Power Technologies Energy Data Book

Fourth Edition

NREL National Renewable Energy Laboratory

Prepared for the Office of Energy Efficiency and Renewable Energy

August 2006 • NREL/TP-620-39728

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

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Fourth Edition

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1.1 - Introduction

About the Power Technologies Energy Data Book (PTEDB), Fourth 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 policy makers 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.

New for this fourth edition of the PTEDB is Chapter 13, which features Geographic Information System (GIS) maps. One set of maps shows the natural resource (biomass, geothermal, solar, and wind) overlaid with the national transmission grid and the major electricity load centers. The other set of maps shows the current installed capacity (biomass, geothermal, concentrating solar power, and wind), as well as a bar chart indicating the historic trend of generating capacity for the state.

The PTEDB is organized into 13 chapters:

Chapter 1 - Introduction
Chapter 2 – Technology profiles
Chapter 3 – Electricity restructuring
Chapter 4 – Forecasts/comparisons
Chapter 5 – Electricity supply
Chapter 6 – Electricity capability
Chapter 7 – Electricity generation
Chapter 8 – Electricity demand
Chapter 9 – Prices
Chapter 10 – Economic indicators
Chapter 11 – Environmental indicators
Chapter 12 – Conversion factors
Chapter 13 – Geographic Information System (GIS) maps.

The sources used for the Power Technologies Energy Data Book represent the latest available data.

This edition updates the same type of information provided 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 fourth edition of the Power Technologies Energy Data Book, as well as previous editions, are available on the Internet at http://www.nrel.gov/analysis/power_databook/. The PTEDB may be downloaded as a single PDF file, individual chapters, or table 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 compared to fossil energy without carbon sequestration, such as coal, oil or natural gas. 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

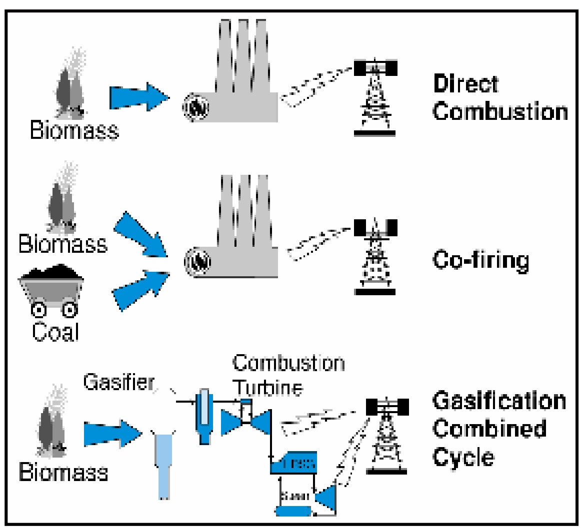
- *Homogenization* is a process by which feedstock is made physically uniform for further processing or for combustion (includes chopping, grinding, baling, cubing, and pelletizing).
- *Gasification* (via pyrolysis, partial oxidation, or steam reforming) converts biomass to a fuel gas that can be substituted 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, as is true for coal. 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 9,700 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 nonhydroelectric 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.
Technology History
• In the latter part of the 19^{th} 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 to in the wood-processing and pulp-and-paper sectors and increased supply of power to the grid. • The combination of low natural gas prices, improved economies of scale in combined cycle palns, and withdrawal of incentives in the late 1980s, led to annual installations declining from about 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 (draft update, September 2005).

Biomass

Market Data

Cumulative Generating Capability, by Type (MW)

Source: Energy Information Administration (EIA), EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), 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	2004
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	2,842	2,856
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	1,389
U.S. Cogenerators[3]													
Municipal Solid Waste[1]			659	786	998	1,062	1,058	1,046	1,094	834	842	961	961
Wood and Other Biomass[2]			4,585	5,298	5,382	5,472	5,364	5,311	4,655	4,394	4,399	4,482	4,502
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	3,803	3,817
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	5,871	5,891
Biomass Total	78	351	8,061	10,269	10,405	10,515	10,495	10,454	10,024	9,709	9,689	9,674	9,708
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)	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
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	18,141	17,809
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	7,402	7,475
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	4,938
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	29,820
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	23,736	22,747
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	37,529	37,295
Biomass Total	433	1,383	45,415	56,926	57,712	58,658	58,786	59,613	60,726	56,964	61,522	61,265	60,042
Rest of World Total[4]							101,214						
World Total							160,000						

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.

[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)	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
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	493.1	492.4
Commercial Sector[1]			16.7	22.3	32.1	34.3	32.7	33.5	26.5	22.6	28.5	30.6	32.2
Industrial Sector[1]			351.0	385.3	407.1	380.7	362.0	373.0	378.8	379.6	481.5	378.7	567.8
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	902.4	1,092.4

Source: EIA, *Annual Energy Review 2004*, Tables 8.4b and 8.4c

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.

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 that 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*.

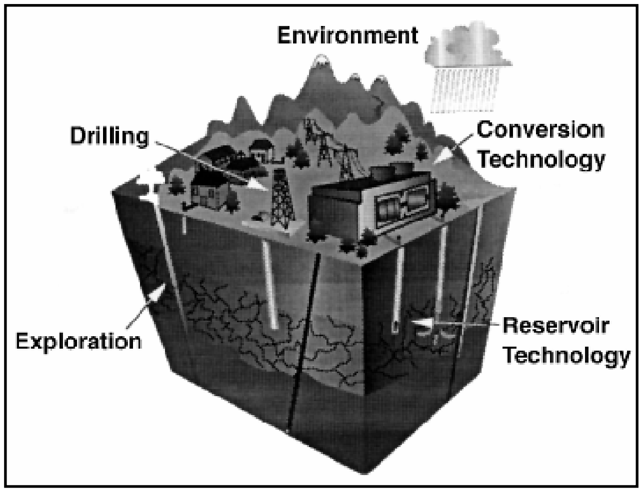
Geothermal Energy

Technology Description

Geothermal energy is heat from within the Earth. Hot water or steam are used to produce electricity or applied directly for space heating and industrial processes. This energy can offset the emission of carbon dioxide from conventional fossil-powered electricity generation, industrial processes, building thermal systems, and other applications.

System Concepts

- Geophysical, geochemical, and geological exploration locates resources to drill, including highly permeable hot reservoirs, shallow warm groundwater, hot impermeable rock masses, and highly pressured hot fluids.
- Well fields and distribution systems allow the hot fluids to move to the point of use, and afterward, back to the earth.
- Utilization systems may apply the heat directly or convert it to another form of energy such as electricity.



Representative Technologies

- Exploration technologies identify geothermal reservoirs and their fracture systems; drilling, reservoir testing, and modeling optimize production and predict useful lifetime; steam turbines use natural steam or hot water flashed to steam to produce electricity; binary conversion systems produce electricity from water not hot enough to flash.
- Direct applications use the heat from geothermal fluids without conversion to electricity. Geothermal heat pumps use the shallow earth as a heat source and heat sink for heating and cooling applications.
- Coproduction, the recovery of minerals and metals from geothermal brine, is being pursued. Zinc is recovered at the Salton Sea geothermal field in California.

Technology Applications

- With improved technology, the United States has a resource base capable of producing up to 100 GW of electricity at less than 5¢/kWh.
- Hydrothermal reservoirs are being used to produce electricity with an online availability of up to 97%; advanced energy-conversion technologies are being implemented to improve plant thermal efficiency.
- Direct-use applications are successful throughout the western United States and provide heat for space heating, aquaculture, greenhouses, spas, and other applications.
- Geothermal heat pumps continue to penetrate markets for heating/cooling (HVAC) services.

Current Status

- The DOE Geothermal Program sponsored research that won two R&D 100 Awards in 2003: Acoustic Telemetry Technology, which provides a high speed data link between the surface and the drill bit; and Low Emission Atmospheric Monitoring Separator, which safely contains and cleans vented steam during drilling, well testing, and plant start-up.
- A second pipeline to carry replacement water has been completed through the joint efforts of industry and federal, state, and local agencies. This will increase production and extend the lifetime of The Geysers Geothermal Field in California. The second pipeline adds 85 MW of capacity.

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.
- With approval of the federal production tax credit and with support from state-level renewable portfolio standards, U.S. geothermal power is poised to double in capacity within the next couple of years.

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.

- Costs at the best sites are competitive at today's energy prices – and investment is limited by uncertainty in prices; lack of new, confirmed resources; high front-end costs; and lag time between investment and return.
- Improvements in cost and accuracy of resource exploration and characterization can lower the electricity cost; demonstration of new resource concepts, such as enhanced geothermal systems, would allow a large expansion of the U.S. use of hydrothermal when economics become favorable.

Market Context

- Hydrothermal reservoirs have an installed capacity of about 2,133 MW electric in the United States and about 8,000 MW worldwide. Direct-use applications have an installed capacity of about 600 MW thermal in the United States. About 300 MW electric are being developed in California, Nevada, and Idaho.
- Geothermal will continue production at existing plants (2.1 GW) with future construction potential (100 GW by 2040). Direct heat will replace existing systems in markets in 19 western states.
- By 2015, geothermal could provide about 10 GW, enough heat and electricity for 7 million homes; by 2020, an installed electricity capacity of 20,000 MW from hydrothermal plants and 20,000 MW from enhanced geothermal systems is projected.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term*. DOE/PI-0002. November 2003 (draft update, September 2005).

Geothermal

Market Data

Cumulative Installed Capacity

Source: U.S. electricity data from EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), 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**	**2004**
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	2,133	2,133
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 Electric Plant 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 Electric Plant 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	163,439
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 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), 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	2004
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	14.4	14.4
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													
World Total				31.2			40		53.0				
			27.4		31.1			47.3					
					35.1								

Annual Geothermal Energy Consumption for Electric Generation (Trillion Btu)

Source: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table 8.4a.

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
U.S.	110	198	326	280	300	309	311	312	296	289	305	303	302
Rest of World													
World Total													

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

Source: EIA, *Renewable Energy Annual 2004*, DOE/EIA-0603(2004) (Washington, D.C., June 2006), Table 58.

	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001***	**2002**	**2003**	**2004**
ARI-320	4,696	4,697	7,772	10,510	7,910	7,808	N/A	6,445	10,306	9,130
ARI-325/330	26,800	25,697	28,335	26,042	31,631	26,219	N/A	26,802	25,211	31,855
Other non-ARI Rated	838	991	1,327	1,714	2,138	1,554	N/A	3,892	922	2,821
Totals	32,334	31,385	37,434	38,266	41,679	35,581	N/A	37,139	36,439	43,806

* No survey was conducted for 2001.

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

Source: EIA, *Renewable Energy Annual 2004*, DOE/EIA-0603(2004) (Washington, D.C., June 2006), Table 59.

	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001***	**2002**	**2003**	**2004**
ARI-320	13,120	15,060	24,708	35,776	27,970	26,469	N/A	16,756	29,238	23,764
ARI-325/330	113,925	92,819	110,186	98,912	153,947	130,132	N/A	96,541	89,731	100,317
Other non-ARI Rated	3,935	5,091	6,662	6,758	9,735	7,590	N/A	12,000	5,469	20,220
Totals	130,980	112,970	141,556	141,446	191,652	164,191	N/A	125,297	124,438	144,301

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 2004*, DOE/EIA-0603(2003) (Washington, D.C., June 2006), Table 61, REA 2003 Table 40, REA 2002 Table 40, REA 2001 Table 40, REA 2000 Table 38, REA 1999 Table 38, and REA 1998 Table 40.

	1996	**1997**	**1998**	**1999**	**2000**	**2001***	**2002**	**2003**	**2004**
Exporter	2,276	226	109	6,172	784	N/A	1,165	945	1,092
Wholesale Distributor	21,444	29,181	14,377	9,193	9,804	N/A	20,888	16,167	23,647
Retail Distributor	8,336	829	3,222	2,555	2,272	N/A	552	1,145	355
Installer	18,762	25,302	18,429	24,917	20,491	N/A	10,999	10,784	13,562

End User	689	657	994	66	63	N/A	207	1,103	397
Others	13	1,727	1,135	6,259	2,167	N/A	3,328	6,295	4,753
Total	51,520	57,922	38,266	49,162	35,581	N/A	37,139	36,439	43,806

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

Source: EIA, *Renewable Energy Annual 2004*, DOE/EIA-0603(2003) (Washington, D.C., June 2006), Table 60, REA 2003 Table 39, REA 2002 Table 39, REA 2001 Table 39, REA 2000 Table 37, REA 1999 Table 37, and REA 1998 Table 39.

	1996	**1997**	**1998**	**1999**	**2000**	**2001***	**2002**	**2003**	**2004**
Export	4,090	2,427	481	6,303	1,220	N/A	3,271	2,764	2,984
Midwest	11,874	13,402	12,240	13,112	10,749	N/A	12,982	12,042	14,650
Northeast	6,417	9,280	5,403	6,044	4,138	N/A	3,903	5,924	8,060
South	25,302	26,788	16,195	20,935	17,403	N/A	13,660	12,543	14,674
West	3,837	6,025	3,947	2,768	2,071	N/A	3,323	3,166	3,438
Total	51,520	57,922	38,266	49,162	35,581	N/A	37,139	36,439	43,806

Technology Performance

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

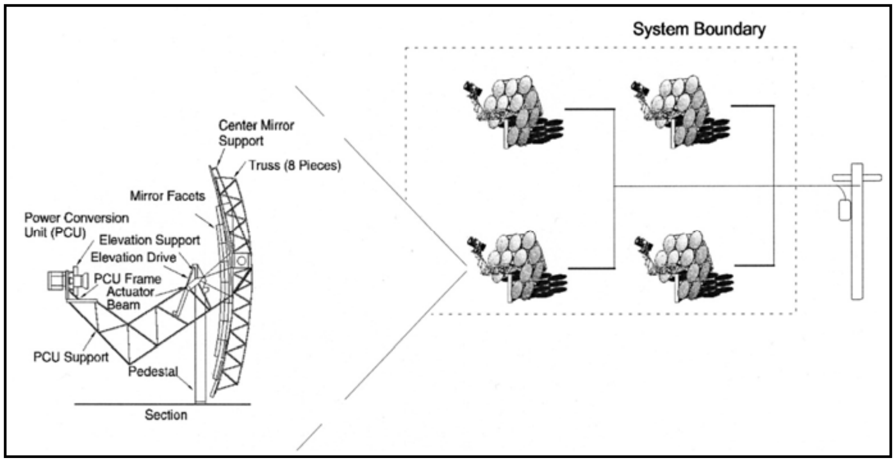
Efficiency		**1980**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Capacity Factor (%)	Flashed Steam			89	92	93	95	96	96
	Binary			89	92	93	95	96	96
	Hot Dry Rock			80	81	82	83	84	85
Cost		**1980**	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**
Capital Cost ($/kW)	Flashed Steam			1,444	1,372	1,250	1,194	1,147	1,100
	Binary			2,112	1,994	1,875	1,754	1,696	1,637
	Hot Dry Rock			5,519	5,176	4,756	4,312	3,794	3,276
Fixed O&M ($/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 10,000 times to produce high-temperature thermal energy, which is used to produce electricity for distributed or bulk generation process applications.

System Concepts



- In CSP systems, highly reflective sun-tracking mirrors produce temperatures of 400°C to 800°C 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 solar-to-electric efficiencies for the system of up to 30%.
- CSP technologies provide firm, nonintermittent electricity generation (peaking or intermediate load capacity) when coupled with storage.
- Because solar-thermal technologies can yield extremely high temperatures, the technologies could some day be used for direct conversion (rather than indirect conversion through electrochemical reactions) of natural gas or water into hydrogen for future hydrogen-based economies.

Representative Technologies

- A parabolic trough system focuses solar energy on a linear oil-filled receiver to collect heat to generate steam to power a steam turbine. When the sun is not shining, steam can be generated with a fossil fuel to meet utility needs. Some of the new trough plants include thermal storage. Plant sizes can range from 1.0 to 100 MW_e.
- 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 extremely efficiently to allow power production to match utility demand, even when the sun is not shining. Plant size can range from 30 to 200 MW_e.
- A dish/engine system 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 2-25 kW in size and can be used individually or in small groups for distributed, remote, or village power; or in clusters (1-10 MW_e) for utility-scale applications, including end-of-line support. They are easily hybridized with fossil fuel.

Technology Applications

- Nine parabolic trough plants, with a rated capacity of 354 MW_e, have been operating in California since the 1980s. Trough system electricity costs of about 12¢-14¢/kWh have been demonstrated commercially.
- Solar Two, a 10-MW_e pilot power tower with three hours of storage, provided all the 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.

Current Status
• New commercial plants are being considered for California, Nevada, New Mexico, Colorado, and Arizona. A 1MW power plant began operation in Arizona in 2005. • The 10-MW Solar Two pilot power tower plant operated successfully near Barstow, California, leading to the first commercial plant being planned in Spain. • Operations and maintenance costs have been reduced through technology improvements at the commercial parabolic trough plants in California by 40%, saving plant operators $50 million.
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%. 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 2003$/kWh) for three CSP configurations are projected at:

	2003	2007	2012	2025
Trough	11.3	6.4	5.4	N/A
Power Tower	12.0	5.7	4.0	N/A
Dish/Engine	40.0	20.0	N/A	6

Source: *Solar Energy Technologies Program Multiyear Technical Plan*, NREL Report No. MP-520-33875; DOE/GO-102004-1775.

- Parabolic troughs have been commercialized and nine plants (354 MW total) have operated in California since the 1980s.
- A 64-MW parabolic trough plant is under construction near Boulder City, Nevada. Nevada Power and Sierra Pacific Power will purchase the power to comply with the solar portion of Nevada's renewable portfolio standard.
- The World Bank's Solar Initiative is pursuing CSP technologies for less-developed countries. The World Bank considers CSP to be a primary candidate for Global Environment Facility funding.

Market Context

- There is currently 350 MW of CSP generation in the United States, all of it in Southern California's Mojave Desert.
- Power purchase agreements have been signed for 800 MW of new dish/engine capacity in California. The plants are anticipated to come on-line within the next several years. Significant domestic and international interest will likely result in additional projects.
- According to a recent study commissioned by the Department of Energy, CSP technologies can achieve significantly lower costs (below 6¢/kWh) at modest production volumes.
- At Congress' request, DOE scoped out what would be required to deploy 1,000MW of CSP in the Southwest United States. DOE is actively engaged with the Western Governors' Association to map a strategy to deploy 1-4 GW of CSP in the Southwest by 2015.
- A near-term to midterm opportunity exists to build production capacity in the United States for both domestic use and international exports.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003 (draft update, September 2005).

Concentrating Solar Power

Market Data

U.S. Installations (electric only)

Source: *Renewable Electric Plant 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* 1998-2006, Table A16, Renewable Resources in the Electric Supply, 1993, Table 4.

	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
U.S.	1*	0.82	0.90	0.89	0.89	0.87	0.49	0.54	0.54	0.57	0.58

* 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 2004,* Table 10.3 and *Renewable Energy Annual 2004* Table 30.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004[P]
Total[1]	19,398	NA	11,409	7,666	7,616	8,138	7,756	8,583	8,354	11,189	11,663	11,444	14,114
Imports	235	NA	1,562	2,037	1,930	2,102	2,206	2,352	2,201	3,502	3,068	2,986	3,723
Exports	1,115	NA	245	530	454	379	360	537	496	840	659	518	813

[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. [P] = Preliminary

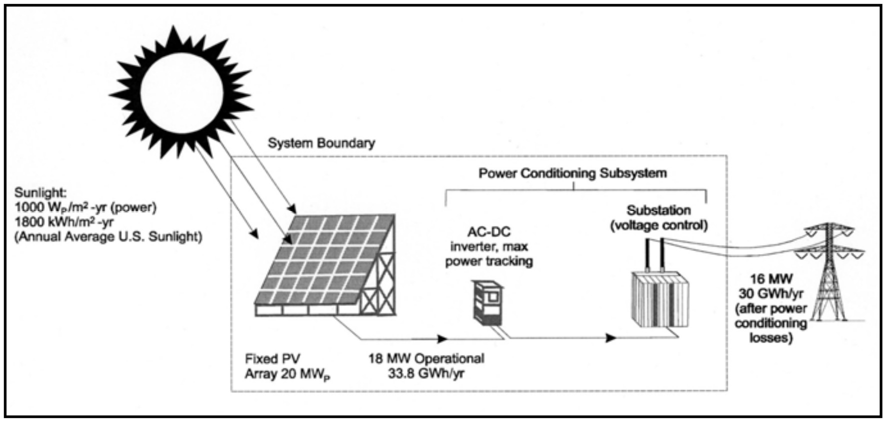
Technology Performance

Efficiency	Source: *Solar Energy Technologies Program Multiyear Technical Plan,* NREL Report No. MP-520-33875; DOE/GO-102004-1775.						
		2003	**2005**	**2007**	**2012**	**2018**	**2025**
Capacity Factor (%)	Power Tower	78	75	73	NA	72	NA
	Trough	28	39	56	56	NA	NA
	Dish	24	NA	24	NA	NA	50
Solar to Electric Eff. (%)	Power Tower	14	16	17	NA	18	NA
	Trough	13	13	16	17	NA	NA
	Dish	20	NA	23	NA	NA	26
Cost*		**2003**	**2005**	**2007**	**2012**	**2018**	**2025**
Total ($/kWe)	Power Tower	6800	4100	3500	NA	2500	NA
	Trough	2805	3556	3422	2920	NA	NA
	Dish	NA	NA	NA	NA	NA	NA
O&M ($/kWh)	Power Tower	.04	.01	.01	NA	.01	NA
	Trough	.02	.01	.01	.007	NA	NA
	Dish	NA	NA	NA	NA	NA	NA
Levelized Cost of Energy ($/kWh)	Power Tower	.12	.06	.06	NA	.04	NA
	Trough	.11	.10	.06	.05	NA	NA
	Dish	.40	NA	.20	NA	NA	.06

Photovoltaics

Technology Description

Solar photovoltaic (PV) arrays use semiconductor devices called solar cells to convert sunlight to electricity without moving parts and without producing fuel wastes, air pollution, or greenhouse gases. Using solar PV for electricity – and eventually using solar PV to produce hydrogen for fuel cells for electric vehicles, by producing hydrogen from water – will help reduce carbon dioxide emissions 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., semitransparent solar canopy). The DC output from PV can be conditioned into grid-quality AC electricity, or DC can be used to charge batteries or to split water to produce hydrogen (electrolysis of water).
- PV systems are expected to be used in the United States for residential and commercial buildings, peak-power shaving, and intermediate daytime load. With energy storage, PV can provide dispatchable electricity and/or produce hydrogen.
- Almost all locations in the United States and worldwide have enough sunlight for cost-effective PV. For example, U.S. sunlight in the contiguous states 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 (for example, on roofs or above parking lots), a PV-generating station 140 km by 140 km sited at a high solar insolation location in the United States (such as the desert Southwest) 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).

Representative Technologies

- Wafers of single-crystal or polycrystalline silicon – best cells: 25% efficiency; commercial modules: 12%-17%. Silicon modules dominate the PV market and currently cost about $\$2/W_p$ to manufacture.
- Thin-film semiconductors (e.g., amorphous silicon, copper indium diselenide, cadmium telluride, and dye-sensitized cells) – best cells: 12%-19%; commercial modules: 6%-11%. 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.
- High-efficiency, single-crystal silicon and multijunction gallium-arsenide-alloy cells for concentrators – best cells: 27%-39% efficient; precommercial modules: 15%-24%; prototype systems are being tested in high solar areas in the southwest United States.
- Grid-connected PV systems currently sell for about $\$6$-$\$7/W_p$ (17¢-22¢/kWh), including support structures, power conditioning, and land.

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 1 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

- Because of public/private partnerships, such as the Thin-Film Partnership with its national research teams, U.S. PV technology leads the world in measurable results such as record efficiencies for cells and modules. Another partnership, the PV Advanced Manufacturing R&D program, has resulted in industry cost reductions of more than 60% and facilitated a sixteen-fold increase of manufacturing capacity during the past 12 years.
- A new generation of potentially lower-cost technologies (thin films) is entering the marketplace. A 30-megawatt amorphous silicon thin-film plant by United Solar reached full production in 2005. Two plants (First Solar and Shell Solar) using even newer thin films (cadmium telluride and copper indium diselenide alloys) are in first-time manufacturing at the MW-scale. Thin-film PV has been a focus of the federal R&D efforts of the past decade, because it holds promise for module cost reductions.
- During the past two years, record sunlight-to-electricity conversion efficiencies for solar cells were set by federally funded universities, national labs, or industry in copper indium gallium diselenide (19%-efficient cells and 13%-efficient modules) and cadmium telluride (16%-efficient cells and 11%-efficient modules). Cell and module efficiencies for these technologies have increased more than 50% in the past decade.
- A unique multijunction (III-V materials alloy) cell was spun off to the space power industry, leading to a record cell efficiency (35%) and an R&D 100 Award in 2001. This device configuration is expected to dominate future space power for commercial and military satellites. Recent champion cell efficiency has reached 39% under concentrated sunlight. DOE is interested in this technology (III-V multijunctions), as an insertion candidate for high efficiency terrestrial PV concentrator systems.

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% 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, increasing 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 2003$/kWh) for PV are projected to be:

	2003	2007	2020	2025
Utility-owned Residential (crystalline Si)	0.25-0.40	0.22	0.8-0.10	NA
Concentrator	0.40	0.20	NA	0.04-0.06

Source: *Solar Energy Technologies Program Multiyear Technical Plan,* NREL Report No. MP-520-33875; DOE/GO-102004-1775.

- Worldwide, approximately 1,200 MW of PV were sold in 2004, with systems valued at more than $7 billion; total installed PV is more than 2 GW. The U.S. world market share fell to about 12% in 2004.
- Worldwide, market growth for PV has averaged more than 20%/year for the past decade as a result of reduced prices and successful global marketing. Worldwide sales grew 36% in 2001, 44% in 2002, 33% in 2003, and 60% in 2004.
- Hundreds of applications are cost-effective for off-grid needs. However, the fastest-growing segment of the market is battery-free, grid-connected PV, such as roof-mounted arrays on homes and commercial buildings in the United States. California is subsidizing PV systems to reduce their dependence on natural gas, especially for peak daytime loads that match PV output, such as air-conditioning.

Market Context

- Electricity for remote locations, especially for billions of people worldwide who do not have electricity.
- U.S. markets include retail electricity for residential and commercial buildings; distributed utility systems for grid support, peak-shaving, and other daytime uses (e.g., remote water pumping).
- Future electricity and hydrogen storage for dispatchable electricity, electric car-charging stations, and hydrogen production for portable fuel.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003 (draft update, September 2005).

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 2004,* DOE/EIA-0384(2004) (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	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total	5.8	13.8	31.1	35.5	46.4	50.6	76.8	88.2	97.7	112.1	109.4	181.1
Imports	0.3	1.4	1.3	1.9	1.9	1.9	4.8	8.8	10.2	7.3	9.7	47.7
Exports	1.7	7.5	19.9	22.4	33.8	35.5	55.6	68.4	61.4	66.8	60.7	102.8
Domestic Total On-Grid*	0.4	0.2	1.7	1.8	2.2	4.2	6.9	4.9	10.1	13.7	18.9	55.9
Domestic Total Off-Grid*	3.7	6.1	9.5	11.2	10.3	10.8	14.4	15.0	26.2	31.6	29.8	22.4

Cumulative Shipments (since 1982)	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Total	35.2	84.7	193.3	228.8	275.2	325.7	402.5	490.7	588.4	700.5	809.8	991.0
Imports	1.0	5.6	14.3	16.2	18	19.9	24.7	33.5	43.7	51.0	60.8	108.5
Exports	5.7	32.9	104	126.5	160.3	195.8	251.3	319.7	381.0	447.8	508.5	611.3
Domestic Total On-Grid*	2.9	4.7	8.2	10.0	12.2	16.5	23.3	28.2	38.3	52.0	70.9	126.9
Domestic Total Off-Grid*	26.6	47.2	81.1	92.3	102.7	113.5	127.9	142.8	169.0	200.6	230.4	252.8

* Domestic Totals include imports and exclude exports. Electricity generation only, excludes water pumping, communications, transportation, consumer goods, health, and original equipment manufacturers.

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., Comm.			1		7	27	36	60	120	199	270
Central Station (>100kW)			1		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											-
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** 0	**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
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; REA 2003, Table 28.											
	1985	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Single-Crystal Silicon			19.9	21.7	30	30.8	47.2	51.9	54.7	74.7	59.4	94.9
Cast and Ribbon Crystalline Silicon			9.9	12.3	14.3	16.4	26.2	33.2	29.9	29.4	38.6	64.2
Crystalline Silicon Total	5.5	12.5	29.8	34	44.3	47.2	73.5	85.2	84.7	104.1	98.0	159.1
Thin-Film Silicon	0.3	1.3	1.3	1.4	1.9	3.3	3.3	2.7	12.5	7.4	11.0	22.0
Concentrator Silicon			0.1	0.2	0.2	0.1	0.1	0.3	0.5	0.6	0.5	0
Other												
Total	5.8	13.8	31.2	35.6	46.3	50.6	76.8	88.2	97.7	112.1	109.5	181.1

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.								
	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.								
	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.							
	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: *Solar Energy Technologies Program Multiyear Technical Plan,* NREL Report No. MP-520-33875; DOE/GO-102004-1775.

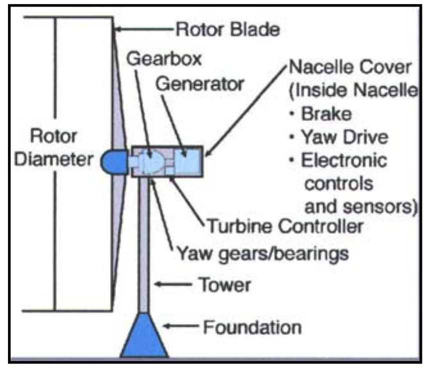
Efficiency		**2003**	**2007**	**2020**	**2025**
Cell (%)	Crystalline Silicon	NA	NA	NA	NA
	Concentrator	25	33	NA	40
Module (%)	Crystalline Silicon	14	15	15-20	NA
	Concentrator	NA	NA	NA	NA
System (%)	Crystalline Silicon	11.5	14	16	NA
	Concentrator	15	22	NA	33
Cost		**2003**	**2007**	**2020**	**2025**
Module ($/Wp)	Crystalline Silicon	4.80	2.50	1.00-1.50	NA
($/m^2)	Concentrator	160	90	NA	80
BOS ($/Wp)	Crystalline Silicon	0.85	0.60	0.40	NA
	Concentrator	0.60	0.30	NA	0.15
Total Installed System ($/Wp)	Crystalline Silicon *	6.20-9.50	5.20	2.30-2.80	NA
	Concentrator	NA	NA	NA	NA
O&M ($/kWh)	Crystalline Silicon	0.08	.0.02	0.005	NA
	Concentrator	0.02	0.01	NA	0.005

Wind Energy

Technology Description

Wind turbine technology converts the kinetic energy in wind to electricity. Grid-connected wind power reduces greenhouse gas 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 in developing countries.

System Concepts



- Most modern wind turbines operate using aerodynamic lift generated by airfoil-type blades, yielding much higher efficiency than traditional windmills that relied on wind "pushing" the blades. Lifting forces spin the blades, driving a generator that produces electric power in proportion to wind speed. Turbines either rotate at constant speed and directly link to the grid, or at variable speed for better performance, using a power electronics system for grid connection. Utility-scale turbines for wind plants range in size up to several megawatts, and smaller turbines (under 100 kilowatts) serve a range of distributed, remote, and stand-alone power applications.

Representative Technologies

- The most common machine configuration is a three-bladed wind turbine, which operates "upwind" of the tower, with the blades facing into the wind. To improve the cost-effectiveness of wind turbines, technology advances are being made for rotors and controls, drive trains, towers, manufacturing methods, site-tailored designs, and offshore and onshore foundations.

Technology Applications

- In the United States, the wind energy capacity exploded from 1,600 MW in 1994 to more than 9,200 MW by the end of 2005 – enough to serve more than 2.5 million households.
- Current performance is characterized by levelized costs of 3¢-5¢/kWh (depending on resource quality and financing terms), capacity factors of 30%-50%, availability of 95-98%, total installed costs of approximately $1,000-$1,300/kW, and efficiencies of 65%-75% of theoretical (Betz limit) maximum.

Current Status

- In 1989, the wind program set a goal of 5¢/kWh by 1995 and 4¢/kWh by 2000 for sites with average wind speeds of 16 mph. The program and the wind industry met the goals as part of dramatic cost reductions from 25¢-50¢/kWh in the early 1980s to 4¢-6¢/kWh today (2005).
- Wind power is the world's fastest-growing energy source. In the past decade, the global wind energy capacity has increased tenfold from 3,500 MW in 1994 to almost 50,000 MW by the end of 2004. During 2004, nearly 8,000 MW of new capacity was added worldwide.
- 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 throughout the country.
- The National Wind Technology Center (operated by the National Renewable Energy Laboratory in Golden, Colorado) is recognized as a world-class center for wind energy R&D and has many facilities – such as blade structural test stands and a large gearbox test stand – not otherwise available to the domestic industry.

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.
- In 2004, Clipper Windpower began testing on its highly innovative, multiple-drive 2.5 MW Liberty prototype wind turbine.
- In 2005, the U.S. wind energy industry had a record-breaking year for new installations, adding more than 2,400 MW of new capacity to the nation's electric grid.
- In 2006, the U.S. Department of Energy signed a $27 million contract with General Electric to develop a multimegawatt offshore wind power system; and Clipper Windpower begins manufacturing its multiple-drive, 2.5 MW turbine.

Technology Future

The levelized cost of electricity (2002 $/MWh) for wind energy technology is projected to be:

	2005	2010	2020	2030	2040	2050
Class 4	5.5	4.0	3.1	2.9	2.9	2.8
Class 6	4.1	3.0	2.6	2.5	2.4	2.3

Source: *Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs – FY 2006 Budget Request*, NREL/TP-620-37931, May 2005.

- Installed wind capacity in the United States expanded from 2,554 MW to 4,150 MW during the period of 2000 to 2005, but still make up less than 1% of total U.S. generation.
- California has the greatest installed wind capacity, followed by Texas, Iowa, Minnesota, Oregon, Washington, Wyoming, New Mexico, Colorado, and Oklahoma.
- Wind technology is competitive today in bulk power markets at Class 5 and 6 wind sites, with support from the production tax credit – and in high-value niche applications or markets that recognize non-cost attributes. Its competitiveness is negatively affected by policies regarding ancillary services and transmission and distribution regulations.
- Continued cost reductions from low wind-speed technologies will increase the resource areas available for wind development by 20-fold and move wind generation five times closer to major load centers.
- Wind energy is often the least variable cost source of generation in grid supplied electricity and due to its less predictable (variable resource) supply; wind usually displaces natural gas and coal generated electricity as these sources adjust to hourly changes in demand and supply. Emerging markets for wind energy include providing energy for water purification, irrigation, and hydrogen production.

- 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, leaving wind power at a disadvantage.
- In the United States, the wind industry is thinly capitalized, except for General Electric Wind Energy, which recently acquired wind technology and manufacturing assets in April 2002. About six manufacturers and six to 10 developers characterize the U.S. industry.
- In Europe, there are about 10 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.
- 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. Because the wind resource is variable, 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 onshore wind turbines. However, offshore resources are located close to major load centers.
- Small wind turbines (100 kW and smaller) for distributed and residential grid-connected applications are being used to harness the nation's abundant wind resources and defer impacts to the long-distance transmission market. Key market drivers include state renewable portfolio standards, incentive programs, and demand for community-owned wind applications.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003 (draft update, September 2005).

