	19	139.04
Sludge Oil	all types	147.00 x S	19	0
Tar Oil	all types	162.70 x S	67	0
Waste Alcohol	all types	0.5	12.4	138.15

Natural Gas and Other Gaseous Fuels		lbs per 10^6 cf	lbs per 10^6 cf	lbs per 10^6 Btu
Natural Gas	all types	0.6	280	116.97
Butane (Gas)	all types	0.6	21	143.2
Hydrogen	all types	0	550	0
Landfill Gas	all types	0.6	550	115.12
Methane	all types	0.6	550	115.11
Other Gas	all types	0.6	550	141.54
Propane (Gas)	all types	0.6	19	139.04

Source: EIA, Electric Power Annual 2003, DOE/EIA-0348(2003) (Washington, D.C., December 2004) Table A1

Notes:

[1] Uncontrolled sulfur dioxide emission factors. "x S" indicates that the constant must be multiplied by the percentage (by weight) of sulfur in the fuel. Sulfur dioxide emission estimates from facilities with flue gas desulfurization equipment are calculated by multiplying uncontrolled emission estimates by one minus the reported sulfur removal efficiencies. Sulfur dioxide emission factors also account for small quantities of sulfur trioxide and gaseous sulfates.

[2] Parenthetic values are for wet bottom boilers; otherwise dry bottom boilers. If bottom type is unknown, dry bottom is assumed. Emission factors are for boilers with a gross heat rate of 100 million Btu per hour or greater.

[3] Uncontrolled carbon dioxide emission estimates are reduced by 1% to account for unburned carbon.

[4] Oil types are categorized by Btu content as follows: heavy (greater than or equal to 144,190 Btu per gallon), and light (less than 144,190 Btu per gallon). cf = Cubic Feet. gal = U.S. Gallons. lbs = Pounds.

Table 12.7 – Global Warming Potentials (GWP)

(100-year time horizon)

Gas	GWP
	SAR
Carbon dioxide (CO2)	1
Methane (CH_4)[1]	21
Nitrous oxide (N_2O)	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{14}	7,400
SF_6	23,900

Source: EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003*, EPA 430-R-05-004 (PUBLIC DRAFT FEBRUARY 2005), Table ES-1.

Notes:

The GWP of a greenhouse gas is the ratio of global warming, or radiative forcing – both direct and indirect – from one unit mass of a greenhouse gas to that of one unit mass of carbon dioxide over a period of time.

GWP from Intergovernmental Panel and Climate Change (IPCC) Second Assessment Report (SAR) and Third Assessment Report (TAR).

Although the GWPs have been updated by the IPCC, estimates of emissions presented in this report use the GWPs from the Second Assessment Report. The UNFCCC reporting guidelines for national inventories were updated in 2002, but continue to require the use of GWPs from the SAR so that current estimates of aggregated greenhouse gas emissions for 1990 through 2001 are consistent with estimates developed prior to the publication of the TAR. Therefore, to comply with international reporting standards under the UNFCCC, official emission estimates are reported by the United States using SAR GWP values.

[1] The methane GWP includes direct effects and those indirect effects due to the production of tropospheric ozone and stratospheric water vapor.

The indirect effect due to the production of CO_2 is not included.

Table 12.8 – Approximate Heat Content of Selected Fuels for Electric Power Generation

Fossil Fuels [1]	
Residual Oil (million Btu per barrel)	6.287
Distillate Oil (million Btu per barrel)	5.825
Natural Gas (Btu per million cubic ft)	1,020
Coal (million Btu per Short Ton)	20.381
Biomass Materials [2]	
Switchgrass Btu per pound	7,341
Bagasse, Btu per pound	6,065
Rice Hulls, Btu per pound	6,575
Poultry Litter, Btu per pound	6,187
Solid wood waste, Btu per pound	6-8,000

Sources:

1. EIA, *Annual Energy Outlook 2005*, DOE/EIA-0383 (2005) (Washington, D.C., February 2005), Table H1.
2. Animal Waste Screening Study, Electrotek Concepts, Inc., Arlington, VA. June 2001.

Table 12.9 – Approximate Heat Rates for Electricity

(Btu per Kilowatthour)

	1980	1990	2000	2001	2002	2003
Fossil-Fueled Steam-Electric Plants[1]	10,388	10,402	10,201	10,146	10,119	10,107
Nuclear Steam-Electric Plants[2]	10,908	10,582	10,429	10,448	10,439	10,439
Geothermal Energy Plants[3]	21,639	21,096	21,017	21,017	21,017	21,017

Source: EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Table A6

Notes:

[1] Through 2000, used as the thermal conversion factor for wood and waste electricity net generation at electric utilities. For all years, used as the thermal conversion factor for hydroelectric, solar, and wind electricity net generation. Through 2000, heat rates are for fossil-fueled steam-electric plants at electric utilities. For 2001 and 2002, heat rates are for fossil-fueled steam-electric plants at electric utilities and independent power producers. For 2003, the heat rate is for all fossil-fueled plants at electric utilities and independent power producers

[2] Used as the thermal conversion factor for nuclear electricity net generation.

[3] Used as the thermal conversion factor for geothermal electricity net generation

Table 12.10 – Heating Degree Days by Month

	1980	1990	2000	2001	2002	2003	2004	Normal[1]
January	887	728	886	935	778	940	957	917
February	831	655	643	725	670	819	769	732
March	680	535	494	669	624	564	487	593
April	338	321	341	302	282	351	302	345
May	142	184	115	115	185	162	NA	159
June	49	29	29	29	23	39	NA	39
July	5	6	12	8	3	2	NA	9
August	10	10	12	6	8	2	NA	15
September	54	56	69	71	38	59	NA	77
October	316	246	244	267	299	252	NA	282
November	564	457	610	400	561	477	NA	539
December	831	789	1,005	696	813	773	NA	817
Total	4,707	4,016	4,460	4,223	4,284	4,440	NA	4,524

Source: EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Table 1.7

Notes:

[1] Based on calculations of data from 1971-2000

Data exclude Alaska and Hawaii. Beginning in 2002, data are weighted by the estimated 2000 population. The population-weighted state figures are aggregated into Census divisions and the national average.

Table 12.11 – Cooling Degree Days by Month

	1980	1990	2000	2001	2002	2003	2004	Normal[1]
January	9	15	10	3	8	2	5	9
February	4	14	10	12	6	6	5	8
March	13	21	25	11	17	20	26	18
April	23	29	28	37	53	38	41	30
May	95	86	131	114	92	106	NA	97
June	199	234	221	220	242	196	NA	213
July	374	316	284	302	369	334	NA	321
August	347	291	302	333	331	332	NA	290
September	192	172	156	138	202	155	NA	155
October	42	57	50	46	57	64	NA	53
November	10	16	8	18	11	24	NA	15
December	5	9	4	11	5	4	NA	8
Total	1,313	1,260	1,229	1,245	1,393	1,281	NA	1,215

Source: EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003) (Washington, D.C., September 2004), Table 1.8

Notes:

[1] Based on calculations of data from 1971-2000

Data exclude Alaska and Hawaii. Beginning in 2002, data are weighted by the estimated 2000 population. The population-weighted state figures are aggregated into Census divisions and the national average.

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