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 Electric Plant 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 and Global Energy Concepts.*

Annual State-Installed Capacity (MW)

Top 10 States	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
California*		N/A	N/A	3.0	0.0	8.4	0.7	250.0	0.0	67.1	108.0	206.3	99.7	61.9
Texas		0	0	41.0	0.0	0.0	0.0	139.2	0.0	915.2	0.0	203.5	0.0	701.8
Minnesota		0	0	0.0	0.0	0.2	109.2	137.6	17.8	28.6	17.9	239.8	52.1	145.3
Iowa		0	0	0.1	0.0	1.2	3.1	237.5	0.0	81.8	98.5	49.2	310.7	202.3
Wyoming		0	0	0.0	0.1	0.0	1.2	71.3	18.1	50.0	0.0	144.0	0.0	3.8
Oregon		0	0	0.0	0.0	0.0	25.1	0.0	0.0	131.8	64.8	41.0	0.0	75.0
Washington		0	0	0.0	0.0	0.0	0.0	0.0	0.0	176.9	48.0	15.6	0.0	149.4
Colorado		0	0	0.0	0.0	0.0	0.0	21.6	0.0	39.6	0.0	162.0	6.0	0.1
New Mexico		0	0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	205.3	60.0	140.0
Oklahoma		0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	176.3	0.0	298.3
Total of 10 States		N/A	N/A	44.1	0.1	9.8	139.3	858.5	35.9	1491.0	337.2	1443.0	528.5	1,777.8
Total U.S.		N/A	N/A	44.0	1.0	16.0	142.0	884.0	67.0	1694.0	449.7	1694.5	559.9	2,431.4

Top 10 States	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
California*		N/A	N/A	1,387.0	1,387.0	1,396.0	1,396.0	1,646.0	1,646.0	1,714.0	1,822.0	2,042.6	2,142.3	2,204.2
Texas		0	0	41.0	41.0	41.0	41.0	180.2	180.2	1,095.5	1,095.5	1,293.0	1,293.0	1,994.8
Minnesota		0	0	25.7	25.7	25.9	135.1	272.7	290.5	319.1	335.9	562.7	614.8	760.1
Iowa		0	0	0.7	0.8	2.0	5.0	242.5	242.5	324.2	422.7	471.2	781.9	984.2
Wyoming		0	0	0.0	0.1	0.1	1.3	72.5	90.6	140.6	140.6	284.6	284.6	288.4
Oregon		0	0	0.0	0.0	0.0	25.1	25.1	25.1	157.5	218.4	259.4	259.4	334.4
Washington		0	0	0.0	0.0	0.0	0.0	0.0	0.0	178.2	228.2	243.8	243.8	393.2
Colorado		0	0	0.0	0.0	0.0	0.0	21.6	21.6	61.2	61.2	223.2	229.2	229.3
New Mexico		0	0	0.0	0.0	0.0	0.0	1.3	1.3	1.3	1.3	206.6	266.6	406.6
Oklahoma			0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	176.3	176.3	474.6
Total of 10 states		N/A	N/A	1,454.4	1,454.6	1,465.0	1,603.5	2,461.9	2,497.8	3,991.6	4,325.8	5,763.4	6,291.9	8,069.7
Total U.S.	10.00	1039.0	1525.0	1,697.0	1,698.0	1,706.0	1,848.0	2,511.0	2,578.0	4,275.0	4,686.0	6,353.0	6,912.9	9,344.3

* 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 later.

Cumulative Installed Capacity (MW)	Source: U.S. - EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), 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**	**2004**
U.S.		17.5	1,799	1,731	1,678	1,610	1,720	2,252	2,377	3,864	4,417	5,995	6,190
IEA R&D Wind Countries[2]								10,040	15,440	21,553	27,935	35,275	
IEA Total	N/A		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 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005),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**	**2004**
U.S.	N/A	0.006	2.8	3.2	3.2	3.3	3.0	4.5	5.6	6.7	10.4	11.2	14.2
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 2004,* DOE/EIA-0384(2003) (Washington, D.C., September 2004), Table 8.4a											
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
U.S. Total	N/A	(s)	29.0	32.6	33.4	33.6	30.9	45.9	57.1	68.4	104.8	114.6	143.0
(s)=Less than 0.5 trillion Btu.													

Technology Performance

Energy Production		Source: *Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs – FY 2006 Budget Request,* NREL/TP-620-37931, May 2005.										
			2005	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	Capacity Factor (%)	Class 4	33.8	40.4	46.3	46.9	47.2	48.0	48.2	48.2	48.2	48.3
		Class 6	43.6	49.5	50.7	51.4	51.7	51.9	52.1	52.2	52.3	52.5

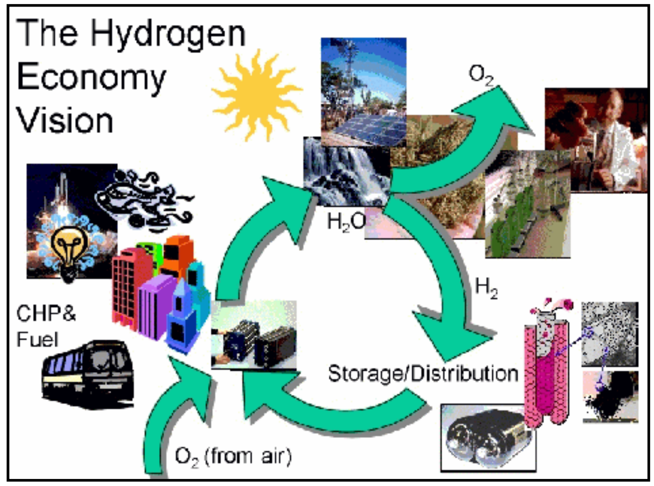
Cost (2002 dollars)		Source: *Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs – FY 2006 Budget Request,* NREL/TP-620-37931, May 2005.										
			2005	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	Capital Cost ($/kW)	Class 4	1103	982	919	893	866	866	861	856	851	840
		Class 6	1050	893	840	819	814	788	777	767	756	746
	O&M ($/kW)	Onshore	25.0	20.0	16.0	15.0	14.2	13.8	13.5	13.2	12.8	12.8

Levelized Cost of Energy* ($/kWh) (2002 dollars)	Source: *Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs – FY 2006 Budget Request,* NREL/TP-620-37931, May 2005.										
		2005	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
	Class 4	55.1	40.3	32.3	30.8	29.6	29.0	28.7	28.5	28.2	27.8
	Class 6	40.9	30.3	27.2	26.1	25.6	24.7	24.3	23.8	23.4	23.1

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 a clean 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 this 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 particulate matter, no carbon dioxide, and no pollution.

System Concepts

- Hydrogen 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.
- 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.

Polymer electrolyte membrane (PEM) fuel cell - The polymer electrolyte 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.

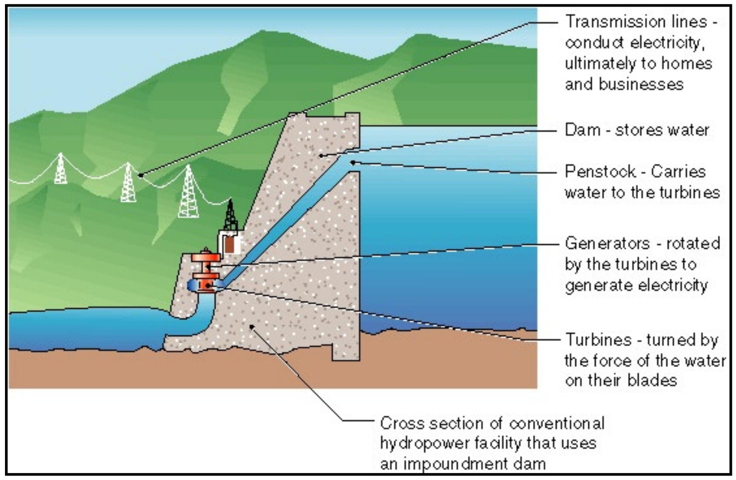
Current Status
• Currently, 48% of the worldwide production of hydrogen is via large-scale steam reforming of natural gas. Today, we safely use about 90 billion cubic meters (3.2 trillion cubic feet) of hydrogen yearly. • Hydrogen technologies are in various stages of development across the system: *Production* - 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 electrolyzer systems are 55-75% 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. Direct conversion of sunlight to hydrogen using a semiconductor-based photoelectrochemical cell was recently demonstrated at 12.4% efficiency. *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 bus and energy companies have been undertaken. Small-scale power systems using fuel cells fuel cells have been introduced to the power generation market, but subsidies are required to be economically competitive. Small fuel cells for battery replacement applications have been developed. The United States is conducting a major five-year learning demonstration of fuel cell vehicles and hydrogen infrastructure. Four teams comprised of automobile manufacturers and energy companies are conducting the study. • Major industrial companies are pursuing R&D in fuel cells and hydrogen production technologies with a mid-term time frame for deployment for both stationary and vehicular applications.
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—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 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 ($2-3/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.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003 (draft update, September 2005); and National Renewable Energy Laboratory. *Gas-Fired Distributed Energy Resource Technology Characterizations.* NREL/TP-620/34783. November 2003.

Advanced Hydropower

Technology Description



Hydroelectric power generates no greenhouse gas. To the extent that existing hydropower can be maintained or expanded through advances in technology, it can continue to be an important part of a greenhouse gas emissions-free energy portfolio. Advanced hydropower is technology that produces hydroelectricity both efficiently and with improved environmental performance. Traditional hydropower may have environmental effects, such as fish mortality and changes to downstream water quality and quantity. The goal of advanced hydropower is to maximize the use of water for generation while improving environmental performance.

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, or canals, or water released from upstream storage reservoirs.
- New environmental and biological criteria for turbine design and operation are being developed to help sustain hydropower's role as a clean, renewable energy source – and to enable upgrades of existing facilities and retrofits at existing dams.

Representative Technologies

- New turbine designs that improve survivability of fish that pass through the power plant.
- Autoventing turbines to increase dissolved oxygen in discharges downstream of dams.
- Re-regulating 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 and to optimize operation of reservoir systems.
- Advanced instrumentation and control systems that modify turbine operation to maximize environmental benefits and energy production.

Technology Applications

- Hydropower provides about 78,000 MW of the nation's electrical-generating capability. This is about 80 percent of the electricity generated from renewable energy sources.
- Existing hydropower generation faces a combination of real and perceived environmental effects, competing uses of water, regulatory pressures, and changes in energy economics (deregulation, etc.); potential hydropower resources are not being developed for similar reasons.
- Some new environmentally friendly technologies such as low head and low impact hydroelectric are being implemented in part stimulated by green power programs.
- DOE's Advanced Hydropower Turbine System (AHTS) program will be completing public-private partnerships with industry to demonstrate the feasibility of new turbine designs (e.g., aerating turbines at the Osage Dam, and a Minimum Gap Runner turbine at the Wanapum Dam).

Current Status
• TVA has demonstrated that improved turbine designs, equipment upgrades, and systems optimization can lead to significant economic and environmental benefits – energy production was increased approximately 12% while downstream fish resources were significantly improved. • Field-testing of the Kaplan turbine Minimum Gap Runner design indicates that fish survival can be significantly increased, if conventional turbines are modified. The full complement of Minimum Gap Runner design features will be tested at the Wanapum Dam in FY 2005.
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, it increased to 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
• Voith Siemens Hydro Power and the TVA have established a partnership to market environmentally friendly technology at hydropower facilities. Their products were developed partly by funding provided by DOE and the Corps of Engineers, as well as private sources. • In a competitive solicitation, DOE accepted proposals for advanced turbine designs from Voith Siemens, Alstom, American Hydro, and General Electric Co. Field verification and testing is underway with some of these designs to demonstrate improved environmental performance. • Flash Technology is developing strobe lighting systems to force fish away from hydropower intakes and to avoid entrainment mortality in turbines. Implementation at more sites may allow improved environmental performance with reduced spillage. Market Context • Advanced hydropower products can be applied at more than 80% of existing hydropower projects (installed conventional capacity is now 94 GW); the potential market also includes 15-20 GW at existing dams (i.e. no new dams required for development) and more than 30 GW of undeveloped hydropower. • Retrofitting advanced technology and optimizing system operations at existing facilities would lead to at least a 6% increase in energy output – if fully implemented, this would equate to 5 GW and 18,600 GWh of new, clean energy production.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003 (draft update, September 2005).

Hydroelectric Power

Market Data

U.S. Installed Capacity (MW)*	Source: *Renewable Electric Plant 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 2004, 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**	**2004**
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	78,694	78,703
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	20,522	20,522
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	99,216	99,225
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	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	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	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	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	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	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 2003*, 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			177	205	251	263	276	289	290	302	265	282
Western Europe			453	453	506	491	506	523	531	555	553	503
Former U.S.S.R.	128		205	231	238	215	216	225	227	228	239	243
Eastern Europe	432		26	23	34	34	36	35	35	31	30	32
China	184		91	125	184	185	193	203	211	241	258	309
Japan			82	88	81	80	89	92	86	86	83	81
Rest of World	27	273	328	435	504	515	522	533	541	558	571	581
	58											
World Total	88	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 2004 – 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	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Washington	19,935	20,487	20,431	20,923	21,012	21,011	21,011	21,006	21,016	21,018	20,941
California	12,687	13,519	13,500	13,475	13,383	13,445	13,475	13,471	13,523	13,306	13,323
Oregon	8,221	8,268	8,267	8,264	8,265	8,249	8,261	8,240	8,211	8,235	8,236
New York	5,345	5,545	5,557	5,565	5,668	5,662	5,659	5,712	5,804	5,842	5,891
Tennessee	3,717	3,818	3,818	3,937	3,950	3,950	3,950	3,948	3,948	3,948	3,948
Georgia	2,453	3,287	3,005	3,305	3,314	3,314	3,313	3,313	3,613	3,414	3,566
South Carolina	2,367	3,468	3,468	3,442	3,442	3,452	3,455	3,453	3,453	3,459	3,499
Virginia	3,072	3,126	3,149	3,082	3,093	3,090	3,091	3,088	3,088	3,088	3,088
Alabama	2,857	2,868	2,864	2,904	2,961	2,961	2,961	2,959	2,959	3,159	3,261
Arizona	2,685	2,885	2,885	2,893	2,893	2,890	2,890	2,890	2,893	2,899	2,903
U.S. Total	89,828	94,513	94,372	95,222	95,496	95,802	95,879	95,844	96,343	96,353	96,699

* 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	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Washington	87.5	82.5	98.5	104.2	79.8	97.0	80.3	54.7	78.2	71.8	71.6
Oregon	41.2	40.8	44.9	46.7	39.9	45.6	38.1	28.6	34.4	33.3	33.1
California	24.8	50.5	46.9	42.1	50.8	40.4	39.3	25.2	30.9	36.4	34.1
New York	27.1	24.8	27.8	29.5	28.2	23.6	23.9	22.2	24.1	24.3	24.0
Montana	10.7	10.7	13.8	13.4	11.1	13.8	9.6	6.6	9.6	8.7	8.9
Alabama	10.4	9.5	11.1	11.5	10.6	7.8	5.8	8.4	8.8	12.7	10.6
Idaho	9.1	11.0	13.3	14.7	12.9	13.5	11.0	7.2	8.8	8.4	8.5
Arizona	7.7	8.5	9.5	12.4	11.2	10.1	8.6	7.9	7.6	7.1	7.0
Tennessee	9.5	9.0	10.8	10.4	10.2	7.2	5.7	6.2	7.3	12.0	10.4
South Dakota	3.9	6.0	8.0	9.0	5.8	6.7	5.7	3.4	4.4	4.3	3.6
U.S. Total	289.4	308.1	344.1	352.4	318.9	313.4	270.0	208.1	255.6	275.8	268.4

* 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 2004, DOE/EIA-0384(2004) (Washington, D.C., August 2005) Table 8.4a*												
	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
U.S. Total	2,900	2,970	3,046	3,205	3,590	3,640	3,297	3,268	2,811	2,201	2,689	2,825	2,725
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.													

Building Technologies

Technology Description

Building equipment

Energy use in buildings depends on equipment to transform fuel or electricity into end-use services such as delivered heat or cooling, light, fresh air, vertical transport, cleaning of clothes or dishes, and information processing. There are energy-saving opportunities within individual pieces of equipment – as well as at the system level – through proper sizing, reduced distribution and standby losses, heat recovery and storage, and optimal control.

Building envelope

The building envelope is the interface between the interior of a building and the outdoor environment. In most buildings, the envelope – along with the outdoor weather – is the primary determinant of the amount of energy used to heat, cool, and ventilate. A more energy-efficient envelope means lower energy use in a building and lower greenhouse gas emissions. The envelope concept can be extended to that of the "building fabric," which includes the interior partitions, ceilings, and floors. Interior elements and surfaces can be used to store, release, control, and distribute energy, thereby further increasing the overall efficiency of the buildings.

Whole building integration

Whole building integration uses data from design (together with sensed data) to automatically configure controls and commission (i.e., start-up and check out) and operate buildings. Control systems use advanced, robust techniques and are based on smaller, less expensive, and much more abundant sensors. These data ensure optimal building performance by enabling control of building systems in an integrated manner and continuously recommissioning them using automated tools that detect and diagnose performance anomalies and degradation. Whole building integration systems optimize operation across building systems, inform and implement energy purchasing, guide maintenance activities, document and report building performance, and optimally coordinate on-site energy generation with building energy demand and the electric power grid, while ensuring that occupant needs for comfort, health, and safety were met at the lowest possible cost.

System Concepts

Building equipment

- Major categories of end-use equipment include heating, cooling, and hot water; ventilation and thermal distribution; lighting; home appliances; miscellaneous (process equipment and consumer products); and on-site energy and power.
- Key components vary by type of equipment, but some crosscutting opportunities for efficiency include improved materials, efficient low-emissions combustion and heat transfer, advanced refrigerants and cycles, electrodeless and solid-state lighting, smart sensors and controls, improved small-power supplies, variable-capacity systems, reduction of thermal and electrical standby losses, cogeneration based on modular fuel cells and microturbines, and utilization of waste heat from fuel cells and microturbines.

Building envelope

- Control of envelope characteristics provides control over the flow of heat, air, moisture, and light into the building. These flows and the interior energy and environmental loads determine the size and energy use of HVAC and distribution systems.

- Materials for exterior walls, roofs, foundations, windows, doors, interior partition walls, ceilings, and floors that can impact future energy use include insulation with innovative formula foams and vacuum panels; optical control coatings for windows and roofs; and thermal storage materials, including lightweight heat-storage systems.

Whole building integration

- The system consists of design tools, automated diagnostics, interoperable control-system components, abundant wireless sensors and controls, and highly integrated operation of energy-using and producing systems.
- These components would work together to collect data, configure controls, monitor operations, optimize control, and correct out-of-range conditions that contribute to poor building performance. Whole building integration would ensure that essential information – especially the design intent and construction implementation data – would be preserved and shared across many applications throughout the lifetime of the building.
- Equipment and system performance records would be stored as part of a networked building performance knowledge base, which would grow over time and provide feedback to designers, equipment manufacturers, and building operators and owners.
- Optimally integrate on-site power production with building energy needs and the electric-power grid by applying intelligent control to building cooling, heating, and power.

Representative Technologies

Building equipment

- Residential gas-fired absorption heat pumps, centrifugal chillers, desiccant preconditioners for treating ventilation air, heat-pump water heaters, proton exchange membrane fuel cells, heat pump water heaters, solid-state lighting, and lighting controls.
- Specialized HVAC (heating, ventilating, and air-conditioning) systems for research laboratories, server/data systems, and other buildings housing high-technology processes.

Building envelope

- *Superinsulation*: Vacuum powder-filled, gas-filled, and vacuum fiber-filled panels; structurally reinforced beaded vacuum panels; and switchable evacuated panels with insulating values more than four times those of the best currently available materials should soon be available for niche markets. High-thermal-resistant foam insulations with acceptable ozone depletion and global warming characteristics should allow for continued use of this highly desirable thermal insulation.
- *Advanced window systems*: Krypton-filled, triple-glazed, low-E windows; electrochromic glazing; and hybrid electrochromic/photovoltaic films and coatings should provide improved lighting and thermal control of fenestration systems. Advanced techniques for integration, control, and distribution of daylight should significantly reduce the need for electric lighting in buildings. Self-drying wall and roof designs should allow for improved insulation levels and increase the lifetimes for these components. More durable high-reflectance coatings should allow better control of solar heat on building surfaces.
- *Advanced thermal storage materials*: Dry phase-change materials and encapsulated materials should allow significant load distribution over the full diurnal cycle and significant load reduction when used with passive solar systems.

Whole building integration

- DOE is developing computer-based building commissioning and operation tools to improve the energy efficiency of “existing” buildings. It is also investing in the next generation of building-simulation programs that could be integrated into design tools.
- DOE, in collaboration with industry, also is developing and testing technologies for combined cooling, heating, and power; and wireless sensor and control systems for buildings.

Technology Applications

Building equipment

- Technology improvements during the past 20 years – through quality engineering, new materials, and better controls – have improved efficiencies in lighting and equipment by 15% to 75%, depending on the type of equipment. Efficiencies of compact fluorescent lamps are 70% better than incandescent lamps; refrigerator energy use has been reduced by more than three-quarters during the past 20 years; H-axis clothes washers are 50% more efficient than current minimum standards. Electronic equipment has achieved order-of-magnitude efficiency gains, at the microchip level, every two to three years.

Building envelope

- Building insulations have progressed from the 2-4 hr ºF ft^2/Btu/in. fibrous materials available before 1970 to foams reaching 7 hr ºF ft^2/Btu/in. Superinsulations of more than 25 ºF ft^2/Btu/in. will be available for niche markets soon. Improvements in window performance have been even more spectacular. In the 1970s, window thermal resistance was 1 to 2 ºF ft^2/Btu. Now, new windows have thermal resistance of up to 6 ºF ft^2/Btu (whole window performance). Windows are now widely available with selective coatings that reduce infrared transmittance without reducing visible transmittance. In addition, variable-transmittance windows under development will allow optimal control to minimize heating, cooling, and lighting loads.

Whole building integration

- Savings from improved operation and maintenance procedures could save more than 30% of the annual energy costs of existing commercial buildings, even in many of those buildings thought to be working properly by their owners/operators. These technologies would have very short paybacks, because they would ensure that technologies were performing as promised, for a fraction of the cost of the installed technology.
- Savings for new buildings could exceed 70%, using integration of building systems; and, with combined cooling, heating and power, buildings could become net electricity producers and distributed suppliers to the electric power grid.

Current Status

Building equipment

- Recent DOE-sponsored R&D, often with industry participation, includes an improved air-conditioning cycle to reduce oversizing and improve efficiency; a replacement for inefficient, high-temperature halogen up-lights (torchieres), which use only 25% of the power, last longer, and eliminate potential fire hazards; ozone-safe refrigerants, where supported R&D was directed toward lubrication materials problems associated with novel refrigerants and ground-source heat pumps.

Building envelope

- A DOE-sponsored RD&D partnership with the Polyisocyanurate Insulation Manufacturers Association, the National Roofing Contractors Association, the Society of the Plastics Industry, and Environmental Protection Agency (EPA) helped the industry find a replacement for chloroflurocarbons (CFCs) in polyisocyanurate foam insulation. This effort enabled the buildings industry to transition from CFC-11 to HCFC-141b by the deadline required by the Montreal protocol.
- Spectrally selective window glazings – which reduce solar heat gain and lower cooling loads – and high-performance insulating materials for demanding thermal applications are available.

Whole building integration

- Energy 10 models passive solar systems in buildings.
- DOE-2: international standard for whole building energy performance simulation has thousands of users. DOE released Energy Plus, new standard for building energy simulation and DOE-2 successor.
- The International Alliance for Interoperability is setting international standards for interoperability of computer tools and components for buildings.
- DOE-BESTEST is the basis for ANSI/ASHRAE Standard 140, Method of Test for the Evaluation of Building Energy Simulation Programs.

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
Building equipment • Building equipment, appliances, and lighting systems currently on the market vary from 20% to 100% efficient (heat pumps can exceed this level by using "free" energy drawn from the environment). This efficiency range is narrower where cost-effective appliance standards have previously eliminated the least-efficient models. • The stock and energy intensity of homes are growing faster than the building stock itself, as manufacturers introduce – and consumers and businesses eagerly accept – new types of equipment, more sophisticated and automated technologies, and increased levels of end-use services. • The rapid turnover and growth of many types of building equipment – especially electronics for computing, control, communications, and entertainment – represent important opportunities to rapidly introduce new, efficient technologies and quickly propagate them throughout the stock. • The market success of most new equipment and appliance technologies is virtually ensured if the efficiency improvement has a 3-year payback or better and amenities are maintained; technologies with payback of 4 to 8-plus years also can succeed in the market, provided that they offer other customer-valued features (e.g., reliability, longer life, improved comfort or convenience, quiet operation, smaller size, lower pollution levels). • Applications extend to every segment of the residential and nonresidential sectors. Major government, institutional, and corporate buyers represent a special target group for voluntary early deployment of the best new technologies. • Building equipment and appliances represent an annual market in the United States, alone, of more than $200B, involving thousands of large and small companies. Certain technologies, such as office and home electronics, compete in global markets with little or no change in performance specifications. ***Building envelope*** • A critical challenge is to ensure that new homes and buildings are constructed with good thermal envelopes and windows when the technologies are most cost-effective to implement. • The market potential is significant for building owners taking some actions to improve building envelopes. Currently, 40% of residences are well insulated, 40% are adequately insulated, and 20% are poorly insulated. More than 40% of new window sales are of advanced types (low-E and gas-filled). In commercial buildings, more than 17% of all windows are advanced types. More than 70% of commercial buildings have roof insulation; somewhat fewer have insulated walls. • Building products are mostly commodity products. A number of companies produce them; and each has a diverse distribution system, including direct sales, contractors, retailers, and discount stores. Another critical challenge is improving the efficiency of retrofits of existing buildings. Retrofitting is seldom cost-effective on a stand-alone basis. New materials and techniques are required. • Many advanced envelope products are cost-competitive now, and new technologies will become so on an ongoing basis. There will be modest cost reductions over time as manufacturers compete. • Building structures represent an annual market in the United States of more than $70B/year and involve thousands of large and small product manufacturers and a large, diverse distribution system that plays a crucial role in product marketing. Exporting is not an important factor in the sales of most building structure products. ***Whole building integration*** • The future vision of buildings technologies is one of "net zero energy" buildings which use a combination of integrated electricity generation--such as photovoltaics--paired with energy efficiency and power controls, to create a building that on average during a year produces enough energy for all the energy demands within the building. • Design tools for energy efficiency are used by fewer than 2% of the professionals involved in the design, construction, and operation of commercial buildings in the United States. A larger fraction of commercial buildings have central building-control systems. Few diagnostic tools are available commercially beyond those used for air-balancing or integrated into equipment (e.g., Trane Intellipack

System) and the recently announced air-conditioning diagnostic hand-held service tool by Honeywell (i.e. Honeywell HVAC Service Assistant). • The Department of Energy – in concert with the California Energy Commission – is testing a number of automated diagnostic tools and techniques with commercial building owners, operators, and service providers in an effort to promote commercial use. About 12 software vendors develop, support, and maintain energy design tools; most are small businesses. Another 15 to 20 building automation and control vendors exist in the marketplace – the major players include Johnson Controls, Honeywell, and Siemens. • Deployment involves four major aspects: seamless integration into existing building design and operation practices and platforms, lowering the cost of intelligent-building and enabling technologies, transforming markets to rapidly introduce new energy-efficient technologies, and a focus on conveying benefits that are desired in the marketplace (not only energy efficiency). • These technologies would apply to all buildings, but especially to existing commercial buildings and all new buildings. In addition, new technologies would be integrated into the building design and operation processes.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003 (draft update, September 2005).

For more data on the Buildings sector, please refer to the "**Buildings Energy Data Book**" which is a comprehensive collection of buildings- and energy-related data. The Buildings Energy Data Book is available online at http://buildingsdatabook.eren.doe.gov/

Solar Buildings

Market Data

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

Source: EIA, *Renewable Energy Annual 2004,* Table 38, REA 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**	**2004**
Annual													
Hot Water				755	765	595	463	373	367	274	423	511	452
Pool Heaters					6,787	7,528	7,201	8,141	7,863	10,797	11,073	10,800	13,634
Total Solar Thermal 1	18,283	19,166	11,164	6,763 7,136	7,162	7,759	7,396	8,046	7,857	10,349	11,004	10,926	14,114
Cumulative													
Hot Water				755	1,520	2,115	2,578	2,951	3,318	3,592	4,015	4,526	4,978
Pool Heaters				6,763	13,550	21,078	28,279	36,420	44,283	55,080	66,153	76,953	90,587
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	317,999

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**	**2004**
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	14,114
Imports		N/A	1,562	2,037	1,930	2,102	2,206	2,352	2,201	3,502	3,068	2,986	3,723
Exports	1,115	N/A	245	530	454	379	360	537	496	840	659	518	813

U.S. Shipments by Cell Type (Thousand sq. ft.)

Source: EIA *Annual Energy Review 2004,* Table 10.3; and *Renewable Energy Annual 2003,* Table 12.

	1980	**1985**	**1990**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
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	13,608
Medium-Temperature Collectors	7,165	N/A	2,527	840	785	606	443	427	400	268	535	560	506
High-Temperature Collectors	N/A	N/A	5,237	13	10	7	21	4	5	2	2	7	0
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	14,114

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.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Market Sector	0	0	0	0	0		0	0	0	0
Residential	1	7	7	18	0		1	2	7	0
Commercial	0	2	0	0	0		0	0	0	0
Industrial	9	0	0	2	4		1	0	0	0
Utility	3	0	0	1	0		0	0	0	0
Other	13	10	7	21	4		2	2	7	0
Total										
End Use	0	0	0	0	0		0	0	0	0
Pool Heating	0	7	7	18	0		0	0	0	0
Hot Water	0	0	0	0	0		0	0	0	0
Space Heating	1	0	0	0	0		0	0	0	0
Space Cooling	0	0	0	0	0		0	2	7	0
Combined Space and Water Heating	0	2	0	0	0		0	0	0	0
Process Heating	9	0	0	2	4		2	0	0	0
Electricity Generation	2	0	0	1	0		0	0	0	0
Other	13	10	7	21	4		2	2	7	0
Total	0	0	0	0	0		0	0	0	0

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.									
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Market Sector										
Residential	774	728	569	355	366		238	481	507	478
Commercial	51	50	35	70	59		23	69	44	0
Industrial	12	1	0	18	0		5	60	0	26
Utility	0	0	0	0			0	4	0	0
Other	3	7	2	0			1	1	2	3
Total	839	786	606	443	426		268	614	553	507
				0						
				2						
End Use										
Pool Heating	32	21	11	36	12		16	28	22	33
Hot Water	743	754	588	384	373		231	421	510	452
Space Heating	62	6	2	13	24		9	145	4	6
Space Cooling	0	0	0	0			0	0	0	0
Combined Space and Water Heating	2	2	3	8	16		12	15	16	16
Process Heating	0	1	0	0			0	4	0	0
				0						
Electricity Generation	0	0	0	0			0	0	0	0
Other	0	0	1	1			0	0	0	0
				0						
Total	839	784	605	442	427		268	614	553	507
				0						
				2						

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.									
	1995	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Market Sector										
Residential	6,192	6,146	6,791	6,810	7,408		9,885	10,519	9,993	12,386
Commercial	552	625	726	429	726		987	524	813	1,178
Industrial	69	51	7	44	18		12	2	71	44
Utility	0	0	0	0	0		0	0	0	0
Other	0	0	0	2	0		34	0	0	0
Total	6,813	6,822	7,524	7,285	8,152		10,919	11,046	10,877	13,608
End Use										
Pool Heating	6,731	6,766	7,517	7,164	8,129		10,782	11,045	10,778	13,600
Hot Water	11	4	0	60	0		42	1	0	0
Space Heating	70	51	7	53	18		61	0	65	8
Space Cooling	0	0	0	0	0		0	0	0	0
Combined Space and Water Heating										0
Process Heating	0	0	0	0	5		34	0	34	0
Electricity Generation	0	0	0	0	0		0	0	0	0
Other	0	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	13,608

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.

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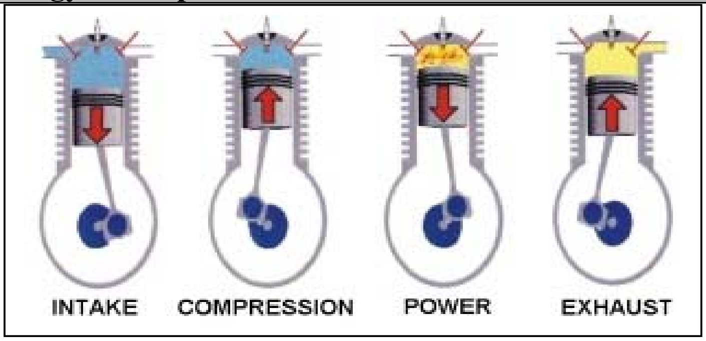
Reciprocating Engines

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 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 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 700-1,200° 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, 2003).

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)."

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 fivefold 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

In 1998, The U.S. Department of Energy – in partnership with the Gas Technology Institute, the Southwest Research Institute, and equipment manufacturers – joined 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 equivalent 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 — Source: Manufacturer Specs

	Low	High
Caterpillar	150	3,350
Waukesha	200	2,800
Cummins	5	1,750
Jenbacher	200	2,600
Wartsila	500	5,000

Market Data

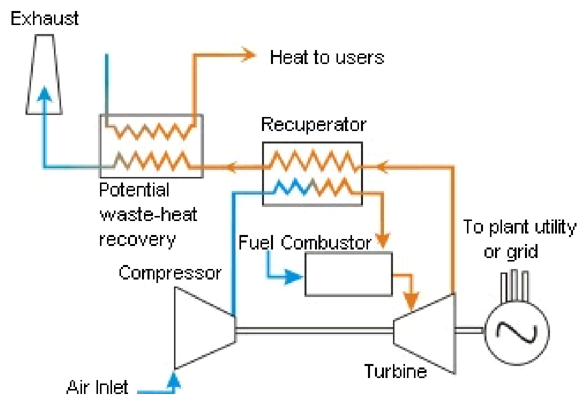
Market Shipments
(GW of units under 10 MW in size)

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 a 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
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 acceptable cost target for microturbine energy is $0.05/kWh, which would present a cost advantage over most nonbaseload utility power. • "Ultra-clean, high-efficiency" microturbine product designs 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	

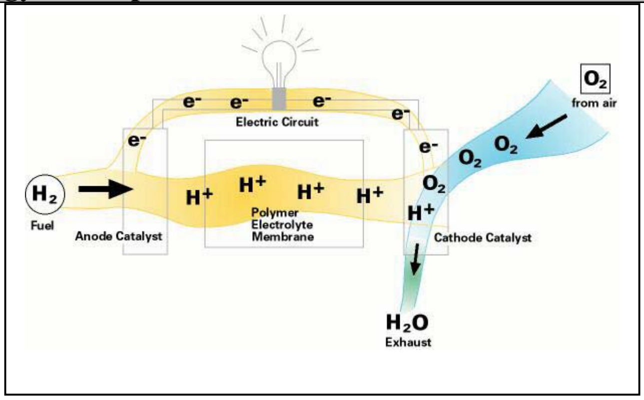
Technology Performance

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%.
- 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

- The cost of fuel cells hinders competition 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 Validatio*n, 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 are in the 250 kW-2 MW range.

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 can lead to technology applications where high temperature heat recovery has value.

Technology Future

- According to the Business Communications Company, the market for fuel cells was about $218 million in 2000 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.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003 (draft update, September 2005); and National Renewable Energy Laboratory. Gas-Fired Distributed Energy Resource Technology Characterizations. NREL/TP-620/34783. November 2003.

Fuel Cells

Technology Performance

Source: *Hydrogen, Fuel Cells & Infrastructure Technologies Program Multiyear Research, Development and Demonstration Plan,* February 2005

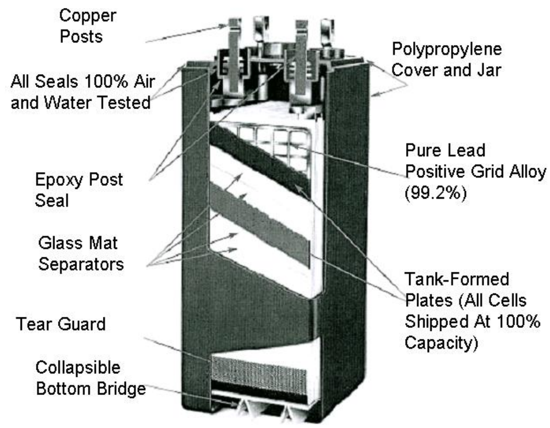
		Small (3-25 kW)			**Large (50-250kW)**		
Characteristic	Units	2004 Status	2005	2010	2004 Status	2005	2010
Electrical Energy Efficiency @ rated power	%	30	32	35	30	32	40
CHP Energy Efficiency @ rated power	%	75	75	80	75	75	80
Cost	$/kW		1500	1000	2500	1500	750
Transient Response Time (from 10% to 90% power)	msec	<3	<3	<3	<3	<3	<3
	3000						
Cold Start-up Time (to rated power @ -20 degrees C ambient) Continuous-use application	min	<90	<60	<30	<90	<60	<30
Survivability (min and max ambient temperature)	C degrees	-25 +40	-30 +40	-35 +40	-25 +40	-30 +40	-35 +40
Durability @ <10% rated power degradation	hour	>8,000	16,000	40,000	15,000	20,000	40,000

Noise	dB(A)	<70 @ 1m	<65 @ 1m	<60 @ 1m	<65 @ 1m	<60 @ 1m	<55 @ 1m
Emissions (Combined NOX, CO, SOX, Hydrocarbon, Particulates)	g/ 1,000 kW	<15	<10	<9	<8	<2	<1.5

a Includes fuel processor, stack, and all ancillaries.
b Ratio of DC output energy to the LHV of the input fuel (natural gas or LPG) average value at rated power over life of power plant.
c For LPG, efficiencies are 1.5 percentage points lower than natural gas because the reforming process is more complex.
d Ratio of DC output energy plus recovered thermal energy to the LHV of the input fuel (natural gas or LPG) average value at rated power over life of power plant
e Includes projected cost advantage of high-volume production (2,000 units/year). Current cost does not include integrated auxiliaries, battery and power regulator necessary for black start.
f Not applicable to backup power because this application does not use a fuel processor.

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 because 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 being developed. 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. The major disadvantage is 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 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 \$5.34 million and \$1.71 million, respectively, in 2000.
- Lead-acid battery manufacturers saw 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.
- About 150 MW of utility peak-shaving batteries were in use in Japan in 2003.
- In 2003, construction began on two 10-MW flow battery systems – one in the U.K. and the other in the United States.

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 because 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.
- Because 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. • The growing market for hybrid vehicles and the potential for "plug-in hybrid" vehicles--that could supply power to the grid as well as draw power from the grid—may increase future demand for batteries. • 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. • 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 (draft update, September 2005).

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

Advanced storage technologies under active development include processes that are mechanical (flywheels, pneumatic), electrochemical (advanced batteries, reversible fuel cells, hydrogen, ultracapacitors), and purely electrical (superconducting magnetic storage). Energy storage devices are added to the utility grid to improve productivity, increase reliability, or defer equipment upgrades. Energy storage devices must be charged and recharged with electricity generated elsewhere. Because the storage efficiency (output compared to input energy) is less than 100%, on a kilowatt-per-kilowatt basis, energy storage does not directly decrease CO_2 production. The exception to this rule is the use of advanced energy storage in conjunction with intermittent renewable energy sources (such as photovoltaics and wind) that produce no direct CO_2. Energy storage allows these intermittent resources to be dispatchable. Energy-storage devices do positively affect CO_2 production on an industrial output basis by providing high-quality power, maximizing industrial productivity. New battery technologies, including sodium sulfur and flow batteries, significantly improve the energy and power densities for stationary battery storage as compared to traditional flooded lead-acid batteries.

System Concepts

- *Stationary applications:* Electric demand falls at night, providing an opportunity for the most cost effective electric generators to produce low cost power at night for storage. The stored energy could displace high cost, less efficient power normally produced at the peak during the day. CO_2 emissions would be reduced if the efficiency of the energy storage were greater than 85%. Energy storage also can be used to alleviate the pressure on highly loaded components in the grid (transmission lines, transformers, etc.)

These components are typically only loaded heavily for a small portion of the day. The storage system would be placed downstream from the heavily loaded component. This would reduce electrical losses of overloaded systems. Equipment upgrades also would be postponed, allowing the most efficient use of capital by utility companies. For intermittent renewables, advanced energy storage technology would improve their applicability.

- *Power quality and reliability:* The operation of modern, computerized manufacturing depends directly on the quality of power the plant receives. Any voltage sag or momentary interruption can trip off a manufacturing line and electronic equipment. Industries that are particularly sensitive are semiconductor manufacturing; plastics and paper manufacturing; electronic retailers; and financial services such as banking, stock brokerages, and credit card-processing centers. If an interruption occurs that disrupts these processes, product is often lost, plant cleanup can be required, equipment can be damaged, and transactions can be lost. Any loss must be made up decreasing the overall efficiency of the operation, thereby increasing the amount of CO_2 production required for each unit of output. Energy-storage value is usually measured economically with the cost of power-quality losses, which is estimated in excess of $1.5 B/year in the United States alone. Industry is also installing energy-storage systems to purchase relatively cheap off-peak power for use during on-peak times. This use dovetails very nicely with the utilities' interest in minimizing the load on highly loaded sections of the electric grid. Many energy-storage systems offer multiple benefits. This 5-MVA, 3.5-MWh valve-regulated lead-acid battery system is installed at a lead recycling plant in the Los Angeles, California, area. The system provides power-quality protection for the plant's pollution-control equipment, preventing an environmental release in the event of a loss of power. The system carries the critical plant loads while an orderly shutdown occurs. The battery system also in discharged daily during the afternoon peak (and recharged nightly), reducing the plant's energy costs.

Technology Applications

- For utilities, the most mature storage technology is pumped hydro; however, it requires topography with significant differences in elevation, so it's only practical in certain locations. Compressed-air energy storage uses off-peak electricity to force air into underground caverns or dedicated tanks, and releases the air to drive turbines to generate on-peak electricity; this, too, is location-specific. Batteries, both conventional and advanced, are commonly used for energy-storage systems. Advanced flowing electrolyte batteries offer the promise of longer lifetimes and easier scalability to large, multi-MW systems. Superconducting magnetic energy storage (SMES) is largely focused on high-power, short-duration applications such as power quality and transmission system stability. Ultracapacitors have very high power density, but currently have relatively low total energy capacity and are also applicable for high-power, short-duration applications. Flywheels are now commercially viable in power quality and UPS applications, and emerging for high power, high-energy applications.

- Each energy-storage system consists of four major components: the storage device (battery, flywheel, etc.); a power-conversion system; a control system for the storage system, possibly tied in with a utility SCADA (Supervisory Control And Data Acquisition) system or industrial facility control system; and interconnection hardware connecting the storage system to the grid. All common energy-storage devices are DC devices (battery) or produce a varying output (flywheels) requiring a power conversion system to connect it to the AC grid. The control system must manage the charging and discharging of the system, monitor the state of health of the various components, and interface with the local environment at a minimum to receive on/off signals. Interconnection hardware allows for the safe connection between the storage system and the local grid.

Current Status

Utilities

Technology	Efficiency [%]	Energy density [W-h/kg]	Power density [kW/kg]	Sizes [MW-h]	Comments
Pumped hydro	75	0.27/100 m	low	5,000-20,000	37 existing in U.S.
Compressed gas	70	0	low	250-2,200	1 U.S., 1 German
SMES	90+	0	high	20 MW	high-power apps
Batteries	70–84	30-50	0.2-0.4	17-40	most common
Flywheels	90+	15-30	1-3	0.1-20 kWh	US & foreign dev.
Ultracapacitors	90+	2-10	high	0.1-0.5 kWh	high-power dens

Technology Future

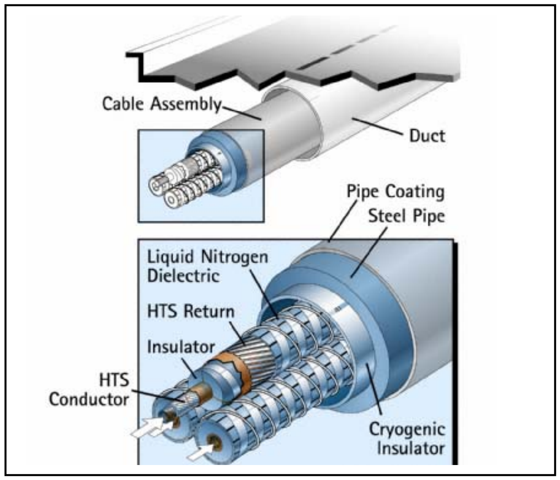
- For utilities, only pumped hydro has made a significant penetration with approximately 21 GW.
- Approximately 150 MW of utility peak-shaving batteries are in service in Japan.
- Two 10-MW flow battery systems are under construction – one in the United Kingdom and the other in the United States.
- Megawatt-scale power quality systems are cost effective and entering the marketplace today.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003 (draft update, September 2005).

Superconducting Power Technology

Technology Description

The United States' ongoing appetite for clean, reliable, and affordable electricity has increased at a rate that seriously threatens to exceed current capacity. Demand is estimated to increase by an average rate of 1.8% per year for the next 20 years, yet investments in transmission and distribution infrastructure have not kept pace with those in generation. Furthermore, a majority of the new gas-fired generation is not optimally sited where existing transmission assets are located. Witnessing the regional outages being experienced throughout the country – and those most recently highlighted in the northeast blackout of August 2003 – the inadequacies of the investment in infrastructure have, in effect, issued a wake-up call for modernizing and expanding grid capacity. High-temperature superconducting (HTS) wires can carry many more times the amount of electricity of ordinary aluminum or copper wires. HTS materials were first discovered in the mid-1980s and are brittle oxide, or ceramic-like materials, that can carry electricity with virtually no resistance losses. Through years of federal research in partnership with companies throughout the nation, technology has developed to bond these HTS materials to various metals, providing the flexibility to fashion these ceramics into wires for use in transmission cables and for coils for power transformers, motors, generators, etc. Superconducting technologies make possible electric power equipment that is half the size of conventional alternatives, with half the energy losses. When HTS equipment becomes pervasive, up to 50% of the energy now lost in transmission and distribution will become available for customer use. HTS also will reduce the impact of power delivery on the environment and is helping create a new high-tech industry to help meet industry challenges due to delays in electric utility restructuring. Other benefits of superconducting electric power systems include improved grid stability, reliability, power quality, and deferred generation expansion. Affordability of capacity expansion is also enhanced, because underground superconducting cables require only 10% of the rights-of-way of conventional overhead transmission; and because HTS cables may be installed in conventional underground ducts without extensive street excavation.



Source: American Superconductor

System Concepts

- HTS cables have almost no resistance losses and can transport three-five times as much power as a conventional cable in the same size conduit.
- HTS power transformers have about 30% reduction in total losses, can be 50% smaller and lighter than conventional units, may have a total ownership cost that is about 20% lower, are nonflammable, and do not contain oil or any other potential pollutant. In addition, there are electrical performance benefits associated with current limiting capacity and reduced impedance that will yield cost savings to power companies.
- HTS Fault Current Limiters can provide power companies with surge protection within the transmission and distribution system. They are reusable, require minimal maintenance, and do not need replacement after being activated.
- HTS motors rated at more than 750 kW would save enough energy over their lifetime to pay for the motor. Replacement of all U.S. motors greater than 750-kW with HTS motors would save consumers $2 billion per year in electricity costs. The motors are 50% smaller and lighter than conventional motors, as well.

- HTS generators with more than 100 MVA output will be more energy efficient, compact, and lighter than the conventional generator. The generator has characteristics that may help stabilize the transmission grid.

System Components

- HTS cables consist of large numbers of wires containing HTS materials operating at 65-77 K, insulated thermally and electrically from the environment. A cryogenic refrigerating system maintains the temperature of the cable at the desired operating temperature, regardless of the load on the cable.
- HTS transformers use the same types of HTS materials as cables, formed into coils and mounted on conventional transformer cores. Electrical insulation is accomplished by means other than conventional oil-and-paper, and typically involves a combination of solid materials, liquid cryogens, and vacuum. HTS transformers may be overloaded for periods of time without loss of transformer life.
- HTS motors, generators, magnetic separators, and current limiters use HTS wires and tapes in a coil form. Rotating cryogenic seals provide cooling for the rotating machines.
- HTS flywheel systems use nearly frictionless bearings made from superconducting "discs," cooled below the transition temperature of the HTS materials.

Technology Applications

- HTS wires: First generation "BSCCO" wires are available today in kilometer lengths at about $200/kA-m. Prototype, pre-commercial, second-generation "coated conductors" have been made in 100 m lengths by industry and are to be scaled up in 2006-2008 to 1,000-m lengths. The 100-m tapes carry approximately 100 amperes of current in nitrogen.
- HTS cables: Under the DOE Superconductivity Partnership with Industry (SPI), a team led by Southwire Company has installed and successfully tested a 30-m prototype cable that has been powering three manufacturing plants in Carrollton, Georgia, since February 2000. Three new HTS cable demonstration projects are underway with partial DOE funding from the SPI for 2006. A 600-m cable to be operated at 138-kV will be installed on Long Island, New York; and a 350-m distribution cable is installed in downtown Albany, New York. A section of the 350-m cable will also be manufactured using second-generation "coated conductors." A 200-m HTS distribution cable carrying 3,000 amperes is installed at a suburban substation in Columbus, Ohio.
- HTS transformers: Waukesha Electric Systems, with partial DOE funding, demonstrated a 1-MVA single-phase prototype transformer in 1999 and is leading a team developing technology needed for electrical insulation that would be used for a pre-commercial, three-phase prototype transformer.
- HTS motors: Rockwell Automation successfully demonstrated a prototype 750-kW motor in 2000 and is researching motor components with improved performance characteristics.

Current Status

- The development at the national laboratories of ion-beam assisted deposition and rolling-assisted, biaxially textured substrate (RABiTS™) technologies for producing high-performance HTS film conductors suitable for cables and transformers, and the involvement of four unique industry-led teams to capitalize on it, was a major success story for FY 1997.
- The world's first HTS cable to power industrial plants exceeded 28,000 hours of trouble-free operation in Carrollton, Georgia, (Southwire Company) in early 2005, and is the world's longest-running superconducting cable. The 30-m cable system has been operating unattended since June 2001. Short lengths of coated conductors made under stringent laboratory conditions exceeded the DOE goal of 1,000 A/cm width.
- SuperPower verified greater than 80% current limiting performance of proof-of-concept Fault Current Limiter at up to 8,660 volts.
- Rockwell Automation demonstrated a prototype 1000-HP synchronous motor that exceeded design specifications by 60%, and is now designing a motor that would use second-generation coated conductors with enhanced performance-to-cost ratio for the industrial marketplace.

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. • 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. This team is now (in 2006) researching motor components.
Technology Future
High-temperature superconducting cables and equipment: Commercialization and market introduction requires development of inexpensive wires for transmission and distribution, and end uses such as electric motors. These wires are now under development under a government-industry partnership but are still years from wide-scale use. In addition, there is an international race underway to develop and deploy the new second-generation coated conductors. Numerous companies in Europe, Japan, Korea and China are pursuing the technologies first demonstrated by the national labs. Using high-temperature superconductivity wires to replace existing electric wires and cables may be analogous to the market penetration that occurred when the United States moved from copper wire to fiber optics in communications. Some pre-commercial demonstrations using commercial BSCCO wires are underway, but the Superconductivity Partnerships with Industry and the Second-Generation Wire Initiative could be expanded to include additional U.S. companies. The Power Delivery Research Initiative, authorized in the 2005 Energy Policy Act, would help enable broad utility involvement in the technology.

Source: National Renewable Energy Laboratory. *U.S. Climate Change Technology Program. Technology Options: For the Near and Long Term.* DOE/PI-0002. November 2003 (draft update, September 2005).

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.

Projected Market for HTS devices (Thousands of Dollars)	Source: *Analysis of Future Prices and Markets for High-Temperature Superconductors,* September 2001, DOE.							
	2011	**2013**	**2015**	**2017**	**2019**	**2021**	**2023**	**2025**
Motors	225	956	4,025	15,399	50,968	108,429	148,770	164,072
Transformers	0	0	243	1,451	9,353	56,081	222,277	390,964
Generators	6,926	24,710	83,634	227,535	445,693	592,904	656,499	675,656
Cables	4,117	14,405	48,335	135,001	318,844	488,783	570,326	586,284
Total	11,270	40,071	136,236	379,386	824,857	1,246,196	1,597,872	1,816,975

Technology Performance

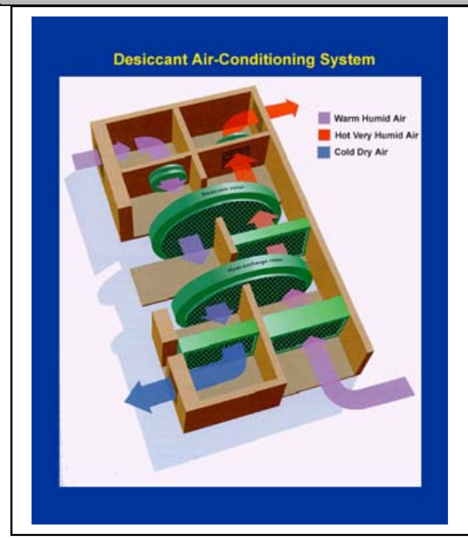
HTS Energy Savings (GWh)	Source: *Oak Ridge National Laboratory – High-Temperature Superconductivity: The Products and Their Benefits*, 2002 Edition, Tables M-2, T-1, G-1, C-2								
	2004	**2006**	**2008**	**2010**	**2012**	**2014**	**2016**	**2018**	**2020**
Motors	0	0	0.4	3	8	21	48	98	172
Transformers	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

HTS Energy Savings (GWh)	Source: *Analysis of Future Prices and Markets for High-Temperature Superconductors,* September 2001, DOE.								
	2009	**2011**	**2013**	**2015**	**2017**	**2019**	**2021**	**2023**	**2025**
Motors	0	0	1	4	15	57	154	300	468
Transformers	0	0	0	0	2	15	94	449	1,194
Generators	2	11	44	171	556	1,417	2,699	4,196	5,785
Cables	1	3	13	55	196	598	1,336	2,289	3,326
Total	3	14	58	231	769	2,086	4,283	7,235	10,774

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

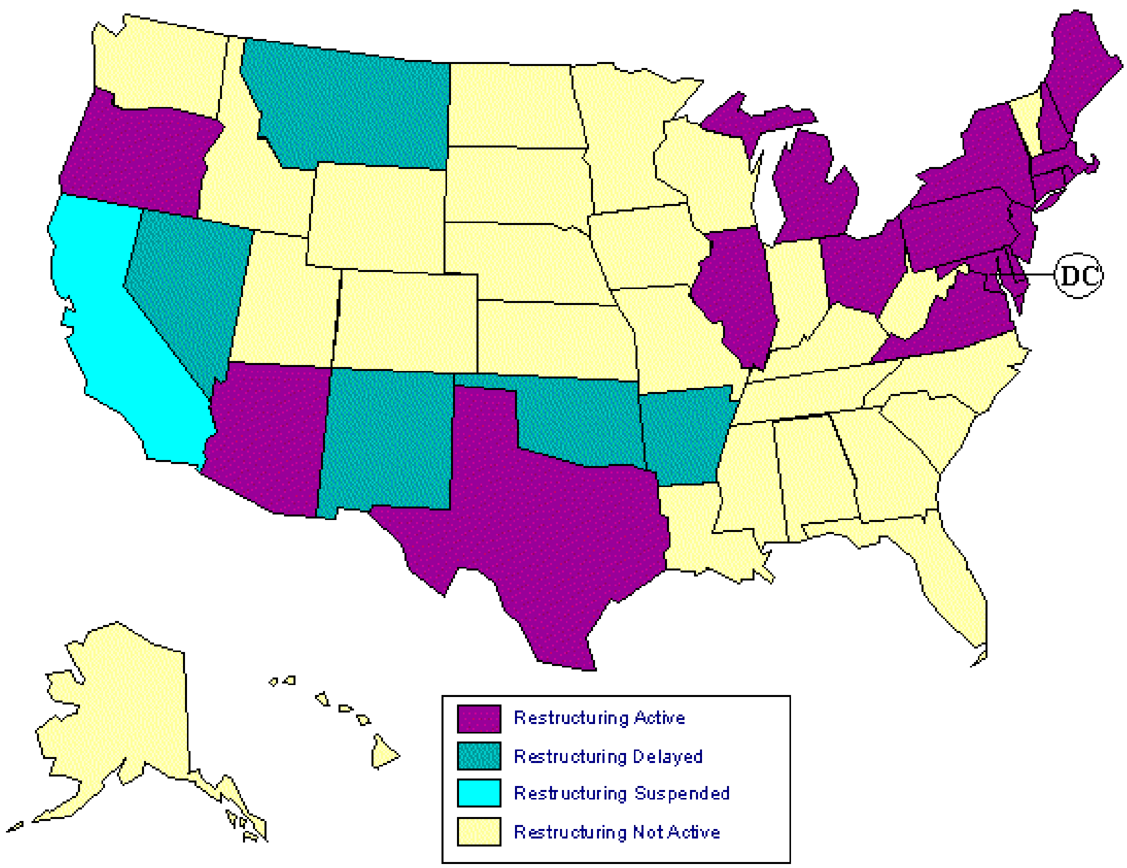
electrical rates, high cooling-season rates, and high demand charges. Facilities with high thermal loads, such as data centers, grocery stores, and casinos, are promising markets for absorption chillers. • Desiccant technology can either supplement a conventional air-conditioning system or act as a standalone 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.
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/H2O 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 (**Figure 3.1.1**) 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. 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, the law allows nonresidential customers retail access.

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.

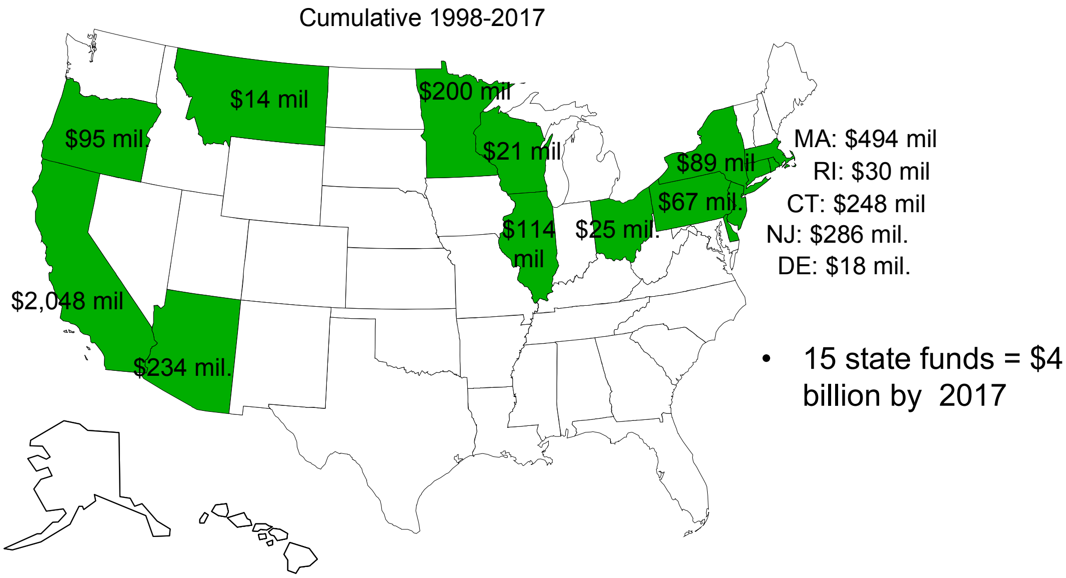


Source: U.S. DOE, Energy Information Administration, last updated February 2003.

Figure 3.1.1: Status of Restructuring of State Electricity Markets

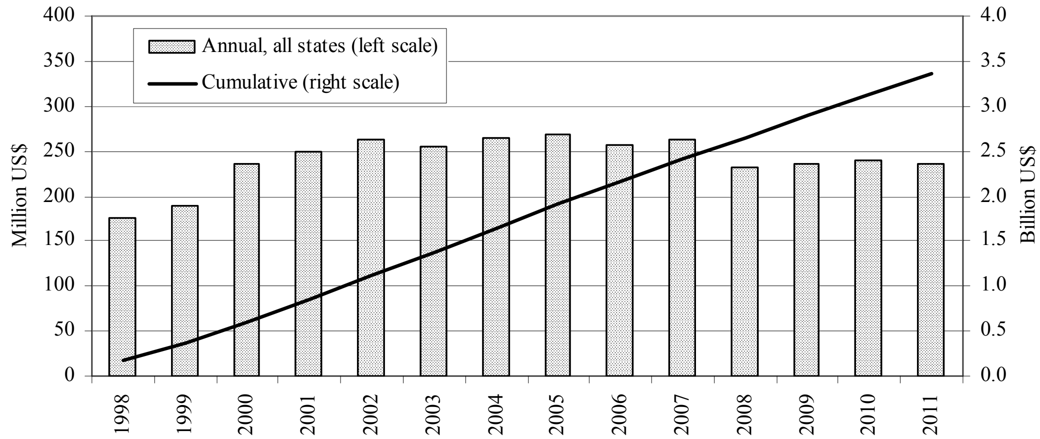
3.2 – States with System Benefit Charges (SBC)

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 (**Table 3.2.1**) through which a portion of the money will be used to support renewable resources. Together, these states will collect about $4 billion (**Figure 3.2.1**) in funds to support renewable resources between 1998 and 2017.



Source: Union of Concerned Scientists, June 2004
http://www.ucsusa.org/clean_energy/clean_energy_policies/state-clean-energy-maps-and-graphs.html

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 National Laboratory, April 2001.

Figure 3.2.2: Aggregation Annual and Cumulative State Funding

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

SBC funding, so far, has supported the development of 707 MW of generating capacity that is online. A further 1,548 MW of new capacity is still pending for a total of 163 different projects. Nationwide, there is currently about $345 million in funding obligated through the respective SBC programs (**Table 3.2.2**).

Table 3.2.2: State SBC Funding for Utility-Scale Renewable Projects (as of September 2004)

Project Location	# of Projects	Original Dollars Obligated ($)	Current Dollars Obligated ($)	Capacity Obligated (MW)	Capacity Cancelled (MW)	Capacity Pending (MW)	Capacity On-Line (MW)
CA	60	$243,573,376	$193,019,993	1,285.3	30.6	830.1	424.5
IL	4	$9,305,000	$9,305,000	101.6	0.0	51.2	50.4
MA	4	$19,469,093	$19,469,093	49.6	0.0	49.6	0.0
MN	68	$61,841,977	$61,841,977	124.9	1.7	91.7	31.5
NH*	1	$2,378,930	$2,378,930	50.0	0.0	50.0	0.0
NJ	5	$14,590,000	$14,590,000	41.1	0.0	41.4	0.0
NY	12	$26,560,000	$26,560,000	325.2	0.0	283.6	41.6
OR	1	$3,800,000	$3,800,000	41.0	0.0	0.0	41.0
PA	8	$17,600,000	$14,000,000	269.6	0.0	151.1	118.5
Total	163	$399,118,376	$344,964,993	2,288.1	32.3	1,548.4	707.4

*New Hampshire does not currently have a clean energy fund. The single project located in New Hampshire is receiving support from Massachusetts' clean energy fund.

Source: Bolinger, M., R. Wiser, and G. Fitzgerald, 2004. *The Impact of State Clean Energy Fund Support for Utility-Scale Renewable Energy Projects.* Prepared by Lawrence Berkeley National Laboratory and the Clean Energy States Alliance, October. http://www.cleanenergystates.org/CaseStudies/LBNL-56422_Utility-Scale_Renewables.pdf

Of the 163 projects announced, the vast majority – both in terms of number of projects and generating capacity – are wind power projects (**Table 3.2.3**). In descending order of capacity are geothermal, landfill gas, biomass, hydropower, waste tire, and digester gas.

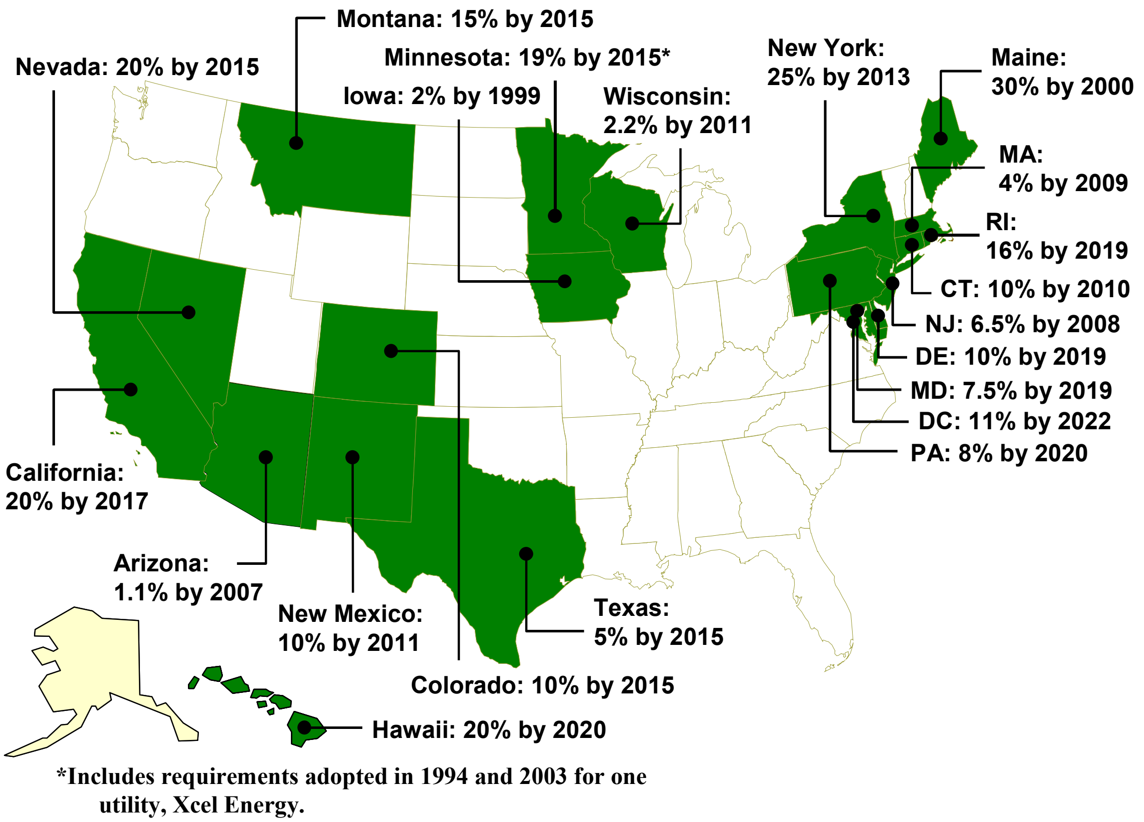
Table 3.2.3: Support for Utility-Scale Renewable Projects by Resource Type (as of September 2004)

Resource Type	# of Projects	Original Dollars Obligated ($)	Current Dollars Obligated ($)	Capacity Obligated (MW)	Capacity Cancelled (MW)	Capacity Pending (MW)	Capacity On-Line (MW)
Biomass	8	$15,406,770	$11,466,832	85.2	9.5	64.4	11.3
Digester Gas	3	$4,108,210	$4,108,210	6.0	0.0	3.9	2.1
Geothermal	4	$80,331,618	$80,331,618	156.9	0.0	97.9	59.0
Hydro	7	$12,977,258	$11,787,988	45.7	0.0	14.5	31.3
Landfill Gas	28	$38,108,552	$31,098,469	90.7	19.8	35.1	35.8
Waste Tire	1	$7,232,413	$3,287,461	30.0	0.0	30.0	0.0
Wind	112	$240,953,555	$202,884,417	1,873.60	3.0	1,302.6	568.0
Total	163	$399,118,376	$344,964,993	2,288.1	32.3	1,548.4	707.4

Source: Bolinger, M., R. Wiser, and G. Fitzgerald, 2004. *The Impact of State Clean Energy Fund Support for Utility-Scale Renewable Energy Projects*. Prepared by Lawrence Berkeley National Laboratory and the Clean Energy States Alliance, October. http://www.cleanenergystates.org/CaseStudies/LBNL-56422_Utility-Scale_Renewables.pdf

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, 20 states plus Washington, D.C., have adopted RPS policies (**Table 3.3.1**) or renewable purchase obligations (**Figure 3.3.1**), while several other states have adopted nonbonding renewable energy goals (**Table 3.3.2**). In addition, a number of states have increased their renewable energy standards in recent years. In conjunction with system benefits funds, RPS policies are expected to lead to the development of more than 29,000 MW of new renewable energy capacity by 2017 (**Figure 3.3.2**).



Source: NREL/Union of Concerned Scientists, October 2005

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
AZ	15% by 2015 (of this 30% must be customer sited)	PV and solar thermal electric, R&D, solar hot water, and in-state landfill gas, wind, and biomass.	No central credit trading system	Under consideration
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	At discretion of CPUC
CO	10% by 2015	Photovoltaics, Landfill Gas, Wind, Biomass, Geothermal Electric, Anaerobic Digestion, Small Hydroelectric, Fuel Cells (Renewable Fuels)	WREGIS system under development	To be determined
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
DE	10% by 2019	Solar Thermal Electric, Photovoltaics, Landfill Gas, Wind, Biomass, Hydroelectric, Geothermal Electric, Anaerobic Digestion, Tidal Energy, Wave Energy, Ocean Thermal, Fuel Cells (Renewable Fuels)	Yes. GATS	Penalty of 2.5¢/kWh (increases to 5¢/kWh for multi-year noncompliance)
DC	11% by 2022 (0.386% solar)	Solar Thermal Electric, Photovoltaics, Landfill Gas, Wind, Biomass, Hydroelectric, Geothermal Electric, Municipal Solid Waste, Cofiring, Tidal Energy, Wave Energy, Ocean Thermal	Yes. GATS. Electric delivery requirement to PJM	Penalty of 2.5¢/kWh for tier 1 resources, 1¢/kWh for tier II, and 30¢/kWh for PV
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	No	Unspecified; standard to be revisited if utilities can not meet it in cost-effective manner
IA	Investor-owned utilities to purchase 105 MW (~2% of 1999 sales)	Solar, wind, methane recovery, and biomass	No	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.	Yes. NEPOOL Generation Information System.	Possible sanctions at discretion of PUC

State	Purchase Requirements	Eligible Resources	Credit Trading	Penalties
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
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.
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
MT	5% in 2008; 10% in 2010; 15% in 2015	Solar Thermal Electric, Photovoltaics, Landfill Gas, Wind, Biomass, Hydroelectric, Geothermal Electric, Anaerobic Digestion, Fuel Cells (Renewable Fuels)	Yes. Electricity must be delivered to MT.	Penalty of 1¢/kWh goes to universal low-income energy assistance fund.
NV	6% in 2005, rising to 20% by 2015. Minimum 5% 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.	Financial penalties may be applied for noncomplian ce.
NJ	Class I or II: 2.5% by 2008 Class I: 4% by 2008, with solar requirement of 0.16% retail sales (90MW) Goal of 20% by 2020.	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.	Yes. GATS.	Alternative Compliance Payment of 5¢/kWh, 30¢/kWh for solar.
NM	5% of retail sales by 2006. Increase by 1%/yr to 10% by January 1,	Solar, wind, hydro (<=5 MW), biomass, geothermal, and fuel cells. 1 kWh solar = 3kWh; 1	Yes. RECs valid for 4 years from date of issuance.	At discretion of PUC.

State	Purchase Requirements	Eligible Resources	Credit Trading	Penalties
	2011 and thereafter.	kWh biomass, geothermal, landfill gas, or fuel cells =2 kWh toward compliance		
NY	25% by 2013; 1% voluntary standard; 2% of total incremental RPS requirement (7.71%) is set-aside for customer-sited	Photovoltaics, Landfill Gas, Wind, Biomass, Hydroelectric, Fuel Cells, CHP/Cogeneration, Biogas, Liquid Biofuel, Anaerobic Digestion, Tidal Energy, Wave Energy, Ocean Thermal	Possibly. Electricity must be delivered to NY.	Unspecified.
PA	18% by 2020; 8% Tier 1 and 10% Tier II Solar set-aside of 0.5% by 2020	Solar Water Heat, Solar Space Heat, Solar Thermal Electric, Solar Thermal Process Heat, Photovoltaics, Landfill Gas, Wind, Biomass, Hydroelectric, Geothermal Electric, Fuel Cells, Municipal Solid Waste, CHP/Cogeneration, Waste Coal, Coal Mine Methane, Coal Gasification, Anaerobic Digestion, Other Distributed Generation Technologies	Yes. GATS	Penalty of 4.5¢/kWh, for solar penalty is 200% of PV REC value.
RI	16% by 2020; 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. NEPOOL Generation Information System.	Penalty of 5¢/kWh can be made to Renewable Energy Developmen t Fund
TX	5880 MW by 2015 (5000 MW new) Target of at least 500 MW from renewables other than wind	Solar, wind, geothermal, hydro, wave, tidal, biomass, including landfill gas. New (operational after Sept. 1, 1999) or small (<2MW) facilities eligible.	Yes. ERCOT REC Trading System.	Lesser of 5¢/kWh or 200% of average market value of renewable energy credits.
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.

Source: Table updated by NREL, March 2006. 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	8% by 2013 (75% wind)	Solar Water Heat, Solar Thermal Electric, Photovoltaics, Landfill Gas, Wind, Biomass, Hydroelectric, CHP/Cogeneration, "Other Such Alternative Sources of Environmentally Preferable Energy"
Minnesota	1% by 2005 increasing by at least 1%/year to 10% by 2015	Wind, solar, hydro (<60 MW), and biomass
Vermont	Meet growth in electricity demand from 2005-2013 with renewable energy sources (becomes mandatory in 2013 if not met).	Solar Thermal Electric, Photovoltaics, Landfill Gas, Wind, Biomass, Hydroelectric, Anaerobic Digestion, Fuel Cells (Renewable Fuels)

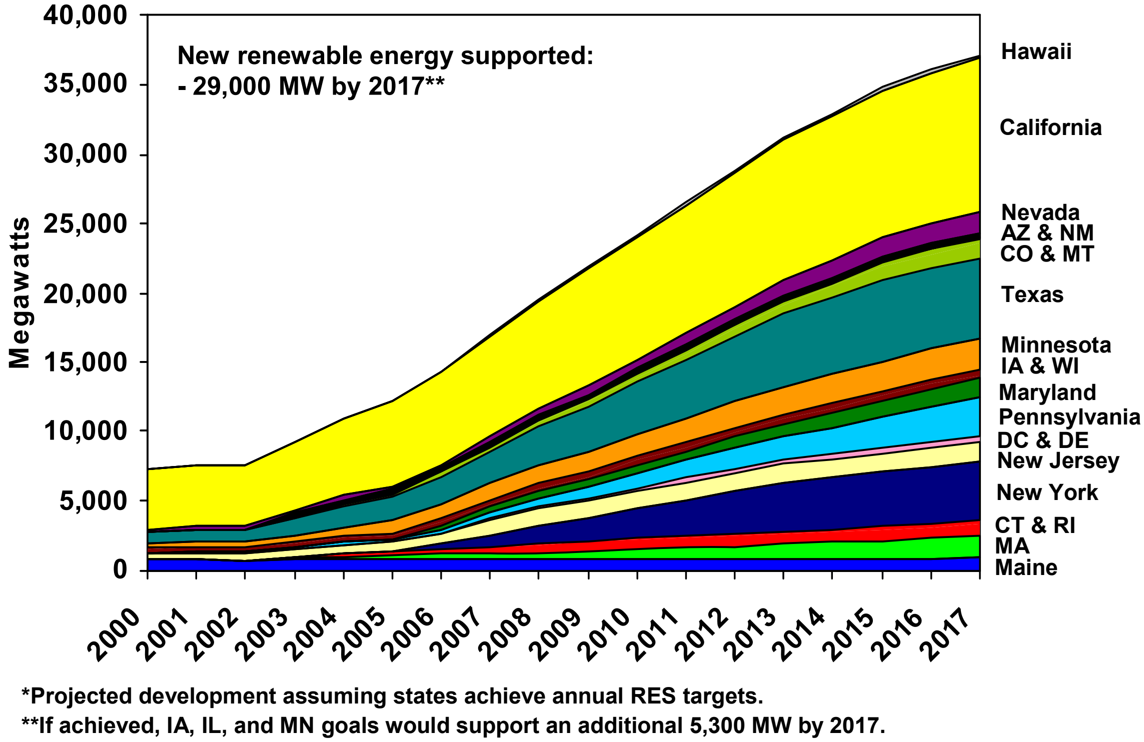
Source: NREL, March 2006.

Nationwide the RPS requirements for renewable energy are estimated to total 2,335 MW of generating capacity. The vast majority (93.5%) is wind power, followed by biomass (2.3%), landfill gas (2.3%), hydropower (1.3%), solar energy (0.4%), and other (0.3%). The five largest states in terms of capacity are Texas, Minnesota, Iowa, California, and Wisconsin.

Table 3.3.3 Estimated Renewable Energy Capacity Satisfying RPS Requirements Through 2003 (Megawatts, Nameplate Capacity)

State	Biomass	Hydro	Landfill Gas	Solar Photovoltaics	Wind	Other/ Unknown	Total
Arizona	0	0	5	9	0	0	14
California	0	20	6	0	175	0	201
Connecticut	0	0	0	0	0	0	0
Maine	0	0	0	0	0	0	0
Massachusetts	0	0	8	0	1	0	9
Nevada	0	0	0	0	0	0	0
New Jersey	0	0	0	0	0	0	0
New Mexico	0	0	0	0	0	0	0
Wisconsin	0	0	3	0	94	0	97
Iowa	16	0	0	0	237	7	260
Minnesota	25	0	0	0	476	0	501
Texas	5	10	31	0.2	1,140	0	1,186
Wisconsin	7	0	0	0	50	0	57
Hawaii	0	0	0	0	0	0	0
Illinois	0	0	0	0	0	0	0
Minnesota	0	0	0	0	0	0	0
Pennsylvania	0	0	0	0	10	0	10
Total	53	30	53	9.2	2,183	7	2,335
Share of Total	2.3%	1.3%	2.3%	0.4%	93.5%	0.3%	100.0%

Source: Petersick, T. 2004. *State Renewable Energy Requirements and Goals: Status Through 2003*, U.S. DOE Energy Information Administration, July http://www.eia.doe.gov/oiaf/analysispaper/rps/index.html



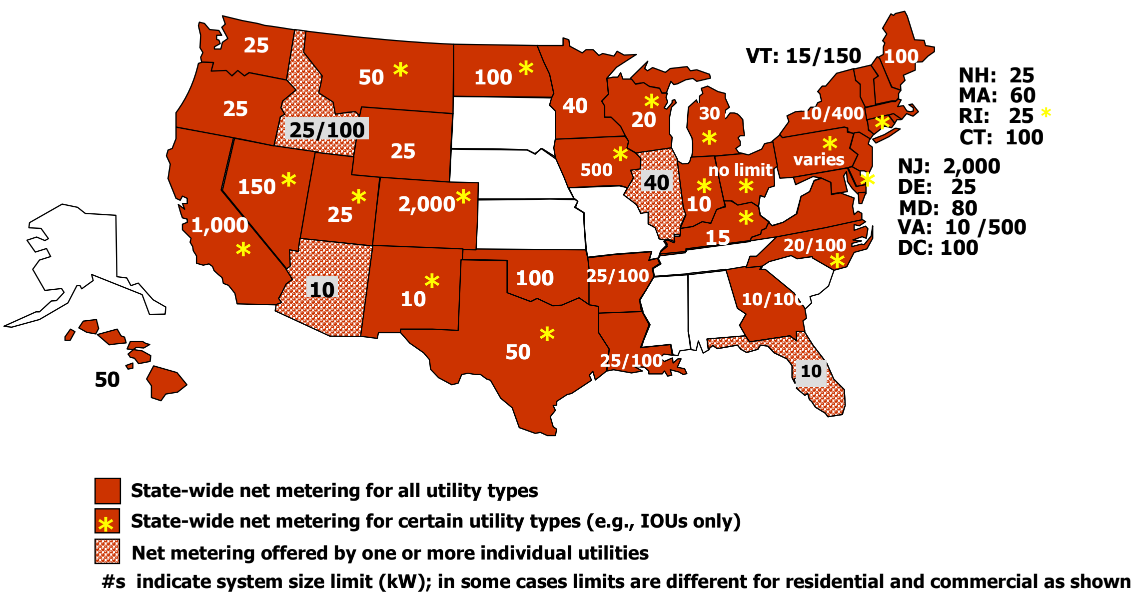
Source: Union of Concerned Scientists, November 2005.

Figure 3.3.2: The Future Impact of State Purchase Mandates and Renewable Energy Funds

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.

Most states have some type of net metering policy (**Figure 3.4.1**). Of the states that do have net metering policies (**Table 3.4.1**) the policies vary significantly in terms of the maximum amount of capacity a consumer is permitted to net meter varies from 10 kW to 2,000 kW. Some states only require certain types of utilities to offer net metering, exempting others.



Source: DSIRE database, January 2006
http://www.dsireusa.org/library/includes/topic.cfm?TopicCategoryID=6&CurrentPageID=10

Figure 3.4.1: Net Metering Policies by State

Table 3.4.1: Summary of State Net Metering Policies

Program	System Size Limit/ Customer Classes Eligible	Eligible Technologies	Limit on Total Capacity	Treatment of Net Excess Generation (NEG)	Interconnection Standards for Net Metering	Utilities Involved
Arizona – Salt River Project	10 kW / Residential	Photovoltaics	None	Purchased monthly by utility at average monthly market price minus a price adjustment of $0.00017/kWh	(Utility guidelines)	Salt River Project
Arizona – Tucson Electric Power	10 kW / Commercial, Residential	Photovoltaics, Wind	500 kW peak aggregate	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	(Utility guidelines)	Tucson Electric Power
Arkansas	25 kW for residential systems; 100 kW for commercial systems	Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells, Microturbines	None	Granted to utility monthly	Yes	All utilities
California	1 MW (three biogas digesters up to 10 MW per unit may net meter) / Commercial, Industrial, Residential	Photovoltaics, Landfill Gas, Wind, Anaerobic Digestion, Fuel Cells	0.5% of a utility's peak demand (separate limit of 50 MW for SDG&E)	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	Yes	All utilities[1]
Colorado	2 MW / Commercial, Industrial, Residential	Solar, Landfill Gas, Wind, Biomass, Anaerobic Digestion, Small Hydro, Fuel Cells (Renewable Fuels)	None	Credited at retail rate to customer's next bill; at end of each calendar year, customer reimbursed for NEG at utility's average hourly incremental cost for the prior 12-month period	Yes	Colorado utilities serving 40,000 or more customers
Colorado – Fort Collins Utilities	10 kW / Residential	Photovoltaics, Wind	25 customers	Credited at retail rate to customer's next bill; granted to utility at end of	Yes	Fort Collins Utilities

[1] In California, all utilities – with the exception of Los Angeles Department of Water & Power (LADWP) -- must offer net metering to customers with PV and wind-energy systems. (LADWP offers net metering voluntarily.) In addition, investor-owned utilities must offer net metering to customers with fuel cells and biomass-energy systems.

Program	System Size Limit/ Customer Classes Eligible	Eligible Technologies	Limit on Total Capacity	Treatment of Net Excess Generation (NEG)	Interconnection Standards for Net Metering	Utilities Involved
				12-month billing cycle		
Colorado – Gunnison County Electric	10 kW / Commercial, Residential	Photovoltaics, Wind	50 customers	Purchased by utility at wholesale rate	Yes	Gunnison County Electric
Colorado – Holy Cross Energy	None / Commercial, Industrial, Residential	Photovoltaics, Wind, Biomass, Hydro, Geothermal	25 kW	Credited at retail rate to customer's next bill; purchased by utility at wholesale rate at end of 12-month billing cycle	Yes	Holy Cross Energy
Connecticut	100 kW for renewables; 50 kW for fossil fuels / Residential, Commercial	Solar, Landfill Gas, Wind, Biomass, Fuel Cells, Municipal Solid Waste, Small Hydro, Tidal Energy, Wave Energy, Ocean Thermal	None	Purchased by utility at spot-market energy rate	Yes	Investor-owned utilities only
Delaware	25 kW / Commercial, Residential	Solar, Wind, Biomass, Hydro, Geothermal	None	Varies by utility	Yes	All utilities (applies to municipal utilities if they opt to compete outside their limits)
District of Columbia	100 kW / Commercial, Industrial, Residential	Renewables (unspecified), Fuel Cells, Microturbines, CHP	None	Credited at retail rate to customer's next bill	Yes (under development)	All utilities
Florida – JEA	10 kW / Residential	Photovoltaics, Wind	None	Credited at retail rate to customer's next bill	(Utility guidelines)	JEA
Florida – New Smyrna Beach Utilities	10 kW / Commercial, Industrial, Residential	Photovoltaics	None	Credited at retail rate to customer's next bill	(Utility guidelines)	New Smyrna Beach Utilities
Georgia	100 kW for commercial systems; 10 kW for residential systems;	Photovoltaics, Wind, Fuel Cells	0.2% of a utility's annual peak demand	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing	Yes	All utilities

Program	System Size Limit/ Customer Classes Eligible	Eligible Technologies	Limit on Total Capacity	Treatment of Net Excess Generation (NEG)	Interconnection Standards for Net Metering	Utilities Involved
				cycle		
Hawaii	50 kW / Commercial, Residential, Government	Photovoltaics, Wind, Biomass, Hydro	0.5% of a utility's annual peak demand	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	Yes	All utilities
Idaho – Idaho Power	100 kW for large commercial and agricultural; 25 kW for residential and small commercial	Photovoltaics, Wind, Biomass, Hydro, Fuel Cells	2.9 MW (0.1% of utility's 2000 peak demand)	Purchased monthly by utility at retail rate for residential and small commercial customers; purchased at 85% of Dow Jones index price for non-firm energy for large commercial and agricultural customers	(Utility guidelines)	Idaho Power
Idaho – Utah Power & Light	100 kW for large commercial and irrigation; 25 kW for residential and small commercial	Solar, Wind, Biomass, Hydro	714 kW (0.1% of utility's Idaho retail peak demand in 2002)	Purchased monthly by utility at retail rate for residential and small commercial customers; purchased at 85% of Dow Jones index price for non-firm energy for large commercial and agricultural customers	(Utility guidelines)	Utah Power & Light
Idaho – Avista Utilities	25 kW / Commercial, Residential, Agricultural	Solar, Wind, Biomass, Hydro, Fuel Cells	1.52 MW (0.1% of utility's 1996 peak demand)	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	(Utility guidelines)	Avista Utilities
Illinois – ComEd Wind and PV Generation Program	40 kW / All retail customers	Photovoltaics, Wind	0.1% of utility's annual peak demand	Purchased monthly by utility at avoided-cost rate; customer receives an annual incentive payment for production	(Utility guidelines)	ComEd

Program	System Size Limit/ Customer Classes Eligible	Eligible Technologies	Limit on Total Capacity	Treatment of Net Excess Generation (NEG)	Interconnection Standards for Net Metering	Utilities Involved
Indiana	10 kW / Residential, Schools	Photovoltaics, Wind, Small Hydro	0.1% of a utility's most recent peak summer load	Credited at retail rate to customer's next bill	Yes	Investor-owned utilities
Iowa	500 kW / Commercial, Industrial, Residential	Photovoltaics, Wind, Biomass, Hydro, Municipal Solid Waste	None	Credited at retail rate to customer's next bill	No	Investor-owned utilities
Kentucky	15 kW Commercial, Residential, Nonprofit, Schools, Agricultural, Institutional, Government	Photovoltaics	0.1% of a utility's single-hour peak load during the previous year	Credit at retail rate to customer's next bill (no expiration)	Yes	Investor-owned utilities, cooperatives
Louisiana	100 kW for commercial and agricultural systems; 25 kW for residential systems	Photovoltaics, Wind, Biomass, Hydro, Geothermal, Fuel Cells (Renewable Fuels), Microturbines	None	Credited at retail rate to customer's next bill indefinitely	Yes	All utilities
Maine	100 kW / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells, Municipal Solid Waste, CHP, Tidal Energy	None	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	No	All utilities
Maryland	200 kW (500 kW with MD PSC permission) / Commercial, Residential, Schools, Government	Photovoltaics, Wind, Biomass	34.7 MW (0.2% of state's adjusted peak load in 1998)	To be determined by MD Public Service Commission	Yes	All utilities
Massachusetts	60 kW / Commercial, Industrial, Residential	Renewables, CHP, Fuel Cells	None	Credited at average monthly market rate to customer's next bill	Yes	All utilities
Michigan	30 kW / Commercial, Industrial, Residential, Nonprofit, Schools,	Solar, Wind, Biomass, Hydro, Geothermal, Municipal Solid Waste	0.1% of a utility's peak load or 100 kW (whichever is greater)	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing	Yes	Various utilities (voluntary participation)

Program	System Size Limit/ Customer Classes Eligible	Eligible Technologies	Limit on Total Capacity	Treatment of Net Excess Generation (NEG)	Interconnection Standards for Net Metering	Utilities Involved
	Government, Agricultural, Institutional			cycle		
Minnesota	40 kW / Commercial, Industrial, Residential	Photovoltaics, Wind, Biomass, Hydro, Municipal Solid Waste, CHP	None	Purchased at average retail utility energy rate	Yes	All utilities
Montana	50 kW / Commercial, Industrial, Residential	Photovoltaics, Wind, Hydro	None	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	Yes	Investor-owned utilities
Montana – Montana Electric Cooperatives	10 kW / Commercial, Residential	Photovoltaics, Wind, Geothermal, Fuel Cells, Small Hydro	None	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	Yes	Most of MEC's 26 member cooperatives
Nevada	150 kW[2] / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro, Geothermal	1% of a utility's peak capacity	Credited at retail rate to customer's next bill; no expiration[3]	Yes	Investor-owned utilities
New Hampshire	25 kW / Commercial, Industrial, Residential	Photovoltaics, Wind, Hydro	0.05% of a utility's peak demand	Credited at retail rate to customer's next bill	Yes	All utilities
New Jersey	2 MW / Commercial, Residential	Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells (Renewable Fuels), Tidal Energy, Wave Energy	None	Credited at retail rate to customer's next bill; purchased by utility at avoided-cost rate at end of 12-month billing cycle	Yes	All utilities
New Mexico	10 kW / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells, Municipal Solid Waste,	None	Credited to customer's next bill or purchased by utility at avoided-cost rate	Yes	Investor-owned utilities, cooperatives

[2] In Nevada, utilities are permitted to require customers with systems of more than 30 kW in capacity to install a second meter at the customer's expense.
[3] In Nevada, it is unclear how NEG is treated for systems of more than 30 kW in capacity.

Program	System Size Limit/ Customer Classes Eligible	Eligible Technologies	Limit on Total Capacity	Treatment of Net Excess Generation (NEG)	Interconnection Standards for Net Metering	Utilities Involved
		CHP, Microturbines				
New York	400 kW for farm waste; 125 kW for farm-based wind; 25 kW for residential wind; 10 kW for solar	Photovoltaics, Biomass, Wind	Solar: 0.1% of a utility's demand in 1996; farm biogas: 0.4% of a utility's demand in 1996; wind: 0.2% of a utility's 2003 demand	Credited to customer's next bill – except NEG from wind systems over 10 kW, which is credited to customer's next bill at the utility's avoided-cost rate. All NEG purchased by utility at avoided-cost rate at end of 12-month billing cycle.	Yes	All utilities
North Carolina	20 kW residential; 100 kW non-residential	Photovoltaics, Wind, Biomass	0.2% of a utility's North Carolina retail peak load for the previous year	Credited at retail rate to customer's next monthly bill; granted to utility every June 1 and October 1	Yes	Investor-owned utilities
North Dakota	100 kW / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro, Geothermal, Municipal Solid Waste, CHP	None	Purchased by utility at avoided-cost rate	No	Investor-owned utilities
Ohio	100 kW for microturbines; no limit for other systems / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro, Fuel Cells, Microturbines	1% of a utility's peak demand	Credited at utility's unbundled-generation rate to customer's next monthly bill	Yes	All competitive utilities
Ohio – Bowling Green Municipal Utilities	25 kW / Commercial, Residential	Photovoltaics, Wind, Hydro, Fuel Cells	None	Negotiated with utility	(Utility guidelines)	Bowling Green Municipal Utilities
Oklahoma	100 kW or 25,000 kWh/year (whichever is less) / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro, Geothermal, Municipal Solid Waste, CHP	None	Granted to utility monthly or credited to customer's next bill at utility's avoided-cost rate (varies by utility)	No	All utilities
Oregon	25 kW / Commercial,	Solar, Wind, Hydro, Fuel	0.5% of a utility's	Credited at retail rate to	Yes	All utilities

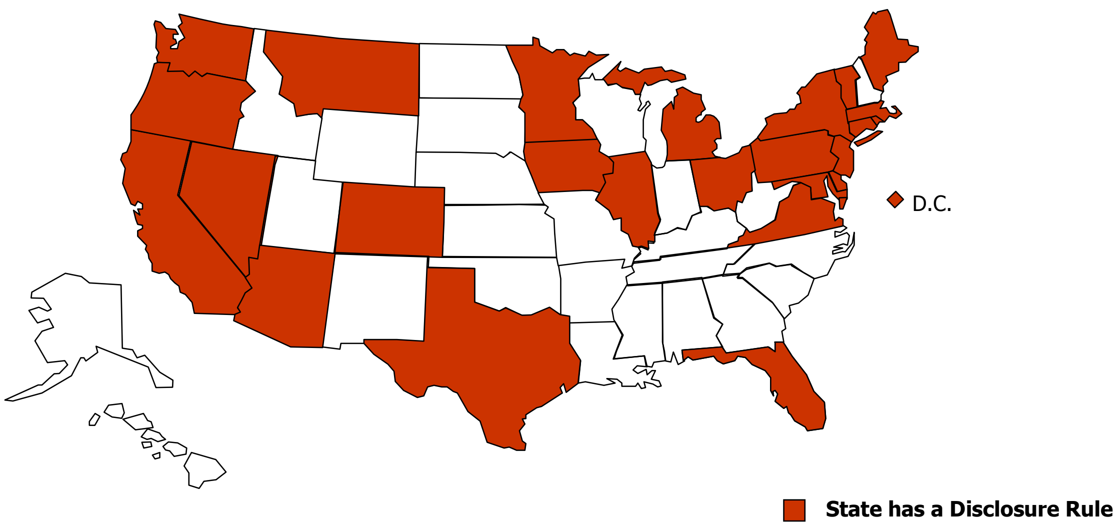
Program	System Size Limit/ Customer Classes Eligible	Eligible Technologies	Limit on Total Capacity	Treatment of Net Excess Generation (NEG)	Interconnection Standards for Net Metering	Utilities Involved
	Industrial, Residential	Cells	historic single-hour peak load	customer's next bill or purchased by utility at avoided-cost rate		
Oregon – Ashland Electric	None / Commercial, Residential	Photovoltaics, Wind	None	Purchased by utility monthly at retail rate (1,000 kWh/month maximum)	(Utility guidelines)	Ashland Electric
Pennsylvania (new rules under development)	Varies by utility / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro	Varies by utility	Varies by utility (granted to utility in most cases)	Varies by utility	All utilities
Rhode Island	25 kW / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells, Municipal Solid Waste, CHP	1 MW (Narragansett territory)	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	No	Narragansett Electric
Texas	50 kW / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro, Geothermal, Fuel Cells, Tidal Energy, Wave Energy, Microturbines	None	Purchased by utility monthly at avoided-cost rate	Yes	Most non-municipal utilities and non-cooperatives
Texas – San Antonio City Public Service	25 kW / Commercial, Residential	Photovoltaics, Wind, Biomass, Hydro, Geothermal, Tidal Energy, Wave Energy	None	Credited at retail rate to customer's next bill at utility's seasonal avoided-cost rate	(Utility guidelines)	San Antonio City Public Service
Texas – Austin Energy	20 kW / Commercial, Residential	Solar, Wind, Biomass, Hydro, Geothermal, Municipal Solid Waste	1% of utility's load	Credited to customer's next bill	(Utility guidelines)	Austin Energy
Utah	25 kW / Commercial, Industrial, Residential	Solar, Wind, Hydro, Fuel Cells	0.1% of a utility's 2001 peak demand	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	Yes	Investor-owned utilities, cooperatives
Vermont	150 kW for farm systems; 15 kW for	Photovoltaics, Wind, Biomass, Fuel	1% of a utility's 1996 peak demand	Credited at retail rate to customer's next	Yes	All utilities

Program	System Size Limit/ Customer Classes Eligible	Eligible Technologies	Limit on Total Capacity	Treatment of Net Excess Generation (NEG)	Interconnection Standards for Net Metering	Utilities Involved
	commercial and residential / Commercial, Residential, Agricultural	Cells	or peak demand during most recent calendar year (whichever is less)	bill; granted to utility at end of 12-month billing cycle		
Virginia	500 kW for non-residential; 10 kW for residential / Commercial, Residential, Nonprofit, Schools, Government, Institutional	Solar, Wind, Hydro	0.1% of a utility's annual peak demand	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	Yes	All utilities
Washington	25 kW / Commercial, Industrial, Residential	Solar, Wind, Hydro, Fuel Cells	0.1% of a utility's 1996 peak load	Credited at retail rate to customer's next bill; granted to utility at end of 12-month billing cycle	Yes	All utilities
Washington – Grays Harbor PUD	25 kW / Commercial, Industrial, Residential	Solar, Wind, Hydro, Fuel Cells	0.1% of utility's 1996 peak load	Purchased by utility annually at 50% of retail rate	Yes	Grays Harbor PUD
Wisconsin	20 kW / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro, Geothermal, Municipal Solid Waste, CHP	None	Purchased by utility at retail rate (renewables) or avoided-cost rate (non-renewables)	Yes	Investor-owned utilities
Wyoming	25 kW / Commercial, Industrial, Residential	Solar, Wind, Biomass, Hydro	None	Credited at retail rate to customer's next bill; purchased by utility at avoided-cost rate at end of 12-month billing cycle	Yes	All utilities

Sources: The Interstate Renewable Energy Council (IREC) and the N.C. Solar Center (NCSC). "Connecting to the Grid" Project Web site, http://www.irecusa.org/connect; Database of State Incentives for Renewable Energy (DSIRE), http://www.dsireusa.org, March 2006. Additional information, including most legislative and regulatory source citations, is available via DSIRE.

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, 25 states and the District of Columbia have environmental disclosure policies in place (**Figure 3.5.1**), 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, January 2006.
http://www.dsireusa.org/index.cfm?&CurrentPageID=10

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 600 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.

Customers

At the end of 2004, more than 500,000 electricity customers nationally were purchasing green power products through regulated utility companies, from green power marketers in a competitive market setting, or in the form of RECs (**Table 3.6.1**). In aggregate, utility green pricing programs have shown steady growth in customers over time as the number of utility programs has increased and as existing programs have grown. On the other hand, competitive markets have been less consistent. While green power sales have grown in Texas and some Northeast states, other markets have failed altogether—most notably in California and Connecticut. While REC customers represent a small fraction of the total customer base, REC sales have increased dramatically because of a number of very large purchases.

Average participation rates among utility green pricing programs have remained steady at just more than 1%, although the top performing utility green pricing programs have achieved rates ranging from 4% to 15%. Competitive markets have experienced penetration rates of from 1% to 2% in states where the market has been conducive to retail competition.

Table 3.6.1: Estimated Green Power Customers by Market Segment

	2000	2001	2002	2003	2004
Utility Green Pricing	130,000*	170,000*	230,000*	270,000	330,000
Competitive Markets	>160,000**	>110,000**	~150,000	>150,000	>180,000
REC Markets	--	--	< 10,000	< 10,000	< 10,000
Retail Total	>290,000	>280,000	~390,000	~430,000	~520,000

* Annual program participant numbers have been adjusted downward from those originally reported in Bird and Swezey (2003), because of program participation revisions made by the Los Angeles Department of Water and Power.
** Includes only customers purchasing Green-e certified green power products, as reported by the Center for Resource Solutions (2001; 2002).

Sales

Retail sales of renewable energy in voluntary purchase markets experienced strong growth in 2004, increasing more than 60% to 6.2 billion kWh annually. This includes sales of renewable energy derived from both new and preexisting renewable energy sources. REC sales nearly tripled, while sales through utility green pricing programs and competitive marketers also exhibited strong annual growth of about 40%.

Table 3.6.2: Estimated Green Power Sales by Market Segment (million kWh)

	2003	2004	Increase
Utility Green Pricing	1,280	1,840	43%
Competitive Markets	1,900	2,650	40%
REC Markets	660	1,720	162%
Retail Total	3,840	6,210	62%

*Includes sales of new and existing renewable energy.

Purchases by residential customers represent slightly more than half of total renewable energy sales in voluntary markets. In 2004, nonresidential customers accounted for 30% and 20% of total renewable energy sales in green pricing programs and competitive markets, respectively, and nearly all REC sales.

Since 2000, the amount of renewable energy capacity serving green power markets has increased more than tenfold. At the end of 2004, more than 2,200 MW of new renewable energy generation capacity was being used to supply green power markets, with another 450 MW planned.

Table 3.6.3: Estimated Green Power Sales by Customer Segment, 2004 (million kWh)

	Green Pricing	Competitive Markets	REC Markets	Total	Share
Residential	1,300	2,140	40	3,480	56%
Nonresidential	540	510	1,690	2,740	44%
Total	1,840	2,650	1,720	6,210	100%

Totals may not add due to rounding.

Table 3.6.4: Estimated New Renewables Capacity Supplying Green Power Markets, 2000-2004 (megawatts)

Market	2000	2001	2002	2003	2004
Utility Green Pricing	77	221	279	510	706
Competitive Markets/RECs	90	542	695	1,126	1,528
Total	167	764	974	1,636	2,233

Totals may not add due to rounding.
Source: Bird and Swezey (2005).

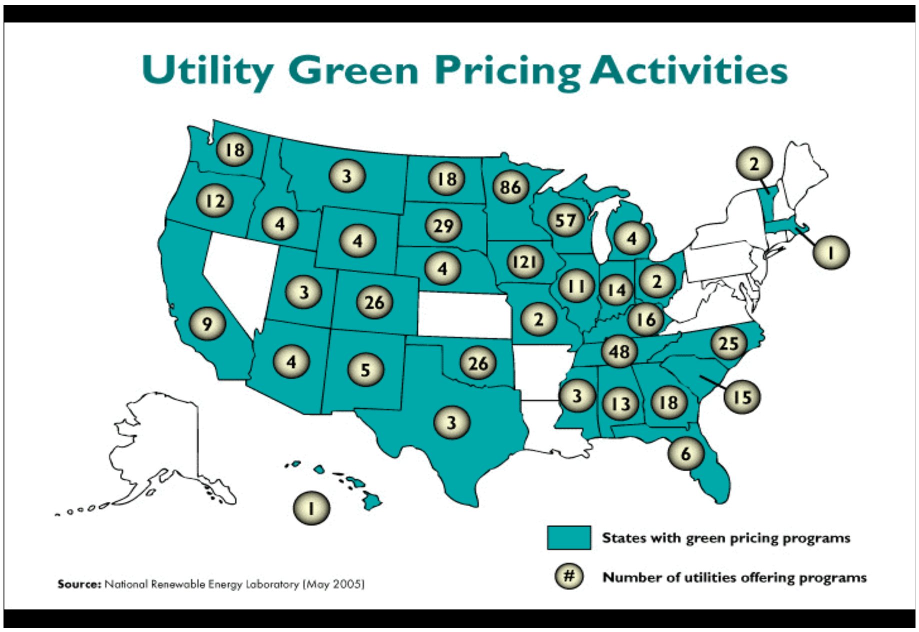
Table 3.6.5: New Renewables Capacity Supplying Green Power Markets, 2004

Source	MW in Place	%	MW Planned	%
Wind	2,045.6	91.6	364.5	80.1
Biomass	135.6	6.1	58.8	12.9
Solar	8.1	0.4	0.4	0.1
Geothermal	35.5	1.6	0.0	0.0
Small Hydro	8.5	0.4	31.3	6.9
Total	2,233.3	100.0	455.0	100.0

Source: L.Bird and B. Swezey, Estimates of New Renewable Energy Capacity Serving U.S. Green Power Markets (2004), National Renewable Energy Laboratory, September 2005. http://www.eere.energy.gov/greenpower/resources/tables/new_gp_cap.shtml

3.7 – 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 and expand business lines and expertise prior to electric market competition. To date, more than 600 investor-owned, municipal, and cooperative utilities in 34 states have either implemented or announced plans to offer a green pricing option (**Figure 3.7.1**).



Source: L. Bird and B. Swezey, National Renewable Energy Laboratory. Updated May 2005. http://www.eere.energy.gov/greenpower/markets/pricing.shtml?page=4

Figure 3.7.1: Number of Utilities Offering Green Pricing Programs by State

Table 3.7.1: New Renewable Energy Capacity Supplying Green Pricing Programs in 2004 (megawatts)

Source	Installed		Planned	
Wind	584.0	82.8%	139.7	61.1%
Biomass	76.3	10.8%	57.5	25.1%
Solar	6.1	0.9%	0.2	0.1%
Geothermal	30.5	4.3%	0.0	0.0%
Small Hydro	8.5	1.2%	31.3	13.7%
Total	705.5	100.0%	228.7	100.0%

Source: Bird and Brown (2005)

Table 3.7.2: Estimated Cumulative Number of Customers Participating in Utility Green Pricing Programs

Customer Segment	1999	2000	2001	2002	2003	2004
Residential	na*	131,000	166,300	224,500	258,700	323,700
Nonresidential	na*	1,700	2,500	3,900	6,500	8,100
Total	66,900	132,700	168,800	228,400	265,000	331,800
% Annual Growth	na	98%	27%	35%	16%	25%
% Nonresidential	na	1.3%	1.5%	1.7%	2.4%	2.5%

*Information on residential and nonresidential participants is not available for 1999.
Source: Bird and Brown (2005)

Table 3.7.3: Customer Participation Rates in Utility Green Pricing Programs by Year

	1999	2000	2001	2002	2003	2004
Average	0.9%	1.2%	1.3%	1.2%	1.2%	1.3%
Median	0.8%	0.7%	0.7%	0.8%	0.9%	1.0%
Top 10 programs for participation *	2.1%–4.7%#	2.6%–7.3%	3.0%–7.0%	3.0%–5.8%	3.9%–1.1%	3.8%–4.5%

*The high end of the range declined from 2000 to 2002, because the utility with the highest participation rate (Moorhead Public Service) experienced an increase in its overall customer base, while the number of participants in its green pricing program remained steady. The program was fully subscribed in 2000, and the utility has not attempted to expand it.
#Data for April 2000 source: Bird and Brown (2005)

Table 3.7.4: Annual Sales of Green Energy through Utility Green Pricing Programs (million kWh)

	2000	2001	2002	2003	2004
Residential customers	---	399.7	661.3	874.1	1,295.0
Nonresidential customers	---	172.8	233.7	410.3	544.2
Total All customers	453.7	572.5	895.0	1,284.4	1,839.2
% Annual Growth		26%	56%	44%	43%
% Nonresidential Customers	---	30%	26%	32%	30%
*Sales information for customer segments not available for 2000.					

Source: Bird and Brown (2005)

Table 3.7.5: Price Premiums Charged for Utility Green Pricing Products (¢/kWh)

	1999	2000	2001	2002	2003	2004
Average	2.15	3.48	2.93	2.82	2.62	2.45
Median	2.00	2.50	2.50	2.50	2.00	2.00
Range	0.4–5.0	(0.5)–20.0	0.9–17.6	0.7–17.6	0.6–17.6	0.33–17.6
10 Programs with Lowest Premiums*	0.4–2.5**	(0.5)–2.5	1.0–1.5	0.7–1.5	0.6–1.3	0.33–1.0
Number of Programs Represented	24	50	60	80	91	101

*Represents the 10 utility programs with the lowest price premiums for new customer-driven renewable energy. This includes only programs that have installed – or announced firm plans to install or purchase power from – new renewable energy sources. In 2001, the discrepancy between the low end of the range for all programs and the Top 10 programs was because the program with the lowest premium (0.9¢/kWh) was not eligible for the Top 10, because it was either selling existing renewables or had not installed any new renewable capacity for its program.
**Data for April 2000.

Source: Bird and Brown (2005)

Table 3.7.6: Utility Green Pricing Programs by State, October 2005

State	Utility Name	Program Name	Type	Start Date	Premium
AK	Golden Valley Electric Association	Sustainable Natural Alternative Power (SNAP)	various local projects	2005	Contribution
AL	Alabama Power Company	Renewable Energy Rate	biomass co-firing	2003	6.0¢/kWh
AL	TVA: City of Athens Electric Department, Cullman Electric Coop, Cullman Power Board, Decator Utilities, Florence Utilities, Hartselle Utilities, Huntsville, Joe Wheeler EMC, Muscle Shoals Electric Board, Scottsboro Electric Power Board, Sheffield Utilities, Tuscumbia Electric Department	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
AZ	Arizona Public Service	APS Solar Partners Program	central PV	1997	17.6¢/kWh
AZ	Salt River Project	EarthWise Energy	central PV, wind, landfill gas, small hydro, geothermal	1998/ 2001	3.0¢/kWh
AZ	Tucson Electric	GreenWatts	landfill gas, PV	2000	10¢/kWh
AZ	UniSource Energy Services	GreenWatts	PV	2004	10¢/kWh
CA	Anaheim Public Utilities	Green Power for the Schools	PV	2002	Contribution
CA	Anaheim Public Utilities	Green Power for the Grid	wind, landfill gas	2002	1.5¢/kWh
CA	Burbank Water and Power	Clean Green Support	various	2001	1.0¢/kWh
CA	Los Angeles Department of Water and Power	Green Power for a Green LA	wind, landfill gas	1999	3.0¢/kWh
CA	PacifiCorp: Pacific Power	Blue Sky Block	wind	2000	1.95¢/kWh
CA	Palo Alto Utilities/3 Phases Energy Services	Palo Alto Green	wind, PV	2003	1.5¢/kWh
CA	Pasadena Water & Power	Green Power	wind	2003	2.5¢/kWh
CA	Roseville Electric	RE Green Energy	geothermal, PV	2000	1.0¢/kWh
CA	Sacramento Municipal Utility District	Greenergy	wind, landfill gas, hydro, PV	1997	1.0¢/kWh or $6/month
CA	Silicon Valley Power / 3 Phases Energy Services	Santa Clara Green Power	wind, PV	2004	1.5¢/kWh
CO	Colorado Springs Utilities	Green Power	wind	1999	3.0¢/kWh
CO	Holy Cross Energy	Wind Power Pioneers	wind	1998	2.5¢/kWh
CO	Holy Cross Energy	Local Renewable Energy Pool	small hydro, PV	2002	3.3¢/kWh
CO	Platte River Power Authority: Estes Park, Fort Collins Utilities, Longmont Power & Communications, Loveland Water & Light	Wind Energy Premium	wind	1999	1.0¢/kWh - 2.5¢/kWh

State	Utility Name	Program Name	Type	Start Date	Premium
CO	Tri-State Generation & Transmission: Carbon Power, Chimney Rock, Gunnison County Electric, Kit Carson Electric, La Plata Electric, Mountain Parks Electric, Mountain View Electric, New Mexico, Northwest Rural, Poudre Valley Rural Electric Association, Public Power District, San Isabel Electric, San Luis Valley Rural Electric Coop, San Miguel Power, Sangre, Springer Electric, United Power, White River (18 of 44 coops offer program)	Renewable Resource Power Service	wind, hydro	1998	2.5¢/kWh
CO	Xcel Energy	Renewable Energy Trust	PV	1993	Contribution
CO	Xcel Energy	WindSource	wind	1997	0.97¢/kWh
CO	Yampa Valley Electric Association	Wind Energy Program	wind	1999	3.0¢/kWh
FL	City of Tallahassee/Sterling Planet	Green for You	biomass, PV	2002	1.6¢/kWh
FL	City of Tallahassee/Sterling Planet	Green for You	PV only	2002	11.6¢/kWh
FL	Florida Power & Light / Green Mountain Energy	Sunshine Energy	biomass, wind, PV	2004	0.975¢/kWh
FL	Gainesville Regional Utilities	GRUgreen Energy	landfill gas, wind, PV	2003	2.0¢/kWh
FL	Keys Energy Services / Sterling Planet	GO GREEN: Florida Ever Green	solar hot water, PV, biomass	2004	2.75¢/kWh
FL	Keys Energy Services / Sterling Planet	GO GREEN: USA Green	wind, biomass,PV	2004	1.60¢/kWh
FL	Tampa Electric Company (TECO)	Tampa Electric's Renewable Energy Program	PV, landfill gas, biomass co-firing	2000	5.0¢/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	2.0¢/kWh-3.3¢/kWh
GA	Georgia Power	Green Energy	landfill gas	2005	5.5¢/ kWh
GA	TVA: Blue Ridge Mountain Electric Membership Corporation, North Georgia Electric Membership Corporation	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/ kWh
HI	Hawaiian Electric	Sun Power for Schools	PV in schools	1997	Contribution
ID	Avista Utilities	Buck-A-Block	wind	2002	0.33¢/kWh
ID	Idaho Power	Green Power Program	various	2001	Contribution
ID	PacifiCorp: Utah Power	Blue Sky	wind	2003	1.95¢/kWh

State	Utility Name	Program Name	Type	Start Date	Premium
ID	Vigilante Electric Cooperative	Alternative Renewable Energy Program	wind, PV, hydro	2003	1.1¢/kWh
IL	CCS/Soyland and Community Energy, Inc (8 of 11 coops offer program): Adams Electric Co-op, Coles-Moultrie Electric, Eastern Illini Electric, McDonough Power, Menard, Rural Electric Convenience Co-op, Shelby Electric, Spoon River Electric Co-op	EcoEnergy	wind	2005	3.0¢/kWh
IL	City of Naperville / Community Energy	Renewable Energy Option	wind, small hydro, PV	2005	2.5¢/kWh
IL	City of St. Charles/ComEd and Community Energy	TBD	wind, landfill gas	2003	Contribution
IL	Dairyland Power Cooperative: Jo-Carroll Energy/Elizabeth	Evergreen Renewable Energy Program	wind	1997	1.5¢/kWh
IN	Hoosier Energy (5 of 17 coops offer program): 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 Plan Green Power Program	geothermal	1998	0.9¢/kWh
IN	PSI Energy/Cinergy	Green Power Rider	wind, PV, 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¢/kWh-1.0¢/kWh
IA	Alliant Energy	Second Nature	landfill gas, wind	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-2.5¢/kWh
IA	Cedar Falls Utilities	Harvest the Wind	wind	2000	2.5¢/kWh
IA	Corn Belt Power Cooperatives (5 of 11 co-ops): Butler County REC, Franklin REC, Grundy County REC, Humboldt County REC, Sac County REC	Energy Wise Renewables	wind	2003	1.5¢/kWh
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

State	Utility Name	Program Name	Type	Start Date	Premium
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, PV	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	1.0¢/kWh-2.5¢/kWh
IA	Muscatine Power and Water	Solar Muscatine	PV	2004	Contribution
IA	Waverly Light & Power	Green Power Choice	wind	2003	Contribution
IA	Waverly Light & Power	Iowa Energy Tags	wind	2001	2.0¢/kWh
KY	East Kentucky Power Cooperative: Blue Grass Energy, Clark, Cumberland, Fleming, Grayson, Inter-county Energy, Jackson, Licking, Mason, Nolin, Owen Electric, Salt River, Shelby, South Kentucky	EnviroWatts	landfill gas	2002	2.75¢/kWh
KY	TVA: Bowling Green Municipal Utilities, Franklin Electric Plant Board	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
MA	Concord Municipal Light Plant (CMLP)	Green Power	hydro	2004	3.0¢/kWh
MI	Consumers Energy	Green Generation	wind, landfill gas	2005	1.67¢/kWh
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	1.5¢/kWh
MI	Upper Peninsula Power Company	NatureWise	wind, landfill gas and animal waste methane	2004	4.0¢/kWh

State	Utility Name	Program Name	Type	Start Date	Premium
MI	We Energies	Energy for Tomorrow	wind, landfill gas, hydro	2000	2.0¢/kWh
MN	Alliant Energy	Second Nature	landfill gas, wind	2002	2.0¢/kWh
MN	Basin Electric Power Cooperative: Minnesota Valley Electric Coop, Sioux Valley Southwestern	Prairie Winds	wind	2002	1.0¢/kWh-2.5¢/kWh
MN	Central Minnesota Municipal Power Agency	Green Energy Program	wind, landfill gas	n/a	1.5¢/kWh-2.5¢/kWh
MN	Dairyland Power Cooperative: Freeborn-Mower Cooperative / Albert Lea, People's / Rochester, Tri-County / Rushford	Evergreen Renewable Energy Program	wind	1997	1.5¢/kWh
MN	Great River Energy (all 28 coops offer program): Agralite, Arrowhead, 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, Nobles Cooperative Electric, North Itasca, Redwood Electric Cooperative, Runestone Electric, South Central Electric Association , Stearns Electric, Steele-Waseca, Todd-Wadena , Wright-Hennepin Electric	Wellspring Renewable Wind Energy Program	wind	1998	1.45¢/kWh-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 munis offer program): 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	1.0¢/kWh-2.5¢/kWh
MN	Moorhead Public Service	Capture the Wind	wind	1998	1.5¢/kWh
MN	Otter Tail Power Company	TailWinds	wind	2002	2.6¢/kWh

State	Utility Name	Program Name	Type	Start Date	Premium
MN	Southern Minnesota Municipal Power Agency (all 18 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	SMMPA Wind Power	wind	2000	1.0¢/kWh
MN	Xcel Energy	WindSource	wind	2003	2.0¢/kWh
MS	TVA: City of Oxford, North East Mississippi Electric Power Asssociation, Starkville Electric System	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh
MO	Boone Electric Cooperative	Renewable Choice	wind	2003	2.0¢/kWh
MO	City Utilities of Springfield	WindCurrent	wind	2000	5.0¢/kWh
MT	Basin Electric Power Cooperative: Lower Yellowstone	Prairie Winds	wind	2000	1.0¢/kWh-2.5¢/kWh
MT	Northwestern Energy	E+ Green	wind, PV	2003	2.0¢/kWh
MT	Park Electric Cooperative	Green Power Program	wind, hydro	2002	1.2¢/kWh
MT	Southern Montana Electric Generation and Transmission Cooperative (5 co-ops): Fergus Electric, Yellowstone Valley, Bear Tooth Electric, Mid Yellowstone, and Tongue River	Environmentally Preferred Power	wind, hydro	2002	1.05¢/kWh
MT	Vigilante Electric Cooperative	Alternative Renewable Energy Program	wind, hydro, PV	2003	1.1¢/kWh
NE	Lincoln Electric System	LES Renewable Energy Program	wind	1998	4.3¢/kWh
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	Los Alamos Department of Public Utilities	Green Power	wind	2005	1.8¢/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
NC	Dominion North Carolina Power	NC GreenPower	biomass, wind, solar	2003	4.0¢/kWh
NC	Duke Power	NC GreenPower	biomass, wind, solar	2003	4.0¢/kWh

State	Utility Name	Program Name	Type	Start Date	Premium
NC	ElectriCities: City of High Point, City of Laurinburg, City of Newton, City of Shelby, City of Statesville, town of Apex, Town of Granite Falls	NC GreenPower	biomass, wind, solar	2003	4.0¢/kWh
NC	NC Electric Cooperatives (15 of 27 cooperatives offer the program): Albemarle EMC, 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, PV	2003	4.0¢/kWh
NC	Progress Energy / CP&L	NC GreenPower	biomass, wind, solar	2003	4.0¢/kWh
NC	TVA: Mountain Electric Cooperative	Green Power Switch	landfill gas, PV, 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-2.5¢/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	1.0¢/kWh-2.5¢/kWh
OH	American Municipal Power-Ohio / Green Mountain Energy: City of Bowling Green, Cuyahoga Falls, Wyandotte	Nature's Energy	small hydro, landfill gas, wind	2003	1.3¢/kWh-1.5¢/kWh
OK	OG&E Electric Services	OG&E Wind Power	wind	2003	2.0¢/kWh
OK	Oklahoma Municipal Power Authority: Tonkawa, Altus, Frederick, Okeene, Prague Municipal Utilities and Edmond Electric	Pure & Simple	wind	2004	1.8¢/kWh

State	Utility Name	Program Name	Type	Start Date	Premium
OK	Western Farmers Electric Cooperative (19 of 19): Alfalfa Electric Cooperative, Caddo Electric Cooperative, Canadian Valley Electric Cooperative, Choctaw Electri Cooperative, Cimmaron Electric Cooperative, Cotton Electric Cooperative, East Central Oklahoma Electric Cooperative, Harmon Electric Cooperative, Kay Electric Cooperative, Kiamichi Electric Cooperative, Kiwash Electric Cooperative, Northfork Electric Cooperative, Northwestern Electric Cooperative, Oklahoma Electric Cooperative, People's Electric Cooperative, Red River Valley Rural Electric Cooperative, Rural Electric Cooperative, Southeastern Electric Cooperative, Southwest Rural Electric Cooperative	WindWorks	wind	2004	0.5¢/kWh
OR	City of Ashland/Bonneville Environmental Foundation	Renewable Pioneers	PV, wind	2003	2.0¢/kWh
OR	Columbia River PUD	Choice Energy	wind	2005	2.0¢/kWh
OR	Emerald People's Utility District/Green Mountain Energy	Choose Renewable Electricity	wind, geothermal	2003	1.2¢/kWh
OR	Eugene Water & Electric Board	EWEB Wind Power	wind	1999	0.71¢/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	PacifiCorp: Pacific Power	Blue Sky QS (Commercial Only)	wind	2004	Sliding scale depending on size
OR	PacifiCorp: Pacific Power	Blue Sky Block	wind	2000	1.95¢/kWh
OR	PacifiCorp: Pacific Power / 3 Phases Energy Services	Blue Sky Usage	wind, biomass, PV	2002	0.78¢/kWh
OR	PacifiCorp: Pacific Power / 3 Phases Energy Services	Blue Sky Habitat	wind, biomass, PV	2002	0.78¢/kWh + $2.50/mo. donation
OR	Pacific Northwest Generating Cooperative: Central Electric Cooperative, Clearwater Power, Consumers Power, Douglas Electric Cooperative, Umatilla Electric Cooperative (5 of 16 coops offer program)	Green Power	landfill gas	1998	1.8¢/kWh-4.0¢/kWh
OR	Portland General Electric / Green Mountain Energy	Green Source	existing geothermal, wind	2002	0.8¢/kWh
OR	Portland General Electric / Green Mountain Energy	Healthy Habitat	existing geothermal, wind	2002	0.8¢/kWh + $2.50/mo. donation
OR	Portland General Electric Company	Clean Wind for Medium to Large Commercial & Industrial Accounts	wind	2003	1.35¢/kWh-1.7¢/kWh

State	Utility Name	Program Name	Type	Start Date	Premium
OR	Portland General Electric Company	Clean Wind Power	wind	2002	1.75¢/kWh
SC	Santee Cooper, Aiken Electric Cooperative, Berkeley Electric Cooperative, Edisto Electric Cooperative, Fairfield Electric Cooperative, Horry Electric Cooperative, Laurens Electric Cooperative, Lynches River Electric Cooperative, Marlboro Electric Cooperative, Mid-Carolina Electric Cooperative, Palmetto Electric Cooperative, Pee Dee Electric Cooperative, Santee Electric Cooperative, Tri-County Electric Cooperative, York 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. Power Assn., 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-2.5¢/kWh
SD	Missouri River Energy Services: City of Vermillion	RiverWinds	wind	2002	1.0¢/kWh-2.5¢/kWh
TN	TVA: 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,	Green Power Switch	landfill gas, PV, wind	2000	2.67¢/kWh

State	Utility Name	Program Name	Type	Start Date	Premium
	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, Memphis Light, Gas & Water, 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				
TX	Austin Energy (City of Austin)	GreenChoice	wind, landfill gas, hydro	2000/1997	0.5¢/kWh
TX	City Public Service of San Antonio	Windtricity	wind	2000	3.0¢/kWh
TX	El Paso Electric Company	Renewable Energy Tariff	wind	2001	1.92¢/kWh
UT	City of St. George	Clean Green Power	wind, small hydro	2005	2.95¢/kWh
UT	Deseret Power	GreenWay	various	2004	1.95¢/kWh
UT	Pacificorp: Utah Power	Blue Sky	wind	2000	1.95¢/kWh
VT	Central Vermont Public Service	CVPS Cow Power	biogas	2004	4.0¢/kWh
VT	Green Mountain Power	CoolHome / CoolBusiness	wind, biomass	2002	Contribution
WA	Avista Utilities	Buck-A-Block	wind	2002	0.33¢/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	Clallam County PUD Green Power Program	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

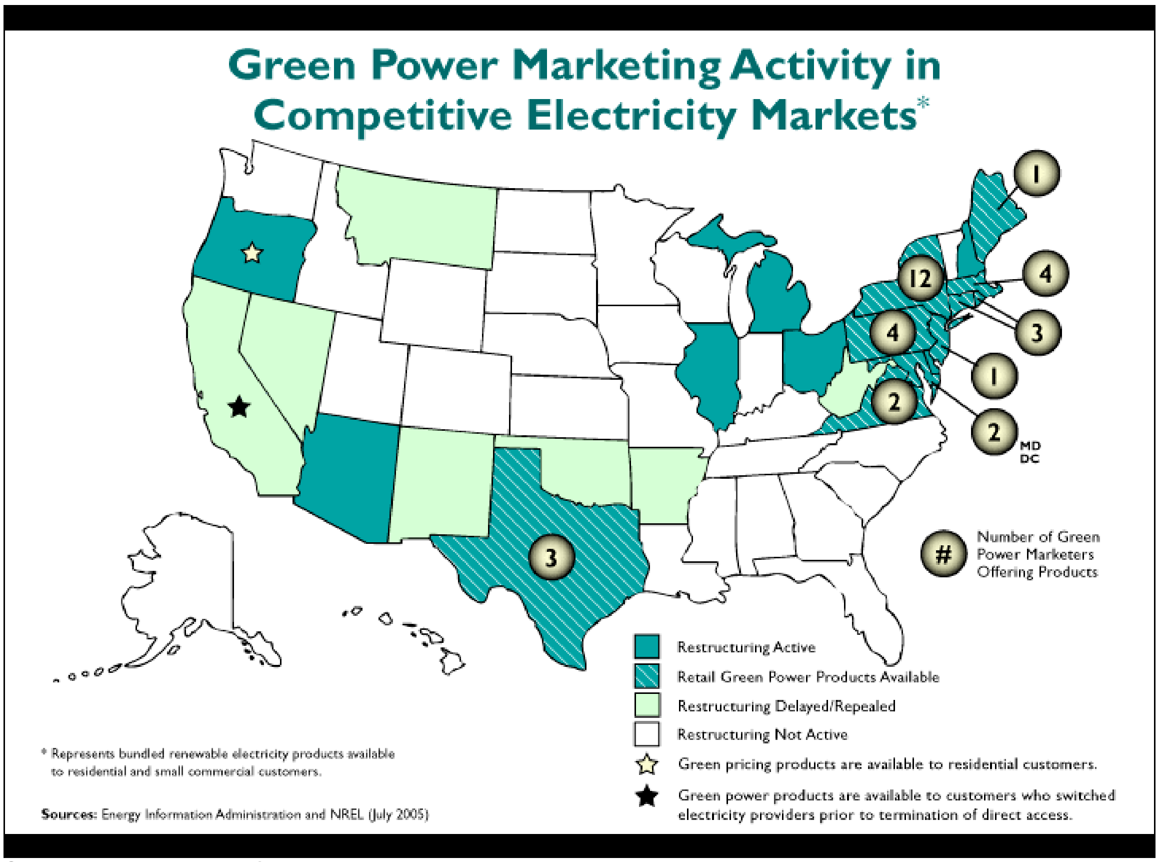
State	Utility Name	Program Name	Type	Start Date	Premium
WA	Grant County PUD	Alternative Energy Resources Program	wind	2002	2.0¢/kWh
WA	Grays Harbor PUD	Green Power	wind	2002	3.0¢/kWh
WA	Lewis County PUD	Green Power Energy Rate	wind	2003	2.0¢/kWh
WA	Mason County PUD No. 3	Mason Evergreen Power	wind	2003	2.0¢/kWh
WA	Orcas Power & Light	Go Green	wind, hydro	1999	3.5¢/kWh
WA	Pacific County PUD	Green Power	landfill gas	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 Plan	wind, PV, biogas	2002	2.0¢/kWh
WA	Seattle City Light	Green UP (C&I only)	wind	2005	1.5¢/kWh
WA	Seattle City Light	Seattle Green Power	PV, biogas	2002	Contribution
WA	Snohomish County Public Utility District	Planet Power	wind	2002	2.0¢/kWh
WA	Tacoma Power	EverGreen Options	small hydro, wind	2000	1.5¢/kWh
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	1998	1.5¢/kWh
WI	Great River Energy: Head of the Lakes	Wellspring Renewable Wind Energy Program	wind	1997	1.45¢/kWh-2.0¢/kWh
WI	Madison Gas & Electric	Wind Power Program	wind	1999	3.3¢/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	1.86¢/kWh
WI	Wisconsin Public Service	Solar Wise for Schools	PV in schools	1996	Contribution

State	Utility Name	Program Name	Type	Start Date	Premium
WY	Lower Valley Energy	Green Power	wind	2003	1.17¢/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
WY	Yampa Valley Electric Association	Wind Energy Program	wind	1999	3.0¢/kWh

3.8 – Competitive Green Power Offerings and Renewable Energy Certificates

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 (**Figure 3.8.1**).

Renewable energy certificates (RECs) – also known as green tags, renewable energy credits, or tradeable renewable certificates – present 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). See our list below of organizations that offer green certificate products.



Source: L. Bird and B. Swezey, National Renewable Energy Laboratory. Updated July 2005. http://www.eere.energy.gov/greenpower/markets/marketing.shtml?page=4

Figure 3.8.1: Green Power Marketing Activity in Competitive Electricity Markets

Based on data received from green power marketers, an estimated 200,000 retail customers were purchasing green power from competitive suppliers – or in the form of RECs – at the end of 2004. Most of these customers are purchasing green power from competitive suppliers in states with retail competition, primarily in the Northeast and Texas, including about 30,000 participants in utility/marketer programs. Of the total, fewer than 10,000 retail customers purchase REC products (**Table 3.8.1**), with most customers concentrated in the Mid-Atlantic and Northeast states where REC marketers tend to be most active. In competitive markets, the vast majority of customers purchasing green power are residential customers, while the fraction of nonresidential customers purchasing RECs is higher – on the order of one-fifth.

Table 3.8.1: Estimated Number of Customers Purchasing RECs or Green Power from Competitive Marketers, 2002-2004

	2002	2003	2004
Competitive Markets	~150,000	>150,000	>180,000
RECs	<10,000	<10,000	<10,000
Total	<160,000	~160,000	~190,000

Table 3.8.2: Retail Sales of Renewable Energy in Competitive Markets and RECs (million kWh)

	2003	2004
Competitive Markets		
Residential	na	2,140
Nonresidential	na	510
Subtotal	1,900	2,650
RECs		
Residential	na	40
Nonresidential	na	1,690
Subtotal	660	1,720
Total Sales	2,560	4,370

na = not available
An estimated 1,530 MW of new renewables capacity is used to supply competitive green power markets, or is being sold as RECs in both retail and wholesale markets; wind energy is the predominant resource type. More than 225 MW of additional renewables capacity is planned, again dominated by wind.

An estimated 4.4 billion kWh of renewable energy was sold to retail customers by competitive and REC marketers. About 2.7 billion kWh of this total was sold to retail customers bundled with electricity in competitive electricity markets – a 40% increase from 2003. This figure includes renewable energy from both existing and new sources, as well as that sold to customers in products that contain only a small percentage of renewable energy. It also includes sales of renewable energy through default utility/supplier programs or utility/marketer partnership in states with retail competition, which totaled 136 million kWh. Retail sales of RECs, which are sold separate from electricity and largely derived from new renewable energy sources, grew nearly threefold, reaching 1.7 billion kWh in 2004.

Table 3.8.3: New Renewables Capacity Supplying Competitive Markets and Renewable Energy Certificates, 2004

Source	MW in Place	%	MW Planned	%
Wind	1,461.6	95.7	224.8	99.3
Biomass	59.3	3.9	1.3	0.6
Solar	2.0	0.1	0.2	0.1
Geothermal	5.0	0.3	0.0	0.0
Small Hydro	0.0	0.0	0.0	0.0
Total	1,527.9	100.0	226.3	100.0

Source: L.Bird and B. Swezey, Estimates of New Renewable Energy Capacity Serving U.S. Green Power Markets (2004), National Renewable Energy Laboratory, September 2005. http://www.eere.energy.gov/greenpower/resources/tables/new_gp_cap.shtml

Table 3.8.4: Estimated Wholesale RECs Supplying Voluntary Markets, 2003

	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 3.8.5: 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 3.8.6: Voluntary Market Wholesale REC Prices for New Sources by Type and Region ($/MWh)

	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 3.8.7: Voluntary Market Wholesale REC Prices for Existing Sources by Type and Region ($/MWh)

	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.

Table 3.8.8: Retail Green Power Product Offerings in Competitive Electricity Markets, October 2005

State	Company	Product Name	Residential Price Premium1	Fee	Resource Mix2	Certification
CT	Community Energy (CT Clean Energy Options Program)	CT Clean Energy Options 50% or 100% of usage	1.1¢/kWh	—	50% new wind, 50% landfill gas	—
CT	Levco	100% Renewable Electricity Program	0.0¢/kWh	—	98% waste-to-energy and hydro (Class II), 2% new solar, wind, fuel cells, and landfill gas	—
CT	Sterling Planet (CT Clean Energy Options Program)	Sterling Select 50% or 100% of usage	1.15¢/kWh	—	33% new wind, 33% existing small low impact hydro, 34% new landfill gas	—
DC	PEPCO Energy Services (3)	Green Electricity 10%, 51% or 100% of usage	1.35¢/kWh (for 100% usage)	—	landfill gas	—
DC	PEPCO Energy Services (3)	NewWind Energy 51% or 100% of usage	2.05¢kWh (for 100% usage)	—	new wind	—
DC	Washington Gas Energy Services / Community Energy	New Wind Energy (5%, 10%, 25%, 50%, or 100% of usage)	2.5¢/kWh	—	new wind	—
ME	Maine Renewable Energy/Maine Interfaith Power & Light (4)	Maine Clean Power	2.37¢/kWh	—	100% low impact hydro	—
ME	Maine Renewable Energy/Maine Interfaith Power & Light (4)	Maine Clean Power Plus	2.87¢/kWh	—	80% low impact hydro, 20% wind	—
MD	PEPCO Energy Services (5)	Green Electricity 10%, 51% or 100% of usage	2.75¢/kWh (for 100% usage)	—	landfill gas	—
MD	PEPCO Energy Services (5)	NewWind Energy 51% or 100% of usage	3.35¢/kWh (for 100% usage)	—	new wind	—
MD	PEPCO Energy Services (5)	Non-residential product	NA	—	50% to 100% eligible renewables	Green-e
MD	Washington Gas Energy Services / Community Energy	New Wind Energy	2.5¢/kWh	—	new wind (5%, 10%, 25%, 50%, or 100% of usage) or 100 kWh blocks	—
MA	Cape Light Compact (6)	Cape Light Compact Green 50% or 100%	1.768¢/kWh (for 100% usage)	—	75% small hydro, 24% new wind or landfill gas, 1% new solar	—
MA	Massachusetts Electric/Nantucket Electric/Community Energy	New Wind Energy 50% or 100% of usage	2.4¢/kWh	—	50% small hydro, 50% new wind	Green-e

State	Company	Product Name	Residential Price Premium1	Fee	Resource Mix2	Certification
MA	Massachusetts Electric/Nantucket Electric/Mass Energy Consumers Alliance	New England GreenStart 50% or 100% of usage	2.4¢/kWh (for 100% usage)	—	75% small hydro, 19% biomass, 5% wind, 1% solar (≥25% of total is new)	—
MA	Massachusetts Electric/Nantucket Electric/Sterling Planet	Sterling Premium 50% or 100% of usage	1.35¢/kWh	—	50% small hydro, 30% bioenergy, 15% wind, 5% new solar	Environmental Resources Trust
NJ	Green Mountain Energy Company (7)	Enviro Blend	1.0¢/kWh	$3.95/mo.	5% new wind, 0.4% solar, 44.6% captured methane, 50% large hydro	—
NJ	PSE&G/JCP&L/ Community Energy	Clean Power Choice Program	1.3¢/kWh	—	50% wind, 49% low impact hydro, 1% solar	—
NJ	PSE&G/JCP&L/ Green Mountain Energy	Clean Power Choice Program	0.9¢/kWh	—	50% wind, 50% low impact hydro	—
NJ	PSE&G/JCP&L/ Jersey-Atlantic Wind	Clean Power Choice Program	2.9¢/kWh	—	50% wind, 50% low impact hydro	—
NJ	PSE&G/JCP&L/ Jersey-Atlantic Wind	Clean Power Choice Program: New Jersey Wind Energy	5.5¢/kWh	—	100-kWh new wind	—
NJ	PSE&G/JCP&L/ Sterling Planet	Clean Power Choice Program	1.2¢/kWh	—	33% wind, 33% small hydro, 34% bioenergy	Environmental Resources Trust
NY	ConEdison Solutions (8) / Community Energy	GREEN Power	0.5¢/kWh	—	25% new wind, 75% small hydro	Green-e
NY	ECONnergy	Keet It Clean	$.10/day for 100kWh $.20/day for 200kWh	—	100% new wind	—
NY	Energy Cooperative of New York (9)	Renewable Electricity	0.5¢/kWh to 0.75¢/kWh	—	25% new wind, 75% existing landfill gas	—
NY	Long Island Power Authority / Community Energy	New Wind Energy	2.5¢/kWh	—	new wind	—
NY	Long Island Power Authority / Community Energy	New Wind Energy and Water	1.3¢/kWh	—	60% new wind, 40% small hydro	—
NY	Long Island Power Authority / EnviroGen	Green Power Program	1.0¢/kWh	—	75% landfill gas, 25% small hydro	—
NY	Long Island Power Authority / Sterling Planet	New York Clean	1.0¢/kWh	—	55% small hydro, 35% bioenergy, 10% wind	—
NY	Long Island Power Authority / Sterling Planet	Sterling Green	1.5¢/kWh	—	40% wind, 30% small hydro, 30% bioenergy	—
NY	NYSEG/Community Energy	Catch the Wind/New Wind Energy	2.5¢/kWh	—	100-kWh blocks of new wind	—

State	Company	Product Name	Residential Price Premium1	Fee	Resource Mix2	Certification
NY	Niagara Mohawk / Community Energy	60% New Wind Energy and 40% Small Hydro	1.0¢/kWh	—	60% new wind, 40% hydro	—
NY	Niagara Mohawk / Community Energy	NewWind Energy	2.0¢/kWh	—	new wind	—
NY	Niagara Mohawk / EnviroGen	Think Green!	1.0¢/kWh	—	75% landfill gas, 25% hydro	—
NY	Niagara Mohawk / Sterling Planet	Sterling Green	1.5¢/kWh	—	40% wind, 30% small hydro, 30% bioenergy	Environmental Resources Trust
NY	Niagara Mohawk/Green Mountain Energy	Green Mountain Energy Electricity	1.3¢/kWh	—	50% small hydro, 50% wind	Green-e
NY	Rochester Gas & Electric/Community Energy	Catch the Wind/NewWind Energy	2.5¢/kWh	—	100-kWh blocks of new wind	—
NY	Suburban Energy Services /Sterling Planet	Sterling Green Renewable Electricity	1.5¢/kWh	—	40% new wind, 30% small hydro, 30% bioenergy	—
PA	Energy Cooperative of Pennsylvania (10)	EcoChoice 100	2.78¢/kWh	—	89% landfill gas, 10% wind, 1% solar	Green-e
PA	Energy Cooperative of Pennsylvania (10)	Wind Energy	2.5¢/kWh	—	wind	—
PA	PECO Energy/Community Energy (10)	PECO Wind	2.54¢/kWh	—	100-kWh blocks of new wind	—
PA	PEPCO Energy Services (10)	Green Electricity 10%, 51% or 100% of usage	3.7¢/kWh (for 100% usage)	—	100% renewable	—
PA	PEPCO Energy Services (10)	NewWind Energy 51% or 100% of usage	4.48¢/kWh (for 100% usage)	—	100% new wind	—
RI	Narragansett Electric / Community Energy, Inc.	NewWind Energy 50% or 100% of usage	2.0¢/kWh	—	50% small hydro, 50% new wind	Green-e
RI	Narragansett Electric / People's Power & Light	New England GreenStart RI 50% or 100% of usage	1.5¢/kWh	—	69% small hydro, 30% new wind, 1% new solar	Green-e
RI	Narragansett Electric / Sterling Planet	Sterling Supreme 100%	1.98¢/kWh	—	40% small hydro, 25% biomass, 25% new solar, 10% wind	Environmental Resources Trust
TX	Gexa Energy (11)	Gexa Green	-1.1¢/kWh	—	100% renewable	—
TX	Green Mountain Energy Company (11)	100% Wind Power: Reliable Rate or Month-to-Month	1.46¢/kWh	$5.34/mo.	wind	—
TX	Green Mountain Energy Company (11)	Pollution Free: Reliable Rate or Month-to-Month	-0.03¢/kWh	$5.34/mo.	wind and hydro	—
TX	Reliant Energy (11)	Renewable Plan	-1.1¢/kWh	—	wind	—
VA	PEPCO Energy Services (12)	Green Electricity 10%, 51% or 100% of usage	4.53¢/kWh (for 100% usage)	—	landfill gas	—

State	Company	Product Name	Residential Price Premium1	Fee	Resource Mix2	Certification
VA	PEPCO Energy Services (12)	NewWind Energy 51% or 100% of usage	5.33¢/kWh (for 100% usage)	—	new wind	—
VA	Washington Gas Energy Services / Community Energy	New Wind Energy Certificates	2.5¢/kWh	—	100 kWh blocks of new wind	—

1 Prices updated as of July 2005 and may also apply to small commercial customers. Prices may differ for large commercial/industrial customers and may vary by service territory.
2 New is defined as operating or repowered after January 1, 1999 based on the Green-e TRC certification standards.
3 Offered in PEPCO service territory. Product prices are for renewal customers based on annual average costs for customers in PEPCO's service territory (6.8¢/kWh).
4 Price premium is for Central Maine Power service territory based on standard offer of 7.13¢/kWh.
5 Product offered in Baltimore Gas and Electric and PEPCO service territories. Price is for PEPCO service territory based on price to compare of 6.55¢/kWh.
6 Price premium is based on a comparison to the Cape Light Compact's standard electricity product.
7 Green Mountain Energy offers products in Conectiv, JCPL, and PSE&G service territories. Product prices are for PSE&G (price to compare of 6.503¢/kWh).
8 Price premium is based on a comparison to ConEdison Solutions' standard electricity product in the ConEdison service territory.
9 Price premium is for Niagara Mohawk service territory. Program only available in Niagara Mohawk service territory. Premium varies depending on energy taxes and usage.
10 Product prices are for PECO service territory (price to compare of 6.21¢/kWh).
11 Product prices are based on price to beat of 12.1¢/kWh for TXU service territory (specifically Dallas, Texas) (Except where noted). Except for Gexa Green, which is listed in price per kWh, prices based on 1000 kwh of usage monthly, and include monthly fees.
12 Products are available in Dominion Virginia Power service territory

Table 3.8.9: Renewable Energy Certificate (REC) Retail Products, October 2005

Certificate Marketer	Product Name	Renewable Resources	Location of Renewable Resources	Residential Price Premiums*	Certification
3 Phases Energy Services	Green Certificates	100% new wind	Nationwide	2.0¢/kWh	Green-e
Blue Sky Energy Corp	Greener Choice™ Green Tags	Landfill Gas	Utah	1.95¢/kWh	—
Bonneville Environmental Foundation	Green Tags	≥98% new wind, ≤1% new solar, ≤1% new biomass	Washington, Oregon, Wyoming, Montana, Alberta	2.0¢/kWh	Green-e
Clean and Green	Clean and Green Membership	100% new wind	National	3.0¢/kWh	Green-e
Clean Energy Partnership/Community Energy	Mid Atlantic Wind	100% new wind	Mid Atlantic	2.0¢/kWh	Green-e
Clean Energy Partnership/Sterling Planet	National New Clean Energy MIx	24% wind, 25% biomass, 50% landfill gas, 1% solar	National	0.6¢/kWh	Environmental Resources Trust
Clean Energy Partnership/Sterling Planet	National and Regional New Wind	100% new wind	National	1.0¢/kWh	Environmental Resources Trust
Community Energy	New Wind Energy	100% new wind	Colorado, Illinois, New York, Pennsylvania, West Virginia	2.0¢/kWh - 2.5¢/kWh	Green-e
Conservation Services Group	ClimateSAVE	95% new wind, 5% new solar	Kansas (wind), New York (solar)	1.65¢/kWh - 1.75¢/kWh	Green-e
EAD Environmental	100% Wind Energy Certificates	100% new wind	Not specified	1.5¢/kWh	—
EAD Environmental	Home Grown Hydro Certificates	100% small hydro (<5MW)	New England	1.2¢/kWh	—
Green Mountain Energy	TBD (Pennsylvania REC product)	100% wind	National	1.7¢/kWh- 2.0¢/kWh	—
Maine Interfaith Power & Light/BEF	Green Tags (supplied by BEF)	≥98% new wind, ≤1% new solar, ≤1% new biomass	Washington, Oregon, Wyoming, Montana, Alberta	2.0¢/kWh	—
Mass Energy Consumers Alliance	New England Wind	100% new wind	Massachusetts	5.0¢/kWh	—
NativeEnergy	CoolHome	New biogas and new wind	Vermont and Pennsylvania (biomass), South Dakota (wind)	0.8¢/kWh - 1.0¢/kWh	**
NativeEnergy	WindBuilders	100% new wind	South Dakota	~1.2¢/kWh, $12 per ton of CO2 avoided	**
Renewable Choice Energy	American Wind	100% new wind	Nationwide	2.0¢/kWh	Green-e

Certificate Marketer	Product Name	Renewable Resources	Location of Renewable Resources	Residential Price Premiums*	Certification
Renewable Ventures	PVUSA Solar Green Certificates	100% solar	California	3.3¢/kWh	Green-e
SKY energy, Inc.	Wind-e Renewable Energy	100% new wind	Nationwide	2.4¢/kWh	Green-e
Sterling Planet	Green America	45% new wind, 50% new biomass, 5% new solar	Nationwide	1.6¢/kWh	Green-e
TerraPass Inc.	TerraPass	Various (including efficiency and CO2 offsets)	Nationwide	~$11/ton CO2	—
Waverly Light & Power	Iowa Energy Tags	100% wind	Iowa	2.0¢/kWh	—
WindCurrent	Chesapeake Windcurrent	100% new wind	Mid-Atlantic States	2.5¢/kWh	Green-e

Premium may also apply to small commercial customers. Large users may be able to negotiate price premiums.
Most product prices are as of July 2005.
** The Climate Neutral Network certifies the methodology used to calculate the CO2 emissions offset.
NA = Not applicable.

3.9 – Federal Agency Purchases of Green Power

The federal government exceeded its goal of obtaining 2.5% of its electricity needs from renewable energy sources by September 30, 2005. The federal renewable energy goal was established under Executive Order 13123, issued by President Clinton in 1999. The federal government, which is the nation's largest energy consumer, purchases 2.375 billion kWh of renewable energy annually.

The Energy Policy Act of 2005, signed into law by President Bush on August 8, 2005, establishes a new set of federal renewable energy goals, calling for agencies to derive 3% of their electric energy from renewable sources in fiscal years 2007 through 2009, increasing to 5% in fiscal years 2010 through 2012, and 7.5% by 2013 and each fiscal year thereafter.

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**).

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; SRP – Earthwise Solar Energy; TEP – SunShare PV Buydown; UES – 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; 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; IID Energy – PV Solutions Rebate Program; LADWP – Solar Incentive Program; Pasadena Water and Power – Solar Power Installation Rebate; Redding Electric – Earth Vantage Renewable Energy Rebate Program; Riverside Public Utilities – Energy Efficiency Construction Incentive; Riverside Public Utilities – Residential Photovoltaic Incentive Program; Roseville Electric – PV Buy Down Program; SMUD Commercial/Industrial PV Rebate; SMUD – PV Pioneers Residential Buy-Down; SMUD – Solar Water Heater Program Rebate; Ukiah Utilities – PV Buy-Down Program Marin County – Solar Rebate Program; San Diego – Residential Solar Electric Incentive for Homes Destroyed in Wildfires Santa Monica – Green Building Grant Program; SMUD – Solar Water Heater Loan Program; Supplemental Energy Payments (SEPs)
CO		Utility PV Rebate; Holy Cross Energy WE CARE Rebates 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
CT	Local Option for Property Tax	Residential Solar PV Rebate Program; Connecticut - Commercial, Industrial, Institutional PV Grant Program; Connecticut - New Energy Technology Program; Energy Conservation Loan; Operational Demonstration Program; Renewable Energy Projects in Pre-Development Program
DE		Green Energy Program Rebates; Research and Development Grants; Technology and Demonstration Grants
DC		District of Columbia Renewable Demonstration Project
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; 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)	Renewable Energy Equipment Sales Tax Refund; BEF - Renewable Energy Grant; BEF – Solar 4R Schools; Low-Interest Loans for Renewable Energy Resource Program
IL	Special Assessment for Renewable Energy Systems	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	Renewable Energy Production Tax Credit (Personal); Renewable Energy Production Tax Credit (Corporate); 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		Solar Water Heater Loan Program
LA	Solar Energy System Exemption	
ME		Solar Rebate Program; Renewable Resources Matching Fund Program
MD	Personal Income Tax Credit for Green Buildings; Corporate Income Tax Credit for Green Buildings; 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; Montgomery County – Clean Energy Rewards Program
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	Commercial, Industrial, & Institutional Initiative Grants; Small Renewables Initiative Rebate; Matching Grants for Communities
MI	Alternative – Energy Personal Property Tax Exemption;	Community Energy Project Grants; Energy Efficiency Grants; Large-Scale PV Demonstration Project Grants; Michigan Biomass Energy Program Grants; Solar Domestic Hot Water System Rebate Program; Small Business P2 Loan Program
MN	Solar-Electric (PV) Sales Tax Exemption; Wind Sales Tax Exemption; Wind and Solar-	State of Minnesota Solar-Electric (PV) Rebate Program; Great River Energy - Solar-Electric (PV) Rebate Program; Minnesota Power Solar-Electric (PV) Rebate Program; Renewable Development Fund

State	Tax Incentives	Grants, Loans, Rebates and Other Incentives
	Electric (PV) Systems Exemption	Grants; Agricultural Improvement Loan Program for Wind Energy; Energy Investment Loan Program; Value-Added Stock Loan Participation Program Renewable Energy Production Incentives
MS		Energy Investment Loan 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 - USB Renewable Energy Fund; BEF - Renewable Energy Grant; BEF – Solar 4R Schools; Alternative Energy Revolving Loan Program
NE		Dollar and Energy Savings Loans
NV	Renewable Energy/Solar Sales Tax Exemption; Property Tax Abatement for Green Buildings; Renewable Energy Producers Property Tax Abatement; Renewable Energy Systems Property Tax Exemption	Solar Generations PV Rebate Program
NH	Local Option Property Tax Exemption for Renewable Energy	
NJ	Solar and Wind Energy Systems Exemption	New Jersey Clean Energy Rebate Program; Renewable Energy Advanced Power Program; Renewable Energy Economic Development Program (REED); Renewable Energy Business Venture Assistance Program (REBVAP); Clean Energy Financing for Local Schools and Governments
NM	Renewable Energy Production Tax Credit; Biomass Equipment and Materials Deduction;	Clean Energy Grants Program; Schools with Sol
NY	Solar and Fuel Cell Tax Credit; Solar Cells Tax Exemption; Solar, Wind and Biomass 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 (EILP)
ND	Geothermal, Solar and Wind Personal Credit; Geothermal, Solar, and Wind Corporate Credit; Hydrogen and 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 Exemption	Residential Renewable Energy Grants; Renewable Energy Loans

State	Tax Incentives	Grants, Loans, Rebates and Other Incentives
OK	Zero-Emission Facilities Production Tax Credit	
OR	Residential Energy Tax Credit; Business Energy Tax Credit; Renewable Energy Systems Exemption	Energy Trust Solar Electric Buy-Down Program; Energy Trust 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; Energy Trust Open Solicitation Program; BEF - Renewable Energy Grant; BEF – Solar 4R Schools; 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
RI	Residential Renewable Energy Tax Credit; Renewable Energy Sales Tax Exemption; Solar Property Tax Exemption	PV & Wind Rebate Program; Small Customer Incentive Program for Green Power Marketers; RFP for Purchase/Sale of Renewable Electricity to Large Customers Renewable Generation Supply Incentive
SC		Residential Solar Initiative for EarthCraft Homes Rebate
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; Renewable Energy Systems Property Tax 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 & Small Wind Incentive Program; CVPS Biomass Grants
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; Clark Public Utilities – Solar Water Heater Rebate Program; Grays Harbor PUD - Solar Water Heating Rebate; Klickitat PUD – Solar Rebate; Orcas Power & Light - Photovoltaic Rebate; Puget Sound Energy - Solar PV System Rebate; Franklin PUD – Photovoltaic and Solar Water Heating Rebate;
WV	Tax Exemption for Wind Energy Generation; Special Assessment for Wind Energy Systems	

State	Tax Incentives	Grants, Loans, Rebates and Other Incentives
WI	Solar and Wind Energy Equipment Exemption	Focus on Energy - Cash-Back Reward; Wisconsin Public Power, Inc. – Residential Renewable Energy Rebate; Focus on Energy - Grant Programs; Focus on Energy – Zero-Interest Loans; Wisconsin Public Power, Inc. – Residential Renewable Energy Loan
WY	Renewable Energy Sales Tax Exemption	Photovoltaic Incentive Program

Source: North Carolina Solar Center, Database of State Incentives for Renewable Energy, http://www.dsireusa.org/summarytables/financial.cfm?&CurrentPageID=7, November 2005.

Table 4.1 – Projections of Renewable Electricity Net Capacity

(Gigawatts)

	Data Sources	Projections					
Renewable Energy		**2006**	**2010**	**2015**	**2020**	**2025**	**2030**
Geothermal	AEO2006 - Reference Case	2.23	2.56	3.19	4.61	6.02	6.64
	AEO2006 - High Renewables		2.80		6.19		9.14
	EERE GPRA FY07		2.21	2.61	3.53	4.88	
Wind	AEO2006 - Reference Case	11.56	16.27	17.71	18.81	19.80	20.10
	AEO2006 - High Renewables		16.27		18.87		22.63
	EERE GPRA FY07		8.91	18.98	77.66	135.85	
Solar[1]	AEO2006 - Reference Case	0.67	1.17	1.31	1.47	1.71	2.62
	AEO2006 - High Renewables		1.17		1.47		2.87
	EERE GPRA FY07		1.97	6.27	31.16	68.86	
Hydroelectric	AEO2006 - Reference Case	78.31	78.32	78.37	78.53	78.53	78.53
	AEO2006 - High Renewables		78.33		78.41		78.76
	EERE GPRA FY07		79.21	79.21	79.21	79.21	
Biomass/Wood (excludes cogen)	AEO2006 - Reference Case	2.09	2.15	2.15	2.46	3.45	4.63
	AEO2006 - High Renewables		2.20		3.96		10.55
	EERE GPRA FY07		1.83	2.01	2.62	4.57	
MSW and LFG	AEO2006 - Reference Case	3.55	3.78	3.92	4.02	4.11	4.14
	AEO2006 - High Renewables		3.79		4.03		4.14
	EERE GPRA FY07[2]		3.83	3.84	3.92	3.93	
Total Renewable Energy	AEO2006 - Reference Case	102.92	109.26	112.12	115.93	120.21	123.95
	AEO2006 - High Renewables		109.82		119.81		137.09
	EERE GPRA FY07[3]		98.54	115.53	196.25	225.38	

Sources: EIA *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Tables A16 and D7. Total Renewable Capacity GPRA projections provided by OnLocation, February 2006.
Notes: OnLocation GPRA07 benefits estimates do not estimate any programmatic influence on biomass power, because 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. The GPRA FY07 modeling effort uses the NEMS model, which uses the EIA *AEO 2005* as the baseline for its analysis.

[1] Solar-thermal and photovoltaic energy.

[2] EERE does not have an R&D program for biomass, LFG/MSW, so they 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)

	Data Sources			Projections			
Renewable Energy		**2006**	**2010**	**2015**	**2020**	**2025**	**2030**
Geothermal	AEO2006 - Reference Case	14.91	17.51	22.84	34.01	46.74	52.70
	AEO2006 - High Renewables		19.16		47.91		73.01
	EERE GPRA FY07		12.30	15.60	23.50	35.00	
Wind	AEO2006 - Reference Case	35.25	50.87	55.98	59.82	63.48	64.51
	AEO2006 - High Renewables		50.87		59.97		73.90
	EERE GPRA FY07		25.80	64.60	309.40	558.60	
Solar[1]	AEO2006 - Reference Case	1.19	2.35	2.69	3.10	3.68	5.71
	AEO2006 - High Renewables		2.36		3.10		6.25
	EERE GPRA FY07		3.90	12.80	63.10	151.10	
Hydroelectric	AEO2006 - Reference Case	293.13	301.40	301.82	302.87	303.06	303.27
	AEO2006 - High Renewables		301.40		302.15		304.46
	EERE GPRA FY07		303.60	303.70	304.00	304.30	
Biomass/Wood (without cogeneration)	AEO2006 - Reference Case	18.87	44.67	44.80	48.59	51.30	57.83
	AEO2006 - High Renewables		45.45		59.94		95.96
	EERE GPRA FY07		27.20	29.60	32.10	39.30	
MSW and LFG	AEO2006 - Reference Case	25.29	27.13	28.20	29.06	29.75	30.03
	AEO2006 - High Renewables		27.13		29.08		30.04
	EERE GPRA FY07[2]		27.70	27.80	28.50	28.60	
Total Renewable Energy	AEO2006 - Reference Case	417.45	475.75	490.86	515.15	539.06	559.14
	AEO2006 - High Renewables		479.65		544.91		638.67
	EERE GPRA FY07[3]		400.70	454.70	742.60	927.90	

Sources: EIA *Annual Energy Outlook 2006,* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Tables A16 and D7. Renewable generation GPRA projections provided by OnLocation, February 2006.
Notes: OnLocation GPRA07 benefits estimates do not estimate any programmatic influence on biomass power, because 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. The GPRA FY07 modeling effort uses the NEMS model, which uses the EIA AEO 2005 as the baseline for its analysis.

[1] Solar-thermal and photovoltaic energy.

[2] EERE does not have an R&D program for biomass, LFG/MSW, so they 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 4.3 – Projections of Renewable Electricity Carbon Dioxide Emissions Savings

(Million Metric Tons Carbon Equivalent per Year)

	Data Sources	Projections 2006	2010	2015	2020	2025	2030
Renewable Energy							
Geothermal	AEO2006 - Reference Case	2.87	3.48	4.22	5.59	7.17	6.88
	AEO2006 - High Renewables		3.81		7.87		9.53
	EERE GPRA FY07		2.44	2.88	3.86	5.37	
Wind	AEO2006 - Reference Case	6.79	10.10	10.34	9.83	9.74	8.42
	AEO2006 - High Renewables		10.10		9.85		9.65
	EERE GPRA FY07		5.12	11.93	50.84	85.69	
Solar[1]	AEO2006 - Reference Case	0.23	0.47	0.50	0.51	0.56	0.75
	AEO2006 - High Renewables		0.47		0.51		0.82
	EERE GPRA FY07		0.77	2.36	10.37	23.18	
Hydroelectric	AEO2006 - Reference Case	56.43	59.86	55.75	49.77	46.49	39.60
	AEO2006 - High Renewables		59.86		49.65		39.75
	EERE GPRA FY07		60.30	56.10	49.96	46.68	
Biomass/Wood	AEO2006 - Reference Case	3.63	8.87	8.27	7.98	7.87	7.55
	AEO2006 - High Renewables		9.03		9.85		12.53
	EERE GPRA FY07		5.40	5.47	5.27	6.03	
MSW and LFG	AEO2006 - Reference Case	4.87	5.39	5.21	4.78	4.56	3.92
	AEO2006 - High Renewables		5.39		4.78		3.92
	EERE GPRA FY07[2]		5.50	5.13	4.68	4.39	
Total Renewable Energy	AEO2006 - Reference Case	80.36	94.49	90.67	84.65	82.69	73.00
	AEO2006 - High Renewables		95.27		89.54		83.39
	EERE GPRA FY07[3]		79.59	83.99	122.03	142.34	
Heat Rate	Btu/kWh	10,796	10,593	9,019	8,266	7,891	6,872
Carbon Coefficient	MMTCE/Tbtu	0.01783	0.01875	0.02048	0.01988	0.01944	0.01900

Sources: Generation data: EIA *Annual Energy Outlook 2006*, DOE/EIA-0383 (06) (Washington, D.C., February 2006), Tables A16 and F8. Renewable generation GPRA projections provided by OnLocation, February 2006. Heat Rate and Carbon Coefficienct data based on GPRA 2003 Data Call.
Carbon emission coefficients and heat rates for 2006-2025: U.S. Department of Energy, GPRA2003 Data Call, Appendix B, pages B-13 and B-16, (September 14, 2001). 2030 values are NREL estimates based on trend.

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, so they 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. Total and Delivered Energy (Overview)

(Quadrillion Btu per year)

	1980	1990	2000	2001	2002	2003	2004 [7]	2010	2015	2020	2025	2030
Total Consumption by Source [1]												
Petroleum [2]	34.20	33.55	38.26	38.19	38.23	38.81	39.83	43.14	45.69	48.14	50.57	53.58
Natural Gas	20.39	19.74	23.91	22.90	23.62	23.07	22.98	24.04	26.67	27.70	27.78	27.66
Coal [3]	15.39	19.58	23.54	22.91	23.10	23.48	23.66	25.09	25.66	27.65	30.89	34.49
Nuclear	2.74	6.10	7.86	8.03	8.14	7.96	8.23	8.44	8.66	9.09	9.09	9.09
Renewable [4]	5.49	6.13	6.16	5.33	5.84	6.08	6.12	7.08	7.43	8.00	8.61	9.02
Other [5]	0.07	-0.03	0.06	-0.02	-0.01	-0.07	0.04	0.07	0.08	0.05	0.05	0.05
Total Primary	78.29	84.71	98.96	96.47	97.87	98.31	99.73	107.87	114.18	120.63	126.99	133.88
Total Consumption by Sector												
Residential	15.85	17.06	20.53	20.29	20.91	21.20	21.18	22.99	24.07	25.17	25.88	26.64
Commercial	10.59	13.32	17.18	17.37	17.58	17.45	17.51	19.51	21.23	23.02	24.82	26.73
Industrial	32.15	31.90	34.70	32.53	32.53	32.56	33.25	34.46	35.60	36.95	38.77	40.58
Transportation	19.70	22.42	26.55	26.28	26.85	27.10	27.79	30.90	33.29	35.50	37.52	39.93
Total Primary [6]	78.29	84.71	98.96	96.47	97.87	98.31	99.73	107.87	114.18	120.63	126.99	133.88
Delivered Consumption by Sector												
Residential	7.50	6.60	7.20	6.91	6.89	7.19	7.02	12.25	12.81	13.31	13.64	14.04
Commercial	4.10	3.85	4.22	4.04	4.10	4.26	4.07	9.00	9.85	10.66	11.50	12.44
Industrial	22.67	21.21	22.80	21.80	21.77	21.48	22.08	26.67	27.72	28.91	30.58	32.19
Transportation	19.66	22.37	26.49	26.22	26.79	27.03	27.71	30.70	33.09	35.30	37.31	39.72
Total Delivered [6]	53.93	54.03	60.72	58.96	59.54	59.95	60.88	78.62	83.46	88.19	93.04	98.40

Sources: EIA, *Annual Energy Outlook 2006,* DOE/EIA-0383(2006) (Washington, D.C., February 2006), Tables A1 and A2; EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), 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 nonpetroleum-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.

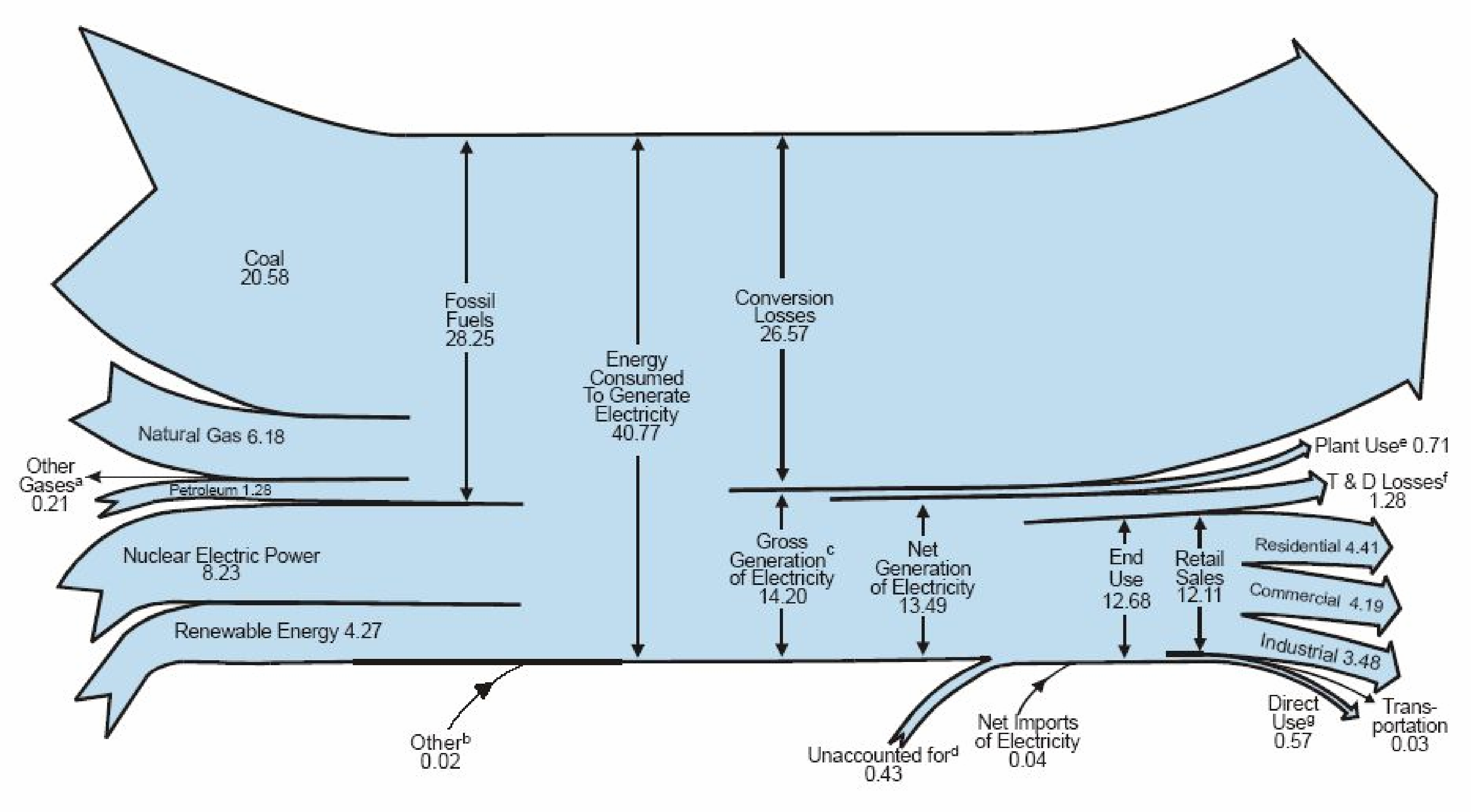
[4] Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; municipal solid waste; other biomass; wind; photovoltaic and solar-thermal sources; nonelectric energy from renewable sources, such as active and passive solar systems, and wood for residential heating; and both the ethanol and gasoline components of E85 (which, due to seasonal adjustments in mix, is E74, on average), but not lower percentage blends of ethanol (e.g. E10). Excludes electricity imports using renewable sources and nonmarketed renewable energy.

[5] For historical figures, this value includes hydroelectric pumped storage and electricity net imports – except in 2004, where it only shows electricity net imports (*AER 2004* no longer includes hydroelectric pumped storage). For forecasted figures, this value includes net electricity imports, methanol, and liquid hydrogen.

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

[7] All 2004 figures are preliminary.

Table 5.2 – Electricity Flow Diagram (Quadrillion Btu)



Source: EIA*, Annual Energy Review 2004,* DOE/EIA-0384(2004) (Washington, D.C., August 2005), Diagram 5.

Notes:

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

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

e Electric energy used in the operation of power plants, estimated as 5% of gross generation.

f Transmission and distribution losses (electricity losses that occur between the point of generation and delivery to the customer) are estimated as 9% of gross generation.

c Estimated as net generation divided by 0.95.

g Use of electricity that is 1) self-generated, 2) produced by either the same entity that consumes the power or an affiliate, and 3) used in direct support of a service or industrial process located within the same facility or group of facilities that house the generating equipment. Direct use is exclusive of station use.

d Data collection frame differences and sampling error.

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

Table 5.3 – Electricity Overview

(Billion Kilowatthours, unless otherwise noted)

	1980	1990	2000	2001	2002	2003	2004 [7]	2010	2015	2020	2025	2030
Electric-Power Sector Generation[1]	2,286	2,901	3,638	3,580	3,698	3,721	3,794	4,196	4,501	4,827	5,121	5,497
End-Use Sector Generation	3	137	164	157	160	162	160	192	226	280	370	429
Total Generation	2,290	3,038	3,802	3,737	3,858	3,883	3,953	4,388	4,727	5,108	5,491	5,926
Capability (gigawatts)												
Electric-Power Sector[2]	579	710	782	819	876	919	938	988	965	1,027	1,098	1,186
End-Use Sector[3]	NA	24	30	29	29	30	30	32	37	44	56	64
Total Capability	579	734	812	848	905	949	968	1,021	1,002	1,072	1,154	1,250
Imports from Canada/Mexico	25	18	49	39	36	30	34	42	41	29	28	27
Exports to Canada/Mexico	4	16	15	16	14	24	22	21	18	15	13	13
Loss and Unaccounted for[4]	216	203	243	226	253	233	248	NA	NA	NA	NA	NA
Retail Sales [5]	2,094	2,713	3,421	3,370	3,463	3,488	3,551	3,978	4,300	4,629	4,956	5,341
Direct Use [6]	NA	125	171	163	166	168	166	177	192	214	252	278
Total Use	2,094	2,838	3,592	3,533	3,629	3,656	3,717	4,155	4,491	4,844	5,208	5,619

Sources: EIA, *Annual Energy Outlook 2006,* DOE/EIA-0383(2006) (Washington, D.C., February 2005), Tables A8, A9, and A10; EIA, *Annual Energy Review 2004,* DOE/EIA-0384(2004) (Washington, D.C., August 2005), 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. All data after 1989 include electric-sector combined-heat-and-power (CHP) plants.

[3] Commercial and industrial combined-heat-and-power (CHP) and electricity-only plants; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid. 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 on-site net electricity generation; and electricity sales among adjacent or colocated facilities for which revenue information is not available.

NA = not available

Table 5.4 – Consumption of Fossil Fuels by Electric Generators

	1980	1990	2000	2001	2002	2003	2004 [8]	2010	2015	2020	2025	2030
Coal (million short tons) [1]	569	781	983	962	975	1,003	1,013	1,140	1,161	1,235	1,354	1,502
Distillate Fuel Oil (million barrels) [2]	29	16	30	29	22	27	18	40	40	41	44	46
Residual Fuel Oil (million barrels) [3]	391	183	138	159	105	137	141	117	116	117	118	128
Petroleum Coke (million short tons)	0.2	1.0	3.2	3.3	5.7	5.7	6.8	NA	NA	NA	NA	NA
Other Liquids (million barrels) [4]	NA	0.02	0.4	0.4	1.2	1.9	2.0	NA	NA	NA	NA	NA
Total Petroleum (million barrels) [5]	421	205	184	205	156	195	195	157	156	158	162	173
Natural Gas (billion cubic feet)	3,682	3,147	5,014	5,142	5,408	4,909	5,217	5,509	7,142	7,459	7,052	6,381
Stocks of Coal and Petroleum (end of year) [6]												
Coal (million short tons)	183	156	102	138	142	122	107	NA	NA	NA	NA	NA
Petroleum (million barrels) [7]	136	84	41	57	52	53	50	NA	NA	NA	NA	NA

Sources: EIA, *Annual Energy Outlook 2006, DOE/EIA-0383(2006)* (Washington, D.C., February 2006), Tables A2, A13, and A15; EIA, *Annual Energy Review 2004,* DOE/EIA-0384(2004) (Washington, D.C., August 2005), 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.

[8] All 2004 figures are preliminary
NA = not available

Table 5.5 – Electric-Power Sector Energy Consumption

(Trillion Btu)

	1980	1990	2000	2001	2002	2003	2004 [5]	2010	2015	2020	2025	2030
Coal	12,123	16,235	20,185	19,494	19,733	20,137	20,227	22,919	23,352	25,018	27,542	30,742
Natural Gas	3,810	3,224	5,120	5,271	5,522	5,009	5,351	5,647	7,320	7,645	7,228	6,541
Petroleum	2,634	1,281	1,145	1,270	955	1,199	1,196	971	960	972	998	1,068
Other Gas [1]	NA	6	19	9	25	30	30	NA	NA	NA	NA	NA
Total Fossil Fuels	18,567	20,746	26,470	26,044	26,235	26,374	26,804	29,537	31,633	33,635	35,768	38,351
Nuclear Electric Power	2,739	6,104	7,862	8,033	8,143	7,959	8,232	8,442	8,659	9,089	9,089	9,088
Hydroelectric Pumped Storage [2]	---	-36	-57	-90	-88	-88	-- [6]	NA	NA	NA	NA	NA
Conventional Hydroelectric	2,867	3,014	2,768	2,209	2,650	2,781	2,673	2,983	2,985	2,994	2,994	2,994
Wood	3	106	126	116	141	156	158	518	522	566	584	633
Waste	2	180	294	314	353	337	334	335	349	360	369	372
Geothermal	110	326	296	289	305	303	302	393	567	918	1,333	1,538
Solar [3]	NA	4	5	6	6	5	6	10	13	15	18	21
Wind	NA	29	57	70	105	115	143	524	577	616	654	665
Total Renewable Energy	2,982	3,658	3,547	3,003	3,560	3,697	3,616	4,763	5,013	5,470	5,953	6,223
Electricity Imports	71	8	115	75	78	22	39	74	79	49	50	48
Other [4]	NA	0.08	1.28	0.00	6.96	15.57	0.09	NA	NA	NA	NA	NA
Total Primary Consumption	24,359	30,517	37,995	37,154	38,022	38,068	38,692	42,817	45,383	48,244	50,860	53,710

Sources: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table 8.4b; and EIA, Annual Energy Outlook 2006, DOE/EIA-0383(2006) (Washington, D.C., February 2006), 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.

[5] All 2004 figures are preliminary

[6] Starting with AER 2004 (August 2005), energy consumed by hydroelectric pumped storage plants is no longer included. According to EIA, the change was made because most of the electricity used to pump water into elevated storage reservoirs is generated by plants other than pumped-storage plants; thus, the associated energy is already accounted for in other data columns in the tables (such as conventional hydroelectric power, coal, and natural gas). The data book has kept historical record of pumped storage hydroelectric pumped storage plants, because the information is useful to some analysts.

NA = not available

Table 5.6 – Fossil-Fuel Generation by Age of Generating Units

(Megawatts)

	1980	1990	1999	2000	2001	2002	2003	2004	2005
0-5	91,001	39,870	34,466	54,274	90,877	155,534	204,504	218,854	233,119
6-10	136,236	54,270	42,215	44,042	42,164	37,735	33,121	33,234	33,976
11-20	145,618	224,879	102,855	92,854	87,057	82,977	83,140	81,085	81,465
21-30	99,223	143,868	226,166	221,690	210,982	196,464	175,461	156,694	156,078
31-40	21,042	93,450	128,613	141,055	155,292	172,139	188,274	205,136	204,382
41-50	4,023	14,701	80,859	86,582	91,321	94,204	95,560	93,156	89,731
>50	4,232	2,566	8,291	11,634	15,259	18,161	24,487	33,967	31,676
Total:	501,376	573,603	623,465	652,129	692,952	757,214	804,546	822,128	830,427

Source: PowerDat, © 2005, Platts, a division of the McGraw-Hill companies.

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	1999	2000	2001	2002	2003	2004	2005
0-5	16,289	30,408	1,270	1,270	0	0	0	0	0
6-10	33,989	25,628	4,810	1,215	2,485	2,485	1,270	1,270	1,270
11-20	6,413	48,929	54,432	56,036	51,537	49,189	47,200	40,278	31,435
21-30	309	6,073	44,558	44,597	46,859	43,105	41,420	39,315	40,533
31-40	0	0	2,143	4,095	6,332	12,435	17,324	26,351	32,940
Total	57,000	111,039	107,214	107,214	107,214	107,214	107,214	107,214	106,177

Source: PowerDat, © 2005, Platts, a division of the McGraw-Hill companies.

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	2001	2002	2003	2004
Investor-Owned Utilities	240	266	238	240	232	230	223	220
Federally Owned Utilities	41	10	9	9	9	9	9	9
Cooperatively Owned Utilities[1]	936	951	901	894	889	882	885	884
Other Publicly Owned Utilities	1,753	2,010	2,012	2,013	2,015	2,012	2,015	2,015
Total Number of Utilities	2,970	3,237	3,160	3,156	3,145	3,120	3,154	3,150
Nonutilities	NA	NA	381	446	1,380	1,500	1,538	1,150
Power Marketers	NA	NA	155	134	127	136	147	153

Sources: EIA, *The Changing Structure of the Electric Power Industry 2000: An Update (historical)*; EIA 861 report (1999+ for utilities) - http://www.eia.doe.gov/cneaf/electricity/page/eia861.html; and Form EIA-906 and EIA-920 databases (2001+ for IPPs) - http://www.eia.doe.gov/cneaf/electricity/page/eia906_920.html

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

NA = not available

1999 and 2000 for nonutilities exclude commercial and industrial generators, while 2001-2004 include commercial and industrial generators.

Table 5.10 – Top 10 U.S. Investor-Owned Utilities & Power Marketers

Utility by Sales (Million kWh)	1990 Rank	1990 Million kWh	2000 Rank	2000 Million kWh	2001 Rank	2001 Million kWh	2002 Rank	2002 Million kWh	2003 Rank	2003 Million kWh	2004 Rank	2004 Million kWh
Florida Power & Light Co.	5	65,222	2	88,128	2	90,495	1	95,543	1	99,339	1	99,144
Georgia Power Co.	8	53,953	4	74,434	5	72,545	3	75,432	3	75,018	2	77,904
Duke Energy Corp	7	58,359	9	53,726	4	72,977	4	75,362	4	73,763	3	75,775
Virginia Electric & Power Co.	9	52,122	8	65,294	7	67,858	6	71,477	5	72,197	4	75,141
TXU Electric Co.[1]	1	78,340	1	100,885	1	102,526	2	90,522	2	79,050	5	71,544
Commonwealth Edison Co.	2	70,852	3	77,176	3	76,918	5	73,835	6	68,384	6	66,419
Alabama Power Co.	12	38,081	10	52,068	9	49,338	8	52,073	8	52,208	7	54,244
Pacific Gas & Electric Co.	3	70,597	7	72,121	12	46,680	9	49,830	10	47,881	8	53,897
Southern California Edison Co.	4	70,063	6	73,686	8	52,034	7	54,391	7	52,229	9	49,123
PacifiCorp	10	40,288	43	18,859	11	47,708	11	47,030	9	48,339	10	48,816

[1] In 2002, electric industry restructuring commenced in Texas and both TXU and Reliant became Power Marketers

Utility by Revenue (Million $)	1990 Rank	1990 Million $	2000 Rank	2000 Million $	2001 Rank	2001	2002 Rank	2002 Million $	2003 Rank	2003 Million $	2004 Rank	2004 Million $
Florida Power & Light Co.	4	4,803	4	6,065	3	7,302	2	7,028	1	7,952	1	8,342
Pacific Gas & Electric Co.	2	6,513	2	6,988	4	7,171	3	6,821	4	6,369	2	6,738
TXU Electric Co.[1]	6	4,200	3	6,433	2	7,748	4	6,520	3	6,437	3	6,434
Southern California Edison Co.	1	6,767	1	7,416	1	7,782	1	7,848	2	6,845	4	5,648
Consolidated Edison Co-NY Inc	5	4,385	6	5,286	6	5,622	6	4,874	5	5,380	5	5,154
Commonwealth Edison Co.	3	5,668	5	5,723	5	5,703	5	5,457	6	5,123	6	5,028
Virginia Electric & Power Co.	10	3,299	9	4,022	7	4,340	7	4,611	7	4,665	7	5,015
Georgia Power Co.	9	3,426	8	4,283	8	4,305	9	4,288	9	4,310	8	4,777
Duke Energy Corp	7	3,681	12	3,151	9	4,159	8	4,345	8	4,335	9	4,502
Reliant Energy HL&P[1]	8	3,436	7	4,743	10	5,622	14	2,898	11	3,437	10	3,915

[1] In 2002, electric industry restructuring commenced in Texas and both TXU and Reliant became Power Marketers

Source: EIA, *Electric Sales and Revenue* , DOE/EIA -0540 (00) (Washington, D.C., December 2005), Table 10 (2005) and Table 17 (previous years)

Table 5.11 – Top 10 Independent Power Producers Worldwide

(Megawatts)

Company	2002 Capacity (MW)	2003 Capacity (MW)	2004 Capacity (MW)
SUEZ Energy International (formerly Tractebel Electricity & Gas Int'l)	50,000	48,317	46,841
AES	55,660	44,917	44,000
ENEL SpA.	46,456	45,744	42,000
Calpine	19,319	29,891	32,149
Dominion Generation	23,830	24,408	28,146
Entergy Wholesale Operations	21,323	30,000	27,086
Reliant	22,349	19,442	18,737
Mirant	22,100	23,254	17,889
NRG Energy	20,954	21,200	15,400
Edison Mission Energy[1]	18,688	18,733	8,834

[1] In 2004, Edison Mission Energy sold most of its international power-generating assets.

Source: Company 10K SEC filings at http://www.sec.gov/ accessed 2/06

Table 5.12 – Utility Mergers and Acquisitions

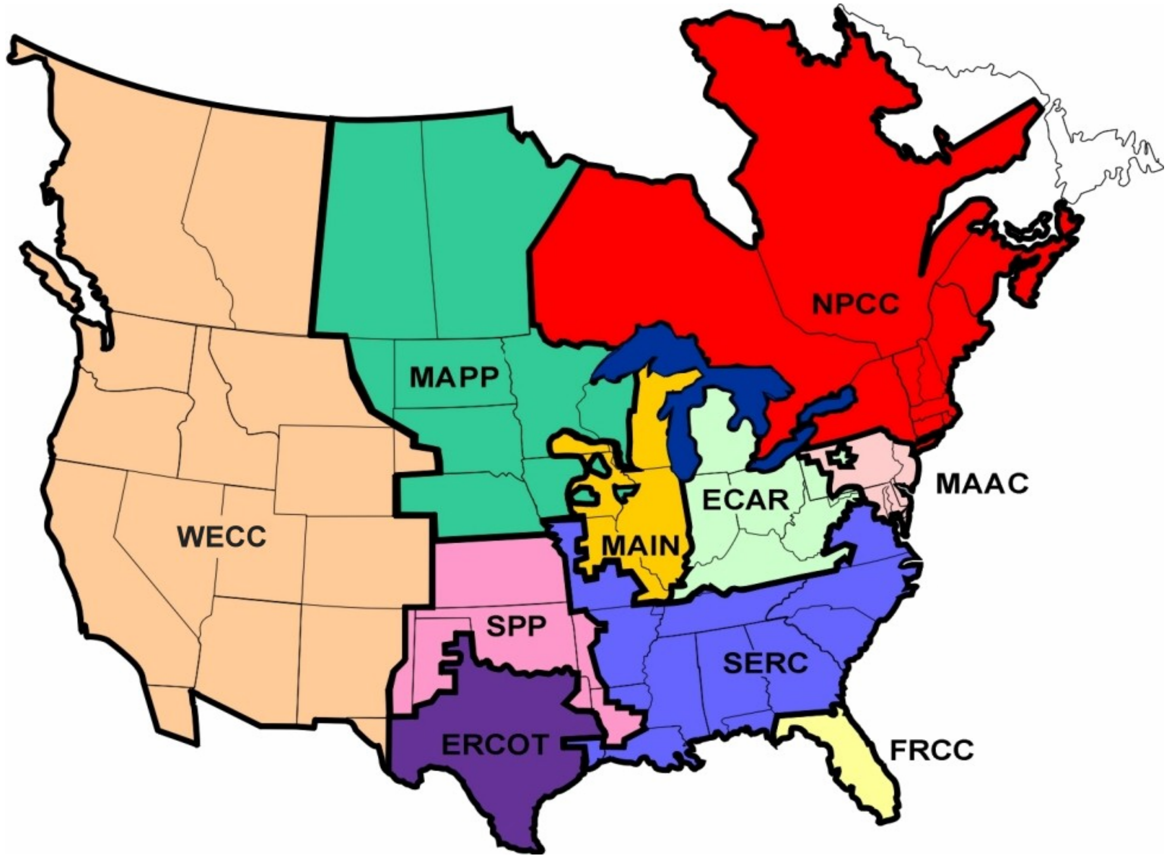
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004[3]
Mergers/Acquisitions																	
IOU-IOU	4	1	2	1	7	4	1	3	1	5	10	4	10	3	7	2	3
Co-op-Co-op	4	3	2	2	7	2	1	4	2	13	15	15	3	3		2	
IOU-Co-op				1	2			1		1					1		
IOU-Gas [1]									1	5	4	3	6	1			
Muni-Muni							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

Source: Calculated from Electrical World, D*irectory of Electric Power Producers*, 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
[3] Includes pending mergers and acquisitions

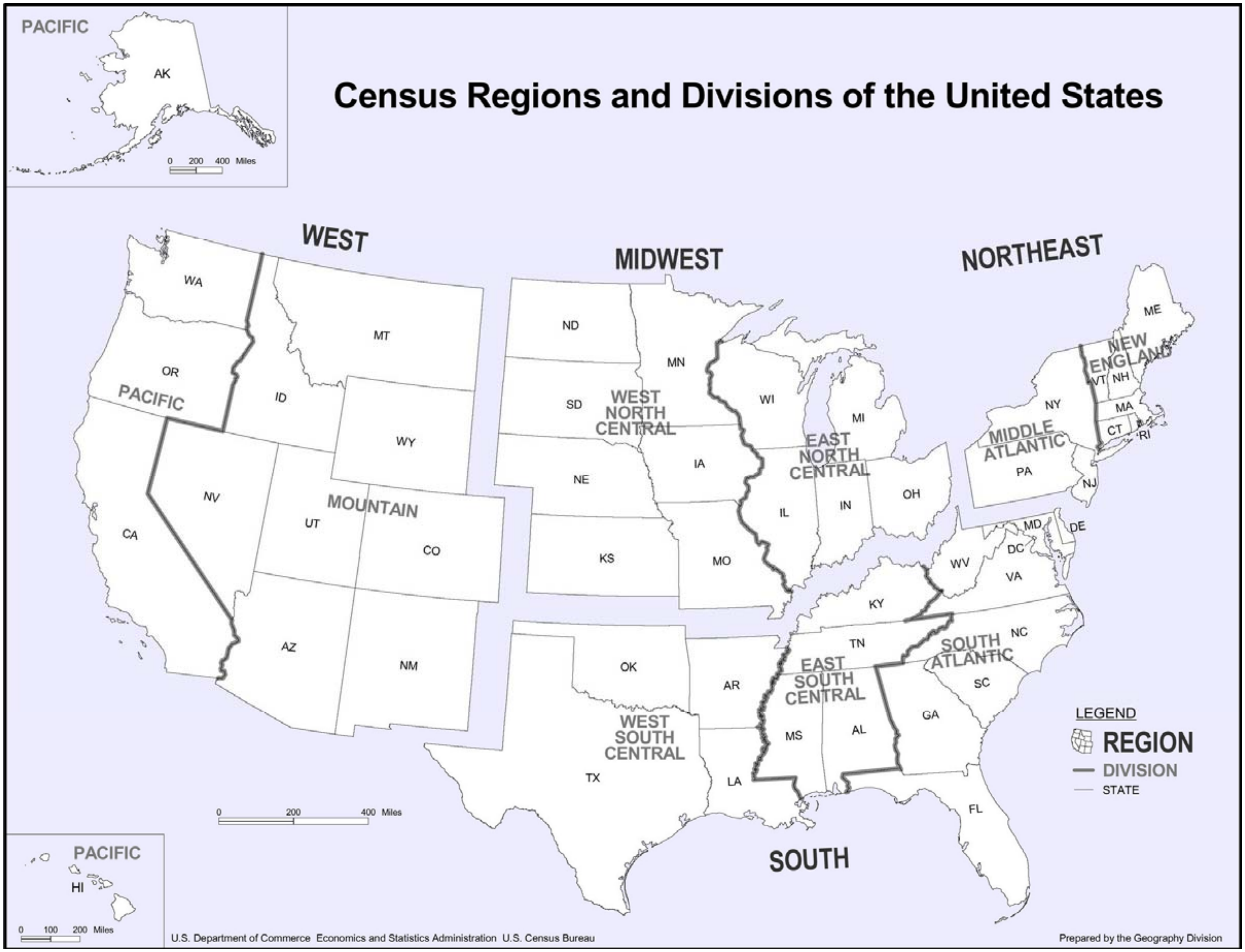
Table 5.13a – North American Electric Reliability Council Map for the United States



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	2004	2010	2015	2020	2025	2030
Coal[1]	NA	307.4	315.1	314.2	315.4	313.0	313.3	322.8	325.5	355.4	409.3	481.0
Petroleum/Natural Gas[2]	NA	220.4	283.8	320.7	374.2	418.2	436.9	466.1	437.9	468.6	491.8	509.8
Total Fossil Energy	444.1	527.8	598.9	634.9	689.5	731.2	750.2	788.9	763.4	824.0	901.1	990.8
Nuclear	51.8	99.6	97.9	98.2	98.7	99.2	99.6	100.9	104.0	108.8	108.8	108.8
Hydroelectric Pumped Storage[3]	NA	19.5	19.5	19.1	20.4	20.5	20.5	20.8	20.8	20.8	20.8	20.8
Conventional Hydroelectric	81.7	73.9	79.4	79.5	79.4	78.7	78.7	78.3	78.4	78.5	78.5	78.5
Geothermal	0.9	2.7	2.8	2.2	2.3	2.1	2.1	2.6	3.2	4.6	6.0	6.6
Wood [4]	0.1	5.5	6.1	5.9	5.8	5.9	5.9	7.2	7.6	8.5	10.1	11.9
Waste [5]	NA	2.5	3.9	3.8	3.8	3.8	3.8	3.8	3.9	4.0	4.1	4.1
Solar Thermal and Photovoltaic	NA	0.3	0.4	0.4	0.4	0.4	0.4	1.2	1.3	1.5	1.7	2.6
Wind	NA	1.8	2.4	3.9	4.4	6.0	6.2	16.3	17.7	18.8	19.8	20.1
Total Renewable Energy	82.7	86.8	94.9	95.7	96.1	96.9	97.1	109.3	112.1	115.9	120.2	123.9
Other [6]	NA	0.5	0.5	0.4	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7
Total Electric Capability	578.6	734.1	811.7	848.3	905.3	948.4	968.1	1020.6	1001.1	1070.2	1151.6	1245.0

Sources: EIA, *Annual Energy Outlook 2006* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Tables A9, A16; EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), 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	2004	2010	2015	2020	2025	2030
Coal [2]	NA	299.9	305.2	305.2	305.8	303.0	303.4	313.7	315.0	340.9	385.7	453.1
Petroleum/Natural Gas [3]	NA	198.7	243.9	279.4	325.1	362.9	378.9	409.4	379.1	407.3	428.1	443.9
Total Fossil Energy	NA	498.6	549.0	584.5	630.9	665.9	682.2	723.1	694.1	748.2	813.8	897.0
Nuclear	NA	99.6	97.9	98.2	98.7	99.2	99.6	100.9	104.0	108.8	108.8	108.8
Hydroelectric Pumped Storage [4]	NA	19.5	19.5	19.1	20.4	20.5	20.5	20.8	20.8	20.8	20.8	20.8
Conventional Hydroelectric	NA	73.3	78.2	78.4	78.3	77.9	77.9	77.7	77.8	77.9	77.9	77.9
Geothermal	NA	2.7	2.8	2.2	2.3	2.1	2.1	2.6	3.2	4.6	6.0	6.6
Wood [5]	NA	1.0	1.5	1.5	1.4	1.4	1.4	2.2	2.2	2.5	3.5	4.6
Waste [6]	NA	1.9	2.8	3.0	3.0	2.8	2.9	3.5	3.7	3.8	3.8	3.9
Solar Thermal and Photovoltaic	NA	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.6	0.7	0.8	0.9
Wind	NA	1.8	2.4	3.6	4.4	6.0	6.0	16.3	17.7	18.8	19.8	20.1
Total Renewable Energy	NA	80.9	88.1	89.1	89.7	90.6	90.7	102.7	105.1	108.2	111.8	114.1
Other	NA	0.0	0.0	0.0	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	876.3	893.1	947.5	924.0	986.0	1055.2	1140.7

Sources: EIA, *Annual Energy Outlook 2006* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), 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	2004	2010	2015	2020	2025	2030
Coal [2]	NA	7.5	10.0	9.1	9.5	10.0	9.9	9.1	10.5	14.5	23.6	27.9
Petroleum/Natural Gas [3]	NA	21.7	39.9	41.3	49.1	55.3	58.0	56.7	58.7	61.4	63.7	65.9
Total Fossil Energy	NA	29.2	49.9	50.4	58.6	65.3	67.9	65.8	69.3	75.9	87.3	93.8
Nuclear	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hydroelectric Pumped Storage	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Conventional Hydroelectric	NA	0.6	1.1	1.1	1.1	0.8	0.8	0.7	0.7	0.7	0.7	0.7
Geothermal	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wood [4]	NA	4.6	4.9	4.6	4.7	4.7	4.8	5.0	5.5	6.0	6.6	7.3
Waste [5]	NA	0.4	0.6	0.5	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3
Solar Thermal and Photovoltaic	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.7	0.8	0.9	1.7
Wind	NA	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Renewable Energy	NA	5.3	6.1	5.8	5.8	5.6	5.6	7.0	7.5	8.1	8.8	10.3
Other	NA	0.5	0.5	0.4	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7
Total Electric Capability [6]	NA	35.5	57.2	57.4	65.6	72.1	75.0	73.4	77.5	84.7	96.8	104.8

Sources: EIA, *Annual Energy Outlook 2006* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Tables A9, A16; EIA, Annual Energy Review 2004, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table 8.11c.

Notes:

Includes combined-heat-and-power (CHP) plants whose primary business is to sell electricity and heat to the public. Includes electric utility CHP plants. 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 and Capacity Margin

(Megawatts, except as noted)

North American Electric Reliability Council Regions

	Summer Peak						Winter Peak					
	1990	**2000**	**2001**	**2002**	**2003**	**2004**	**1990**	**2000**	**2001**	**2002**	**2003**	**2004**
ECAR	79,258	92,033	100,235	102,996	98,487	102,423	67,097	84,546	85,485	87,300	86,332	87,972
ERCOT	42,737	57,606	55,201	56,248	59,996	61,432	35,815	44,641	44,015	45,414	42,702	43,556
FRCC	NA	37,194	39,062	40,696	40,475	42,705	NA	38,606	40,922	45,635	36,841	45,418
MAAC	42,613	49,477	54,015	55,569	53,566	56,886	36,551	43,256	39,458	46,551	45,625	45,471
MAIN	40,740	52,552	56,344	56,396	56,988	57,868	32,461	41,943	40,529	42,412	41,719	42,409
MAPP (U.S.)	24,994	28,605	28,321	29,119	28,831	29,244	21,113	24,536	21,815	23,645	24,134	24,628
NPCC (U.S.)	44,116	50,057	55,949	56,012	55,018	57,535	40,545	43,852	42,670	46,009	48,079	47,986
SERC	121,943	156,088	149,293	158,767	153,110	157,961	117,448	139,146	135,182	141,882	137,972	141,176
SPP	52,541	40,199	40,273	39,688	40,367	40,089	38,949	30,576	29,614	30,187	28,450	28,469
WECC[2] (U.S.)	97,389	114,602	109,119	119,074	122,537	122,870	94,252	97,324	96,622	95,951	102,020	104,393
Contiguous U.S.	546,331	678,413	687,812	714,565	709,375	729,013	484,231	588,426	576,312	604,986	593,874	611,478
ASCC (Alaska)	463	NF	NF	NF	NF	NF	613	NF	NF	NF	NF	NF
Hawaii	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF	NF
U.S. Total	546,794	678,413	687,812	714,565	717,652	729,013	484,844	588,426	576,312	604,986	608,729	611,478
Capacity Margin (%) [3]	21.6	15.7	14.5	16.4	18.6	19.2	NA	29.5	28.9	29.4	33.5	33.4

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 available

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	2015	2020	2025	2030
Cumulative Planned Additions					
Coal Steam	8.3	9.3	9.3	9.3	9.3
Other Fossil Steam [2]	0.1	0.1	0.1	0.1	0.1
Combined Cycle	25.7	25.7	25.7	25.7	25.7
Combustion Turbine/Diesel	5.3	5.3	5.3	5.3	5.3
Nuclear	0.0	0.0	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0	0.0	0.0
Renewable Sources [3]	10.0	11.0	11.1	11.2	11.4
Distributed Generation [4]	0.0	0.0	0.0	0.0	0.0
Total Planned Additions	49.4	51.5	51.6	51.7	51.8
Cumulative Unplanned Additions					
Coal Steam	3.4	7.0	32.9	77.7	145.1
Other Fossil Steam [2]	0.0	0.0	0.0	0.0	0.0
Combined Cycle	0.0	5.5	29.9	41.9	46.8
Combustion Turbine/Diesel	4.7	11.6	21.5	31.3	46.2
Nuclear	0.0	2.2	6.0	6.0	6.0
Pumped Storage	0.0	0.0	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0	0.0	0.0
Renewable Sources [3]	0.4	1.7	4.8	8.3	10.4
Distributed Generation [4]	0.2	0.6	1.4	2.4	5.5
Total Unplanned Additions	8.8	28.6	96.5	167.7	260.0
Cumulative Retirements					
Coal Steam	3.0	6.8	6.8	6.8	6.8
Other Fossil Steam [2]	2.0	37.9	44.0	45.1	49.0
Combined Cycle	0.6	0.6	0.6	0.6	0.6
Combustion Turbine/Diesel	1.4	8.2	8.2	8.2	8.2
Nuclear	0.0	0.0	0.0	0.0	0.0
Pumped Storage	0.0	0.0	0.0	0.0	0.0
Fuel Cells	0.0	0.0	0.0	0.0	0.0
Renewable Sources [3]	0.1	0.1	0.1	0.1	0.1
Total Retirements	7.1	53.6	59.8	60.8	64.7

Sources: EIA, *Annual Energy Outlook 2006,* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), 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]	2004 [2]
230	NA	70,511	76,762	76,437	80,515	81,252	82,238	81,992
345	NA	47,948	49,250	51,025	53,855	54,827	54,195	55,429
500	NA	23,958	26,038	25,000	27,343	27,587	27,407	28,011
765	NA	2,428	2,453	2,426	2,518	2,560	2,560	2,560
Total	NA	144,845	154,503	154,888	164,231	166,226	166,400	167,992

Sources: EIA, Electricity Transmission Fact Sheets, http://www.eia.doe.gov/cneaf/electricity/page/fact_sheets/transmission.html; NERC, Electricity Supply and Demand Database, 2005, 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	2004	2010	2015	2020	2025	2030
Coal [1]	1,162	1,594	1,966	1,904	1,933	1,974	1,976	2,218	2,277	2,505	2,896	3,381
Petroleum [2]	246	127	111	125	95	119	118	105	104	107	108	115
Natural Gas [3]	346	373	601	639	691	650	700	774	1,018	1,102	1,069	990
Other Gases [4]	NA	10	14	9	11	16	15	12	12	12	12	12
Total Fossil Energy	1,754	2,104	2,692	2,677	2,730	2,759	2,809	3,108	3,411	3,725	4,085	4,497
Nuclear	251	577	754	769	780	764	789	809	829	871	871	871
Hydroelectric Pumped Storage[5]	NA	-4	-6	-9	-9	-9	-8	-9	-9	-9	-9	-9
Conventional Hydroelectric [6]	279	293	276	217	264	276	270	301	302	303	303	303
Geothermal	5	15	14	14	14	14	14	18	23	34	47	53
Wood [7]	0	33	38	35	39	38	37	76	79	86	103	103
Waste [8]	0	13	23	22	23	24	23	27	28	29	30	30
Solar Thermal and Photovoltaic	NA	0	0	1	1	1	1	2	3	3	4	6
Wind	NA	3	6	7	10	11	14	51	56	60	63	65
Total Renewable Energy	285	357	356	295	351	363	359	476	491	515	549	559
Generation for Own Use [9]	NA	NA	NA	NA	NA	NA	NA	-177	-192	-214	-252	-278
Other [10]	NA	4	5	5	6	6	6	12	12	12	12	12
Total Electricity Generation	2,290	3,038	3,802	3,737	3,858	3,883	3,953	4,388	4,727	5,108	5,491	5,926

Sources: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table 8.2a; and EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383(2006) (Washington, D.C., February 2006), 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.

NA = not available

Table 7.2 – Net Generation at Electricity-Only Plants

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2004	2010	2015	2020	2025	2030
Coal [1]	1,162	1,560	1,911	1,852	1,881	1,916	1,916	2,164	2,209	2,405	2,728	3,178
Petroleum [2]	246	118	98	113	83	109	108	90	89	90	93	99
Natural Gas [3]	346	265	399	427	457	421	486	533	743	814	775	691
Other Gases [4]	NA	0	0	0	0	0	0	NA	NA	NA	NA	NA
Total Fossil Energy	1,754	1,942	2,408	2,392	2,422	2,446	2,510	2,787	3,041	3,310	3,596	3,968
Nuclear	251	577	754	769	780	764	789	809	829	871	871	871
Hydroelectric Pumped Storage[5]	NA	-4	-6	-9	-9	-9	-8	-9	-9	-9	-9	-9
Conventional Hydroelectric [6]	276	290	271	214	260	272	264	297	297	298	299	299
Geothermal	5	15	14	14	14	14	14	18	23	34	47	53
Wood [7]	0.3	6	7	7	7	7	7	45	45	49	51	58
Waste [8]	0.2	10	18	17	17	18	18	25	26	27	28	28
Solar Thermal and Photovoltaic	NA	0.4	0.5	0.5	0.6	0.5	0.6	1	1	1	2	2
Wind	NA	3	6	7	10	11	14	51	56	60	63	65
Total Renewable Energy	282	324	316	259	311	323	319	436	448	469	489	504
Other [10]	0	0	0	0	1	1	3	NA	NA	NA	NA	NA
Total Electricity Generation	2,286	2,840	3,473	3,411	3,505	3,525	3,611	4,020	4,306	4,638	4,945	5,332

Sources: EIA, *Annual Energy Review 2004,* DOE/EIA-0384(2004) (Washington, D.C., August 2005),Table 8.2c; and EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383(2006) (Washington, D.C., February 2006), 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] Includes nonutility and end-use sector generation for own use.
[10] Batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.
NA = not available

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

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2004	2010	2015	2020	2025	2030
Coal [1]	NA	34	56	52	52	58	61	53	68	99	168	203
Petroleum [2]	NA	9	13	12	11	11	10	15	15	17	15	16
Natural Gas [3]	NA	108	202	212	234	229	213	241	275	288	294	299
Other Gases [4]	NA	10	14	9	11	15	15	4	4	5	5	5
Total Fossil Energy	NA	161	284	285	309	313	299	313	363	408	482	522
Nuclear	NA	0	0	0	0	0	0	0	0	0	0	0
Hydroelectric Pumped Storage [5]	NA	0	0	0	0	0	0	0	0	0	0	0
Conventional Hydroelectric [6]	NA	3	4	3	4	4	5	4	4	4	4	4
Geothermal	NA	0	0	0	0	0	0	0	0	0	0	0
Wood [7]	NA	27	30	29	31	30	30	32	35	38	51	45
Waste [8]	NA	3	6	5	5	6	5	2	2	2	2	2
Solar Thermal and Photovoltaic	NA	0	0	0	0	0	0	1	1	2	2	4
Wind	NA	0	0	0	0	0	0	0	0	0	0	0
Total Renewable Energy	NA	33	40	36	41	40	40	40	43	46	50	55
Other [9]	NA	4	5	5	4	5	3	12	12	12	12	12
Total Electricity Generation	NA	198	329	326	354	358	342	364	417	466	543	589

Sources: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005),Table 8.2c and 8.2d; and EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383(2006) (Washington, D.C., February 2006), Tables A8 and A16.

Notes:

Includes combined-heat-and-power (CHP) plants, whose primary business is to sell electricity and heat to the public. Includes electric utility CHP plants. 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, plus a small amount of supplemental gaseous fuels that cannot be identified separately. 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.

[6] Includes CHP plants that use multiple sources of energy, including hydropower.

[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.

NA = not available

Table 7.4 – Generation and Transmission/Distribution Losses

(Billion kWh)

	1980	1990	2000	2001	2002	2003	2004	2010	2015	2020	2025	2030
Net Generation Delivered	2,290	3,038	3,802	3,737	3,858	3,883	3,953	4,211	4,536	4,893	5,240	5,648
Generation Losses [1]	4,859	6,316	7,809	7,617	7,798	7,756	8,006	8,339	8,764	9,232	9,652	10,094
Transmission and Distribution Losses [2]	NA	219	258	243	266	257	271	251	254	274	294	317

Sources: Calculated from EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Tables 8.1, 8.2a, and 8.4a; and EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383(2006) (Washington, D.C., February 2006), 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.

NA = not available

Table 7.5 – Electricity Trade

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2004	2010	2015	2020	2025	2030
Interregional Electricity Trade												
Gross Domestic Firm Power Trade	NA	NA	NA	143	139	137	142	105	82	51	38	38
Gross Domestic Economy Trade	NA	NA	NA	182	174	215	233	231	200	168	165	158
Gross Domestic Trade	NA	NA	NA	325	313	352	376	337	283	219	203	196
International Electricity Trade												
Firm Power Imports from Mexico and Canada	NA	NA	NA	12	10	11	12	3	2	1	0	0
Economy Imports from Mexico and Canada	NA	NA	NA	26	27	19	22	40	39	29	27	26
Gross Imports from Mexico and Canada	25	18	49	39	36	30	34	42	41	29	28	27
Firm Power Exports to Mexico and Canada	NA	NA	NA	7	6	5	7	1	1	0	0	0
Economy Exports to Mexico and Canada	NA	NA	NA	10	9	19	16	20	17	15	13	13
Gross Exports to Canada and Mexico	4	16	15	16	14	24	23	21	18	15	13	13

Sources: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table 8.1; and EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383(2006) (Washington, D.C., February 2006), Table A10.

Notes:
All data are from EIA AEO except Gross Imports and Exports for 1980-2004.
NA = not available

Table 8.1 – Electricity Sales

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2004	2010	2015	2020	2025	2030
Electricity Sales by Sector[1]												
Residential	717	924	1,192	1,203	1,267	1,273	1,293	1,461	1,576	1,691	1,787	1,897
Commercial	559	838	1,159	1,197	1,218	1,200	1,229	1,430	1,592	1,762	1,944	2,151
Industrial	815	946	1,064	964	972	1,008	1,021	1,060	1,103	1,147	1,195	1,262
Transportation/Other [2]	3	5	5	5	6	7	8	26	28	29	30	31
Total Sales	2,094	2,713	3,421	3,370	3,463	3,488	3,551	3,978	4,300	4,629	4,956	5,341
Direct Use [3]	NA	125	171	163	166	168	166	177	192	214	252	278
Total	2,094	2,837	3,592	3,532	3,629	3,656	3,717	4,155	4,491	4,844	5,208	5,619

Sources: 2010-2030 - EIA, *Annual Energy Outlook 2006,* DOE/EIA-0383(2006) (Washington, D.C., February 2006), Table A8; 1980-2004 - EIA, *Annual Energy Review 2004,* DOE/EIA-0384(2004) (Washington, D.C., August 2005), 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 on-site 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	2004
Load Management Peak Load Reductions (MW)[1]	NA	NA	10,027	11,928	9,516	9,323	9,260
Energy Efficiency Peak Load Reductions (MW)[2]	NA	NA	12,873	13,027	13,420	13,581	14,272
Total Peak Load Reductions (MW)	NA	13,704	22,901	24,955	22,936	22,904	23,532
Energy Savings (Million kWh)	NA	20,458	53,701	54,762	54,075	50,265	54,710
Costs (Million 2004$)[3]	NA	1,562	1,694	1,723	1,690	1,325	1,557

Sources: 1980-2003 - EIA, *Annual Energy Review 2004,* DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table 8.13; 2004 - EIA, Electric Power Annual 2004 Tables, (Washington, D.C., December 2005), Table 9.1, 9.2, 9.4, 9.6, and 9.7 http://www.eia.doe.gov/cneaf/electricity/epa/epat9p1.html

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 2004 dollars using EIA *Annual Energy Review 2004*, Appendix D.

Table 8.3 – Electricity Sales, Revenue, and Consumption by Census Division and State, 2004

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	**125,249**	**13,284**	**10.6**	**8,796**	**East South Central**	**319,085**	**18,618**	**5.8**	**18,114**
Connecticut	32,215	3,305	10.3	9,177	Alabama	86,871	5,278	6.1	19,060
Maine	12,368	1,198	9.7	9,359	Kentucky	86,521	4,004	4.6	20,732
Massachusetts	56,142	6,045	10.8	8,774	Mississippi	46,033	3,221	7.0	15,759
New Hampshire	10,973	1,248	11.4	8,377	Tennessee	99,661	6,115	6.1	16,713
Rhode Island	7,888	865	11.0	7,329	**West South Central**	**494,966**	**36,952**	**7.5**	**14,683**
Vermont	5,664	624	11.0	9,090	Arkansas	43,672	2,475	5.7	15,714
Middle Atlantic	**366,176**	**37,679**	**10.3**	**9,063**	Louisiana	79,737	5,682	7.1	17,627
New Jersey	77,593	7,984	10.3	8,900	Oklahoma	50,942	3,313	6.5	14,358
New York	145,082	18,209	12.6	7,535	Texas	320,615	25,482	7.9	14,025
Pennsylvania	143,501	11,486	8.0	11,545	**Mountain**	**237,632**	**16,306**	**6.9**	**11,711**
East North Central	**571,151**	**37,920**	**6.6**	**12,374**	Arizona	66,933	4,985	7.4	11,270
Illinois	139,254	9,465	6.8	10,910	Colorado	46,724	3,247	6.9	10,015
Indiana	103,094	5,749	5.6	16,437	Idaho	21,809	1,085	5.0	15,260
Michigan	106,606	7,401	6.9	10,533	Montana	12,957	830	6.4	13,848
Ohio	154,221	10,629	6.9	13,453	Nevada	31,312	2,681	8.6	12,967
Wisconsin	67,976	4,677	6.9	12,278	New Mexico	19,846	1,409	7.1	10,291
West North Central	**261,030**	**16,095**	**6.2**	**13,173**	Utah	24,512	1,395	5.7	9,925
Iowa	40,903	2,619	6.4	13,789	Wyoming	13,540	674	5.0	26,585
Kansas	37,127	2,364	6.4	13,527	**Pacific Contiguous**	**378,382**	**36,407**	**9.6**	**8,215**
Minnesota	63,340	3,950	6.2	12,340	California	252,764	28,935	11.4	6,996
Missouri	74,054	4,494	6.1	12,767	Oregon	45,636	2,833	6.2	12,534
Nebraska	25,876	1,475	5.7	14,712	Washington	79,982	4,638	5.8	12,720
North Dakota	10,516	599	5.7	16,518	**Pacific Noncontiguous**	**16,520**	**2,321**	**14.0**	**2,832**
South Dakota	9,214	594	6.4	11,875	Alaska	5,788	636	11.0	1,270

South Atlantic	**778,026**	**54,874**	**7.1**	**13,973**	Hawaii	10,732	1,685	15.7	8,416
Delaware	11,761	885	7.5	13,943	**U.S. Total**	**3,548,218**	**270,456**	**7.6**	**11,971**
District of Columbia	11,415	852	7.5	225,943					
Florida	218,584	17,835	8.2	12,287					
Georgia	129,466	8,525	6.6	14,270					
Maryland	66,892	4,785	7.2	11,944					
North Carolina	125,657	8,756	7.0	14,471					
South Carolina	79,908	4,972	6.2	18,780					
Virginia	105,424	6,780	6.4	13,931					
West Virginia	28,919	1,483	5.1	15,917					

Sources: EIA, *Electric Sales and Revenue 2004 Spreadsheets*, Data Tables, http://www.eia.doe.gov/cneaf/electricity/esr/esr_sum.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, 2005* (NST-EST2004-01) - State Population Estimates 2005, http://www.census.gov/popest/states/tables/NST-EST2005-01.xls

Notes:
Revenue in 2004 dollars.
Includes bundled and unbundled consumers

Table 9.1 – Price of Fuels Delivered to Electric Generators

(2004 Dollars per Million Btu) [1]

	1980	1993	2000	2001	2002	2003	2004	2010	2015	2020	2025	2030
Distillate Fuel	NA	NA	NA	NA	NA	6.65	9.23	9.04	9.02	9.62	10.05	10.28
Residual Fuel [2]	NA	2.88	4.48	3.87	3.44	4.40	4.29	5.70	5.72	6.02	6.43	6.73
Natural Gas [3]	NA	3.11	4.61	4.70	3.67	5.46	5.96	5.46	5.08	5.40	5.87	6.26
Steam Coal [4]	NA	1.69	1.29	1.29	1.29	1.29	1.36	1.48	1.40	1.39	1.44	1.51
Fossil Fuel Average [5]	NA	1.93	1.86	1.81	1.56	2.31	2.57	2.41	2.41	2.46	2.50	2.49

Sources: EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383(2006) (Washington, D.C., February 2006), Table A3; and EIA, *Electric Power Annual 2004*, DOE/EIA-0348(2004) (Washington, D.C., November 2005), 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.

NA = not available

Table 9.2 – Electricity Retail Sales

(Billion Kilowatthours)

	1980	1990	2000	2001	2002	2003	2004	2010	2015	2020	2025	2030
Retail Sales [1]												
Residential	717	924	1,192	1,203	1,267	1,273	1,293	1,461	1,576	1,691	1,787	1,897
Commercial [2]	559	838	1,159	1,197	1,218	1,200	1,229	1,430	1,592	1,762	1,944	2,151
Industrial [3]	815	946	1,064	964	972	1,008	1,021	1,060	1,103	1,147	1,195	1,262
Transportation [4]	3	5	5	5	6	7	8	26	28	29	30	31
Total [5]	2,094	2,713	3,421	3,370	3,463	3,488	3,551	4,155	4,491	4,844	5,208	5,619

Sources: EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006), (Washington, D.C., February 2006), Table A8; and EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., September 2005), Table 8.9.

Notes:

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

[2] Commercial sector, including public street and highway lighting, interdepartmental sales, and other sales to public authorities.

[3] Industrial sector. Through 2002, excludes agriculture and irrigation; beginning in 2003, includes agriculture and irrigation.

[4] Transportation sector, including sales to railroads and railways.

[5] The sum of "Residential," "Commercial," "Industrial," and "Transportation."

Table 9.3 – Prices of Electricity Sold

(2003 cents per Kilowatthour) [1]

	1980	1990	2000	2001	2002	2003	2004	2010	2015	2020	2025	2030
Price by End-Use Sector[2]												
Residential	10.8	10.4	8.9	9.1	8.8	8.9	8.9	8.5	8.3	8.3	8.4	8.5
Commercial	11.0	9.7	8.0	8.4	8.2	8.1	8.2	7.6	7.4	7.5	7.7	7.8
Industrial	7.4	6.3	5.0	5.3	5.1	5.2	5.1	5.3	5.1	5.2	5.4	5.4
Transportation / Other[3]	9.6	8.5	7.1	7.4	7.0	7.7	6.5	7.1	6.9	7.0	7.1	7.2
End-Use Sector Average	9.4	8.7	7.4	7.7	7.5	7.6	7.6	7.3	7.1	7.2	7.4	7.5
Price by Service Category[2]												
Generation	NA	NA	NA	NA	NA	5.0	5.8	4.7	4.6	4.8	5.0	5.1
Transmission	NA	NA	NA	NA	NA	0.5	0.5	0.6	0.6	0.7	0.7	0.7
Distribution	NA	NA	NA	NA	NA	2.1	2.0	2.0	1.9	1.9	1.8	1.8

Sources: EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006), (Washington, D.C., February 2006), Table A8; and EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), 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 (2004) dollars, calculated by using gross domestic product implicit price deflators using EIA Annual Energy Review 2004 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.

NA = not available

Table 9.4 – Revenue from Electric-Utility Retail Sales by Sector

(Millions of 2004 Dollars)

	1980	1990	2000	2001	2002	2003	2004	2010	2015	2020	2025	2030
Residential	77,598	95,980	106,351	109,579	111,453	113,090	115,594	124,185	130,808	140,353	150,108	161,245
Commercial	61,537	81,624	93,235	100,369	99,536	97,760	100,369	108,680	117,808	132,150	149,688	167,778
Industrial	60,399	59,455	53,448	51,368	49,331	52,803	52,173	56,180	56,259	59,658	64,533	68,165
Transportation/Other [1]		289	424	355	372	420	542	519	1,846	1,932	2,030	2,130
All Sectors [2]	197,153	236,419	252,190	260,731	259,589	264,291	268,811	303,315	318,865	348,741	385,392	421,425

Sources: Calculated from EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006), (Washington, D.C., February 2006), Table A8; EIA, *Annual Energy Review 20*04, DOE/EIA-0384 (2004) (Washington, D.C., August 2005), 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, 2004

(Millions of 2004 Dollars)

Census Division/ State	Residen- tial	Commer- cial	Industrial	Other[1]	All Sectors [2]
New England	**5,560**	**5,696**	**1,995**	**33**	**13,284**
Connecticut	1,537	1,332	423	14	3,305
Maine	527	428	244	-	1,198
Massachusetts	2,323	2,858	844	19	6,045
New Hampshire	535	480	233	-	1,248
Rhode Island	366	373	126	-	865
Vermont	273	226	126	-	624
Middle Atlantic	**14,890**	**17,221**	**5,266**	**302**	**37,679**
New Jersey	3,148	3,793	1,012	32	7,984
New York	6,890	9,654	1,455	210	18,209
Pennsylvania	4,853	3,774	2,799	60	11,486
East North Central	**14,847**	**12,855**	**10,187**	**32**	**37,920**
Illinois	3,638	3,570	2,232	25	9,465
Indiana	2,277	1,448	2,022	1	5,749
Michigan	2,759	2,925	1,717	0	7,401
Ohio	4,251	3,510	2,864	5	10,629
Wisconsin	1,922	1,401	1,353	-	4,677
West North Central	**7,044**	**5,505**	**3,544**	**1**	**16,095**
Iowa	1,132	731	756	-	2,619
Kansas	962	893	510	-	2,364
Minnesota	1,624	1,287	1,038	1	3,950
Missouri	2,185	1,648	661	0	4,494
Nebraska	610	497	369	-	1,475

Census Division/ State	Residen- tial	Commer- cial	Industrial	Other[1]	All Sectors [2]
East South Central	**7,934**	**5,551**	**5,134**	**0**	**18,618**
Alabama	2,295	1,506	1,477	0	5,278
Kentucky	1,538	1,034	1,432	0	4,004
Mississippi	1,444	1,019	759	0	3,221
Tennessee	2,657	1,992	1,466	0	6,115
West South Central	**16,701**	**11,299**	**8,945**	**7**	**36,952**
Arkansas	1,150	605	720	0	2,475
Louisiana	2,324	1,710	1,646	1	5,682
Oklahoma	1,520	1,116	677	0	3,313
Texas	11,707	7,867	5,902	6	25,482
Mountain	**6,732**	**5,975**	**3,596**	**3**	**16,306**
Arizona	2,447	1,901	637	0	4,985
Colorado	1,307	1,343	596	1	3,247
Idaho	446	294	344	0	1,085
Montana	319	321	190	0	830
Nevada	1,034	752	895	0	2,681
New Mexico	488	609	312	0	1,409
Utah	528	551	314	2	1,395
Wyoming	163	203	308	0	674
Pacific Contiguous	**13,990**	**16,307**	**6,063**	**46**	**36,407**
California	10,628	13,554	4,710	43	28,935
Oregon	1,293	1,010	529	1	2,833
Washington	2,069	1,742	825	3	4,638

North Dakota	249	225	124	-	599
South Dakota	283	224	87	-	594
South Atlantic	**27,510**	**18,973**	**8,310**	**80**	**54,874**
Delaware	378	300	207	-	885
District of Columbia	147	670	13	22	852
Florida	10,086	6,601	1,140	7	17,835
Georgia	4,016	2,912	1,587	9	8,525
Maryland	2,181	1,304	1,269	31	4,785
North Carolina	4,369	2,871	1,516	-	8,756
South Carolina	2,267	1,390	1,315	-	4,972
Virginia	3,397	2,530	843	10	6,780
West Virginia	670	394	419	0	1,483
Pacific Noncontiguous	**828**	**874**	**619**	**0**	**2,321**
Alaska	256	286	94	0	636
Hawaii	571	588	526	0	1,685
U.S. Total	**116,037**	**100,255**	**53,661**	**504**	**270,456**

Source: EIA, *Electric Sales and Revenue 2004 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[1,3]				
	1990	1995	2000	2002	2003	2004	1990	1995	2000	2002	2003
Production Expenses											
Cost of Fuel	32,635	29,122	32,555	24,132	26,476	28,678	5,276	5,664	7,702	9,348	10,378
Purchased Power	20,341	29,981	61,969	58,828	62,173	67,354	10,542	11,988	16,481	24,446	26,078
Other Production Expenses	9,526	9,880	12,828	7,688	7,532	8,256	155	212	225	1,647	1,285
Total Production Expenses[2]	62,502	68,983	107,352	90,649	96,181	104,288	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	4,519	604	663	845	951	977
Distribution Expenses	2,444	2,561	3,115	3,113	3,185	3,301	950	630	854	1,000	1,044
Customer Accounts Expenses	3,247	3,613	4,246	4,165	4,180	4,087	375	448	662	700	754
Customer Service and Information Expenses	1,181	1,922	1,839	1,821	1,893	2,012	75	120	233	354	311
Sales Expenses	212	348	403	261	234	238	29	30	82	84	95
Administrative and General Expenses	10,371	13,028	13,009	12,872	13,466	13,519	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	27,676	3,653	4,018	4,772	5,683	5,923

Source: EIA, *Electric Power Annual 2004,* DOE/EIA-0348(2004) (Washington, D.C., November 2005), 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 and 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 and 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.
[3] Collection of Form EIA-412 has been suspended, data for 2004 not available.

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	2004
Utility Operating Expenses	142,471	165,321	210,324	188,745	197,459	207,161
Electric Utility	127,901	150,599	191,329	171,291	175,473	182,337
Operation	81,086	91,881	132,662	116,374	122,723	131,962
Production	62,501	68,983	107,352	90,649	96,181	104,287
Cost of Fuel	32,635	29,122	32,555	24,132	26,476	28,678
Purchased Power	20,341	29,981	61,969	58,828	62,173	67,354
Other	9,526	9,880	12,828	7,688	7,532	8,256
Transmission	1,130	1,425	2,699	3,494	3,585	4,519
Distribution	2,444	2,561	3,115	3,113	3,185	3,301
Customer Accounts	3,247	3,613	4,246	4,165	4,180	4,087
Customer Service	1,181	1,922	1,839	1,821	1,893	2,012
Sales	212	348	403	261	234	238
Administrative and General	10,371	13,028	13,009	12,872	13,466	13,519
Maintenance	11,779	11,767	12,185	10,843	11,141	11,774
Depreciation	14,889	19,885	22,761	17,319	16,962	16,373
Taxes and Other	20,146	27,065	23,721	26,755	24,648	22,228
Other Utility	14,571	14,722	18,995	17,454	21,986	24,823
Operation (Mills per Kilowatthour) [1]						
Nuclear	10.04	9.43	8.41	8.54	8.86	8.3
Fossil Steam	2.21	2.38	2.31	2.54	2.50	2.68
Hydroelectric and Pumped Storage	3.35	3.69	4.74	5.07	4.50	5.05
Gas Turbine and Small Scale [2]	8.76	3.57	4.57	2.72	2.76	2.73
Maintenance (Mills per Kilowatthour) [1]						
Nuclear	5.68	5.21	4.93	5.04	5.23	5.38
Fossil Steam	2.97	2.65	2.45	2.68	2.73	2.96
Hydroelectric and Pumped Storage	2.58	2.19	2.99	3.58	3.01	3.64
Gas Turbine and Small Scale [2]	12.23	4.28	3.50	2.38	2.26	2.16

Source: EIA, *Electric Power Annual 2004*, DOE/EIA-0348(2004) (Washington, D.C., November 2005), 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 and Table 21; EIA, *Financial Statistics of Major U.S. Publicly Owned Electric Utilities 2000*, DOE/EIA-0437(00)/2 (Washington, D.C., November 2001), Table 10 and 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: EIA suspended collection of this dataset in 2004.

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

[2] Number of employees was 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.

NA = not available

Table 9.7 – Environmental Compliance Equipment Costs

(Nominal Dollars)

	1990	1995	2000	2001	2002	2003	2004
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	1.38
Average Installed Costs ($/kW)	118	126	124	131	124	124	145

Source: *Electric Power Annual 2004*, Table 5.3., DOE/EIA-0348(04) (November 2005). EIA, *Electric Power Annual 2001*, DOE/EIA-0348(01) (March 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

(2004 Dollars, per Million Btu)[1]

	1970	1980	1990	2000	2005	2010	2015	2020	2025	2030
Coal	1.49	2.92	1.98	1.34	1.52	1.51	1.43	1.42	1.46	1.53
Natural Gas	2.32	5.73	5.07	6.08	9.60	7.19	6.60	6.93	7.47	7.98
Distillate Fuel	4.56	13.42	10.19	10.67	15.28	13.30	13.72	14.07	14.52	15.04
Jet Fuel	2.87	12.74	7.54	7.14	12.64	9.67	9.87	10.49	10.92	11.53
Liquified Petroleum Gases	5.74	11.30	8.97	11.03	18.04	13.39	13.19	14.38	15.66	16.90
Motor Gasoline	11.20	19.71	12.10	13.00	18.60	16.52	16.34	17.02	17.49	17.92
Residual Fuel	1.65	7.77	4.21	4.68	6.79	6.07	6.03	6.31	6.75	7.12
Other [2]	5.42	14.10	7.72	7.54	NA	NA	NA	NA	NA	NA
Petroleum Total	6.76	14.82	9.91	10.73	15.28	13.30	13.72	14.07	14.52	15.04
Nuclear Fuel	0.71	0.86	0.89	0.50	N/A	N/A	N/A	N/A	N/A	N/A
Wood and Waste	5.07	4.53	1.72	1.73	N/A	N/A	N/A	N/A	N/A	N/A
Primary Energy Total [3]	4.25	9.15	5.90	6.18	13.61	11.52	11.40	11.89	12.35	12.86
Electric Utility Fuel	1.26	3.52	1.95	1.78	NA	NA	NA	NA	NA	NA
Electricity Purchased by End Users	19.58	27.94	25.64	21.69	24.44	21.43	20.87	21.23	21.69	22.00
Total Energy [3]	6.49	13.80	10.94	11.18	15.57	13.32	13.16	13.66	14.14	14.64
	1.49	2.92	1.98	1.34	1.52	1.51	1.43	1.42	1.46	1.53

Sources: EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006), (Washington, D.C., February 2006), Table A3; and EIA, *Annual Energy Review 2004*, DOE/EIA-0384 (2004) (Washington, D.C., August 2005), Table 3.3.

Notes:
[1] Historical data converted to 2004$/MMBtu using GDP deflators from EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., September 2005), Table D.1.
[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.
NA = not available

Table 10.2 – Economy-Wide Indicators

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

	1980	1990	2000	2004	2010	2015	2020	2025	2030
GDP Chain Type Price Index (2000 = 1.000)	0.541	0.816	1.000	1.091	1.235	1.398	1.597	1.818	2.048
Real Gross Domestic Product	5,162	7,113	9,817	10,756	13,043	15,082	17,541	20,123	23,112
Real Consumption	3,374	4,770	6,739	7,589	9,128	10,373	11,916	13,555	15,352
Real Investment	645	895	1,736	1,810	2,259	2,713	3,293	4,025	4,985
Real Government Spending	1,115	1,530	1,722	1,952	2,150	2,296	2,464	2,631	2,838
Real Exports	324	553	1,096	1,118	1,831	2,671	3,776	5,083	6,833
Real Imports	311	607	1,476	1,719	2,295	2,857	3,659	4,734	6,156
Real Disposable Personal Income	3,858	5,324	7,194	8,004	9,622	11,058	13,057	15,182	17,562
Consumer Price Index (2002 = 1.000)	0.824	1.307	1.722	1.889	2.153	2.464	2.862	3.310	3.783
Unemployment Rate (percent)	7.1	5.6	4.0	5.5	4.7	4.6	4.4	4.8	4.9
Housing Starts (millions)	1.3	1.2	1.6	2.1	2.0	2.0	1.9	1.8	1.8
Gross Output									
Total Industrial				5,643	6,355	7,036	7,778	8,589	9,578
Non-Manufacturing				1,439	1,572	1,689	1,808	1,926	2,069
Manufacturing				4,204	4,783	5,347	5,969	6,664	7,509
Energy-Intensive Manufacturing				1,161	1,265	1,350	1,441	1,529	1,627
Non-Energy-Intensive Manufacturing				3,044	3,518	3,997	4,528	5,135	5,882
Population (all ages, millions)	226.5	248.8	281.4	294.1	310.1	323.5	337.0	350.6	364.8
Employment Non-Agriculture (millions)	95.9	115.6	134.4	131.4	142.1	147.6	156.2	164.2	173.6
Employment Manufacturing (millions)	20.4	19.2	17.5	14.3	14.0	13.5	13.3	12.9	12.6

Sources: EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383(2006) (Washington, D.C., February 2006), Table A19; EIA, *Annual Energy Review 2003*, DOE/EIA-0384(2003) (Washington, D.C., October 2004), 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, 2004

(Million 2004 Dollars)

	Investor-Owned Electric Utilities	Publicly Owned Generator Electric Utilities [1, 2]	Cooperative Borrower Owned Electric Utilities
Operating Revenue - Electric	213,539	46,360	30,650
Operating Expenses - Electric	182,337	41,118	27,828
Operation Including Fuel	131,962	32,737	25,420
Production	104,287	26,813	20,752
Transmission	4,519	977	665
Distribution	3,301	1,044	1,860
Customer Accounts	4,180	754	595
Customer Service	2,012	311	141
Sales	238	95	80
Administrative and General	13,519	2,742	1,327
Maintenance	11,774	2,504	NA
Depreciation and Amortization	16,373	4,555	2,182
Taxes and Tax Equivalents	22,228	1,323	226
Net Electric Operating Income	33,158	5,242	2,822

Source: EIA, *Electric Power Annual 2004*, DOE/EIA-0348(2003), (Washington, D.C., November 2005), Tables 8.1, 8.3, 8.4, and 8.6.

Note:
[1] The data represent those utilities meeting a threshold of 150 million kilowatthours of customer sales or resale for the two previous years.
[2] Values for 2003. In 2004, Form EIA-412 has been suspended until further notice. Includes utilities with and without generating facilities.
NA= not available

Table 11.1 – Emissions from Electricity Generators

(Thousand short tons of gas)

	1990	2000	2001	2002	2003	2004	2010	2015	2020	2025	2030
Coal Fired											
Carbon Dioxide	1,674,521	2,090,644	2,034,867	2,043,795	2,086,014	2,087,667	2,367,580	2,412,270	2,583,310	2,843,355	3,170,875
Sulfur Dioxide	15,220	10,623	10,004	9,732	NA	NA	NA	NA	NA	NA	NA
Nitrogen Oxide	5,642	4,563	4,208	4,094	NA	NA	NA	NA	NA	NA	NA
Methane	11	13	13	13	13	13	NA	NA	NA	NA	NA
Nitrous Oxide	25	31	31	31	31	32	NA	NA	NA	NA	NA
Petroleum Fired											
Carbon Dioxide	111,223	100,200	111,885	85,870	107,034	107,365	82,091	81,142	82,153	84,251	90,185
Sulfur Dioxide	639	482	529	343	NA	NA	NA	NA	NA	NA	NA
Nitrogen Oxide	221	166	170	130	NA	NA	NA	NA	NA	NA	NA
Methane	1	1	1	1	1	1	NA	NA	NA	NA	NA
Nitrous Oxide	1	1	1	1	1	1	NA	NA	NA	NA	NA
Gas Fired											
Carbon Dioxide	194,999	310,190	319,119	336,866	306,002	326,174	327,857	425,185	444,001	419,658	379,553
Sulfur Dioxide	1	232	262	8	NA	NA	NA	NA	NA	NA	NA
Nitrogen Oxide	565	422	359	270	NA	NA	NA	NA	NA	NA	NA
Methane	0	1	1	1	1	1	NA	NA	NA	NA	NA
Nitrous Oxide	0	1	1	1	1	1	NA	NA	NA	NA	NA
Other [1]											
Carbon Dioxide	NA	NA	NA	NA	NA		14,290	15,024	15,806	16,535	16,834
Sulfur Dioxide 2	49	59	55	210	NA	NA	NA	NA	NA	NA	NA
Nitrogen Oxide 2	235	180	180	206	NA	NA	NA	NA	NA	NA	NA
Methane	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrous Oxide 3	1	1	0	1	1	1	NA	NA	NA	NA	NA
Total											
Carbon Dioxide	1,987,578	2,512,498	2,478,216	2,480,862	2,511,947	2,533,773	2,791,819	2,933,621	3,125,269	3,363,800	3,657,447
Sulfur Dioxide	15,909	11,396	10,850	10,293	10,596	10,888	6,515	5,101	4,453	4,189	4,103

Nitrogen Oxide	6,663	5,330	4,917	4,699	4,119	3,742	2,585	2,312	2,345	2,379	2,390
Mercury	NA	NA	NA	50,081	50,695	53,306	41,595	26,503	20,653	18,283	16,872
Methane	12	14	14	14	14	14	NA	NA	NA	NA	NA
Nitrous Oxide	26	33	33	33	33	33	NA	NA	NA	NA	NA
Sulfur Hexafluoride [4]	2	1	1	1	1	1	NA	NA	NA	NA	NA

Sources: EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2005) (Washington, D.C., February 2006), Tables A8 and A18; EIA, *Emissions of Greenhouse Gases in the United States 2004*, DOE/EIA-0573(2003) (Washington, D.C., November 2005) Tables 10, 17, 25, 29; and EPA, *National Emission Inventory - Air Pollutant Emission Trends*, “Average Annual Emissions, All Criteria Pollutants,” August 2004, 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.

NA = not available

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

(Megawatts)

	1990	2000	2001	2002	2003	2004
Coal Fired						
Particulate Collectors	315,681	321,636	329,187	329,459	328,587	NA
Cooling Towers	134,199	146,093	154,747	154,750	155,158	NA
Scrubbers	69,057	89,675	97,804	98,363	99,257	NA
Total[1]	317,522	328,741	329,187	329,459	328,587	NA
Petroleum and Gas Fired						
Particulate Collectors	33,639	31,090	31,575	29,879	29,422	NA
Cooling Towers	28,359	29,427	34,649	45,747	55,770	NA
Scrubbers	65	0	184	310	310	NA
Total[1]	59,372	57,697	61,634	71,709	81,493	NA
Total						
Particulate Collectors	349,319	352,727	360,762	359,338	358,009	355,782
Cooling Towers	162,557	175,520	189,396	200,497	210,928	214,989
Scrubbers	69,122	89,675	97,988	98,673	99,567	101,492
Total[1]	376,894	386,438	390,821	401,168	409,954	409,769

Source: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., September 2005), Table 12.8. 2004 Total Data: *EIA Electric Power Annual.* DOE/EIA-0348(2004), http://www.eia.doe.gov/cneaf/electricity/epa/epat5p2.html, Table 5.2.

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.

NA = not available

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

	EPA Base Case 2004				EPA CAIR Case 2004			
	2007	2010	2015	2020	2007	2010	2015	2020
SO_2 (Thousand Tons)	10,374	9,908	9,084	8,876	7,733	6,351	5,227	4,480
NOx (Thousand Tons)	3,665	3,679	3,721	3,758	3,600	2,453	2,212	2,231
CO_2 (Thousand Tons)	2,391	2,470	2,599	2,796	2,365	2,452	2,571	2,776

Source: Environmental Protection Agency (EPA), Runs Table for EPA Modeling Applications 2004, using IPM http://www.epa.gov/airmarkets/epa-ipm/iaqr.html, EPA Base Case for 2004 Analyses http://www.epa.gov/airmarkets/epa-ipm/iaqr/basecase2004.zip, and 2004 CAIR Case Final 2004 http://www.epa.gov/airmarkets/epa-ipm/iaqr/cair2004_final.zip

Notes:
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 multiregional, 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 (SO_2), nitrogen oxides (NOx), carbon dioxide (CO_2), and mercury (Hg) from the electric-power sector

Table 11.4 – Origin of 2004 Allowable SO_2 Emissions Levels

Type of Allowance Allocation	Number of SO_2 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 specified in the Clean Air Act.
Allowance Auctions	250,000	The allowance auction provides 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 2004.
TOTAL 2004 ALLOCATION	**9,541,085**	
Banked Allowances	8,646,818	Banked Allowances are those allowances accrued in a unit's account from previous years, which can be used for compliance in 2004 or any future year.
TOTAL 2004 ALLOWABLE	**18,187,903**	

Source: EPA, *Acid Rain Program 2004 Progress Report*, Document EPA-430-R-05-011, November 2005, Figure 4. http://www.epa.gov/airmarkets/cmprpt/arp04/2004report.pdf

Table 12.1 – Renewable Energy Impacts Calculation

Conversion Formula:

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)	11,558,205	2,232,495	6,594,096	78,312,583	280,355	388,893
(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)	36,449,954,187	17,600,991,128	46,211,427,727	303,176,455,525	552,579,314	831,235,472
(E) Competing Heat Rate (Btu/kWh)	10,107	10,107	10,107	10,107	10,107	10,107
(F) Annual Output (Trillion Btu)	368	178	467	3,064	6	8
(G) Carbon Coefficient (MMTCB/Trillion Btu)	0.01783	0.01783	0.01783	0.01783	0.01783	0.01783
(H) Annual Carbon Displaced (MMTC)	6.569	3.172	8.328	54.635	0.100	0.128

Sources:
Capacity: Projected values for the year 2006 from EIA, *Annual Energy Outlook 2006,* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), 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 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table A6.

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

Notes:
For illustrative purposes only, displacement of fossil generation depends on power system generation portfolio and dispatch order.
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)	11,558,205	2,232,495	6,594,096	78,312,583	280,355	388,893
(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)	36,449,954,187	17,600,991,128	46,211,427,727	303,176,455,525	552,579,314	831,235,472
(E) Average Annual Household Electricity Consumption (kWh)	11,586	11,586	11,586	11,586	11,586	11,586
(F) Number of Households	3,148,804	1,520,497	3,992,068	26,190,515	47,736	71,808

Sources: Capacity: Projected values for the year 2006 from EIA, *Annual Energy Outlook 2006,* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table A16, 2006.

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: Calculated from EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006) (Washington, D.C., February), Tables A4 and A8, 2006.

Notes:
For illustrative purposes only.
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)	11,558,205	2,232,495	6,594,096	78,312,583	280,355	388,893
(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)	36,449,954,187	17,600,991,128	46,211,427,727	303,176,455,525	552,579,314	831,235,472
(E) Competing Heat Rate (Btu/kWh)	10,107	10,107	10,107	10,107	10,107	10,107
(F) Total Output (Million Btu)	368,399,686	177,893,217	467,058,900	3,064,204,435	5,584,919	8,401,296
(G) Coal Heat Rate (Btu per short ton)	20,411,000	20,411,000	20,411,000	20,411,000	20,411,000	20,411,000
(H) Coal (short tons)	18,049,076	8,715,556	22,882,705	150,125,150	273,623	411,606

Sources: Capacity: EIA, *Annual Energy Outlook 2006,* DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table A16, 2006.

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 2004, DOE/EIA-0384(2003) (Washington, D.C., August 2005), Table A6.

Heat Rate: Annual Energy Outlook 2006, DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table H1.

Notes:
For illustrative purposes only, displacement of fossil generation depends on power system generation portfolio and dispatch order.
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	2004
SO_2 (lbs)	34,523,334,000	32,184,330,000	31,466,566,000	23,671,357,600	22,404,150,534	20,518,221,256
SO_2 Heat Factor (lb/MMBtu)	1.935	1.748	1.599	1.081	0.875	0.778
NO_x (lbs)	-	-	-	11,682,226,600	12,024,262,800	10,209,031,650
NO_x Heat Factor (lb/MMBtu)	-	-	-	0.534	0.470	0.387
Heat (MMBtu)	17,838,745,941	18,414,433,865	19,684,094,492	21,889,662,875	25,606,076,726	26,358,516,161

Source: EPA, Clean Air Markets Web site - Data and Maps, Emissions section, http://cfpub.epa.gov/gdm/ accessed February 2006.

Table 12.5 – SO_2, NOx, CO_2 Emission Factors for Coal-Fired and Noncoal-Fired Title IV Affected Units

	1996	1997	1998	1999	2000	2001	2002	2003	2004
SO_2 (lbs/mmBtu)									
Coal	1.241	1.245	1.222	1.166	1.036	1.008	0.976	0.968	0.941
Noncoal	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	0.375	0.340
Noncoal	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	201.741	201.513
Noncoal	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 2004, 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/ accessed March 2006.

Table 12.6a – Sulfur Dioxide Uncontrolled Emission Factors, Electricity Generators

		Boiler Type/Firing Configuration					
Fuel	Emissions Units[1]	Cyclone	Fluidized Bed	Opposed Firing	Spreader Stoker	Tangential	All Other
Agricultural Byproducts	Lbs per ton	0.08	0.01	0.08	0.08	0.08	0.08
Blast Furnace Gas	Lbs per MMCF	3.5	0.35	3.5	3.5	3.5	3.5
Bituminous Coal*	Lbs per ton	38	3.1	38	38	38	38
Black Liquor	Lbs per ton ***	7	0.7	7	7	7	7
Distillate Fuel Oil*	Lbs per MG	142	14.2	142	142	142	142
Jet Fuel*	Lbs per MG	142	14.2	142	142	142	142
Kerosene*	Lbs per MG	142	14.2	142	142	142	142
Landfill Gas	Lbs per MMCF	3.5	0.35	3.5	3.5	3.5	3.5
Lignite Coal*	Lbs per ton	30	1	30	30	30	30
Municipal Solid Waste	Lbs per ton	1.7	0.17	1.7	1.7	1.7	1.7
Natural Gas	Lbs per MMCF	0.6	0.06	0.6	0.6	0.6	0.6
Other Biomass Gas	Lbs per MMCF	3.5	0.35	3.5	3.5	3.5	3.5
Other Biomass Liquids	Lbs per MG	1.42	1.42	1.42	1.42	1.42	1.42
Other Biomass Solids	Lbs per ton	0.08	0.01	0.08	0.08	0.08	0.08
Other Gases	Lbs per MMCF	3.5	0.35	3.5	3.5	3.5	3.5
Other	Lbs per MMCF	0.6	0.06	0.6	0.6	0.6	0.6
Petroleum Coke*	Lbs per ton	39	3.9	39	39	39	39
Propane Gas	Lbs per MMCF	0.6	0.06	0.6	0.6	0.6	0.6
Residual Fuel Oil*	Lbs per MG	157	15.7	157	157	157	157
Synthetic Coal*	Lbs per ton	38	3.1	38	38	38	38
Sludge Waste	Lbs per ton	2.8	0.28	2.8	2.8	2.8	2.8
Subbituminous Coal*	Lbs per ton ***	35	3.1	35	38	35	35
Tire Derived Fuel*	Lbs per ton	38	3.8	38	38	38	38
Waste Coal*	Lbs per ton	38	3.1	38	38	38	38
Wood Waste Liquids	Lbs per MG	1.42	1.42	1.42	1.42	1.42	1.42
Wood Waste Solids	Lbs per ton	0.08	0.01	0.08	0.08	0.08	0.08
Waste Oil*	Lbs per MG	147	14.7	147	147	147	147

Source: EIA, *Electric Power Annual 2004,* DOE/EIA-0348(2004) November 2005, Table A1.

Notes:
[1] Lbs = pounds, MMCF = million cubic feet, MG = thousand gallons.
* For these fuels, emissions are estimated by multiplying the emissions factor by the physical volume of fuel and the sulfur percentage of the fuel (other fuels do not require the sulfur percentage in the calculation). Note that EIA data do not provide a sulfur content for TDF. The value used (1.56 percent) is from http://www.epa.gov/appcdwww/aptb/EPA-600-R-01-109A.pdf, Table A-11.
** Source is EPA emission factors reported in http://www.epa.gov/ttn/chief/ap42/ and http://www.epa.gov/ttn/chief/software/fire/index.html.
*** Although SLW and BLQ consist substantially of liquids, these fuels are measured and reported to EIA in tons.

Table 12.6b – Nitrogen Oxide Uncontrolled Emissions Factors, Electricity Generators

		Boiler Type/Firing Configuration[1]					
Fuel	Emissions Units[2]	Cyclone	Fluidized Bed	Opposed Firing	Spreader Stoker	Tangential	All Other
Agricultural Byproducts	Lbs per ton	1.20	1.20	1.20	1.20	1.20	1.20
Blast Furnace Gas	Lbs per MMCF	15.40	15.40	15.40	15.40	15.40	15.40
Bituminous Coal	Lbs per ton	33.00	5.00	22.00	11.00	15.0 [14.0]	22.0 [31.0]
Black Liquor	Lbs per ton ***	1.50	1.50	1.50	1.50	1.50	1.50
Distillate Fuel Oil	Lbs per MG	24.00	24.00	24.00	24.00	24.00	24.00
Jet Fuel	Lbs per MG	24.00	24.00	24.00	24.00	24.00	24.00
Kerosene	Lbs per MG	24.00	24.00	24.00	24.00	24.00	24.00
Landfill Gas	Lbs per MMCF	72.40	72.40	72.40	72.40	72.40	72.40
Lignite Coal	Lbs per ton	15.00	3.60	13.00	5.80	7.10	7.1 [13.0]
Municipal Solid Waste	Lbs per ton	5.90	5.90	5.90	5.90	5.90	5.90
Natural Gas	Lbs per MMCF	280.00	280.00	280.00	280.00	170.00	280.00
Other Biomass Gas	Lbs per MMCF	72.40	72.40	72.40	72.40	72.40	72.40
Other Biomass Liquids	Lbs per MG	1.66	1.66	1.66	1.66	1.66	1.66
Other Biomass Solids	Lbs per ton	1.20	1.20	1.20	1.20	1.20	1.20
Other Gases	Lbs per MMCF	14.90	14.90	14.90	14.90	14.90	14.90
Other	Lbs per MMCF	1.50	1.50	1.50	1.50	1.50	1.50
Petroleum Coke	Lbs per ton	21.00	21.00	21.00	21.00	21.00	21.00
Propane Gas	Lbs per MMCF	19.00	19.00	19.00	19.00	19.00	19.00
Residual Fuel Oil	Lbs per MG	47.00	47.00	47.00	47.00	32.00	47.00
Synthetic Coal	Lbs per ton	33.00	5.00	22.00	11.00	15.00	22.00
Sludge Waste	Lbs per ton	5.00	5.00	5.00	5.00	5.00	5.00
Subbituminous Coal	Lbs per ton ***	17.00	5.00	12.00	8.80	8.40	12.0 [24.0]

Tire Derived Fuel	Lbs per ton	33.00	5.00	22.00	11.00	15.00	22.00
Waste Coal	Lbs per ton	21.70	21.70	21.70	21.70	21.70	21.70
Wood Waste Liquids	Lbs per MG	1.66	1.66	1.66	1.66	1.66	1.66
Wood Waste Solids	Lbs per ton	1.50	1.50	1.50	1.50	1.50	1.50
Waste Oil	Lbs per MG	19.00	19.00	19.00	19.00	19.00	19.00

Source: EIA, *Electric Power Annual 2004*, DOE/EIA-0348(2004) November 2005, Table A1.

Notes:

[1] All Dry-Bottom Boilers, Except Wet-Bottom as indicated by values in brackets

[2] Lbs = pounds, MMCF = million cubic feet, MG = thousand gallons.

** Source is EPA emission factors reported in http://www.epa.gov/ttn/chief/ap42/ and http://www.epa.gov/ttn/chief/software/fire/index.html.

*** Although Sludge Waste and Black Liquor consist substantially of liquids, these fuels are measured and reported to EIA in tons.

Table 12.6c – Uncontrolled Carbon Dioxide Emissions Factors, Electricity Generators

Fuel	Factor (lbs of CO2 per MMBtu)*
Blast Furnace Gas	116.97
Bituminous Coal	205.45
Distillate Fuel Oil	161.27
Geothermal	0.34
Jet Fuel	159.41
Kerosene	159.41
Landfill Gas	115.12
Lignite Coal	215.53
Municipal Solid Waste	14.63
Natural Gas	116.97
Other Biomass Gas	115.11
Other Gases	141.54
Petroleum Coke	225.13
Propane Gas	139.04
Residual Fuel Oil	173.72
Synthetic Coal	205.45
Subbituminous Coal	212.58
Waste Coal	205.16
Waste Oil	163.61

Source: EIA, *Electric Power Annual 2004*, DOE/EIA-0348(2004), November 2005, Table A1.
* CO_2 factors do not vary by boiler type or firing configuration.

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-05-003 (Final Version: April 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)	5.799
Natural Gas (Btu per million cubic ft)	1,027
Coal (million Btu per Short Ton)	20.411
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	6,000-8,000

Sources:

1. EIA, *Annual Energy Outlook 2006*, DOE/EIA-0383 (2006) (Washington, D.C., February 2006), Table G1.
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	2004
Fossil-Fueled Steam-Electric Plants[1, 2]	10,388	10,402	10,201	10,146	10,119	10,107	10,107
Nuclear Steam-Electric Plants[3]	10,908	10,582	10,429	10,448	10,439	10,439	10,439
Geothermal Energy Plants[4]	21,639	21,096	21,017	21,017	21,017	21,017	21,017

Source: EIA, *Annual Energy Review 2004*, DOE/EIA-0384 (2004) (Washington, D.C., August 2005), 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 hydro, solar, and wind electricity net generation.
[2] Through 2000, heat rates are for fossil-fueled steam-electric plants at electric utilities. Beginning in 2001, heat rates are for all fossil-fueled plants at electric utilities and independent power producers.
[3] Used as the thermal-conversion factor for nuclear electricity net generation.
[4] 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	944	957	917
February	831	655	643	725	670	801	769	732
March	680	535	494	669	624	572	487	593
April	338	321	341	302	282	344	302	345
May	142	184	115	115	185	165	105	159
June	49	29	29	29	23	41	28	39
July	5	6	12	8	3	4	5	9
August	10	10	12	6	8	5	16	15
September	54	56	69	71	38	62	42	77
October	316	246	244	267	299	261	241	282
November	564	457	610	400	561	477	484	539
December	831	789	1,005	696	813	784	788	817
Total	4,707	4,016	4,460	4,223	4,284	4,460	4,224	4,524

Source: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table 1.7

Notes:

[1] Based on calculations of data from 1971-2000

• This table excludes Alaska and Hawaii. • Degree-days are relative measurements of outdoor air temperature. Heating degree-days are deviations below the mean daily temperature of 65° F. For example, a weather station recording a mean daily temperature of 40° F would report 25 heating degree-days. • Temperature information recorded by weather stations is used to calculate statewide degree-day averages based on resident state population. 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. Web Pages: • For data not shown for 1951-1969, see http://www.eia.doe.gov/emeu/aer/overview.html.• For current data, see http://www.eia.doe.gov/emeu/mer/overview.html. Sources: • 1949-2003 and Normals—U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center, Asheville, North Carolina, Historical Climatology Series 5-1. • 2004—Energy Information Administration, Monthly Energy Review, February 2004-January 2005 issues, Table 1.10, which reports data from NOAA, National Weather Service Climate Prediction Center, Camp Springs, Maryland.

Table 12.11 – Cooling Degree-Days by Month

	1980	1990	2000	2001	2002	2003	2004	Normal[1]
January	9	15	10	3	8	5	5	9
February	4	14	10	12	6	7	5	8
March	13	21	25	11	17	24	26	18
April	23	29	28	37	53	30	41	30
May	95	86	131	114	92	110	140	97
June	199	234	221	220	242	187	208	213
July	374	316	284	302	369	336	310	321
August	347	291	302	333	331	345	254	290
September	192	172	156	138	202	156	178	155
October	42	57	50	46	57	65	69	53
November	10	16	8	18	11	21	17	15
December	5	9	4	11	5	4	6	8
Total	1,313	1,260	1,229	1,245	1,393	1,281	1,260	1,215

Source: EIA, *Annual Energy Review 2004*, DOE/EIA-0384(2004) (Washington, D.C., August 2005), Table 1.8

Notes:

[1] Based on calculations of data from 1971-2000

• This table excludes Alaska and Hawaii. • Degree-days are relative measurements of outdoor air temperature. Cooling degree-days are deviations above the mean daily temperature of 65° F. For example, a weather station recording a mean daily temperature of 78° F would report 13 cooling degree-days. • Temperature information recorded by weather stations is used to calculate statewide degree-day averages based on resident state population. 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. Web Pages: • For data not shown for 1951-1969, see http://www.eia.doe.gov/emeu/aer/overview.html. • For current data, see http://www.eia.doe.gov/emeu/mer/overview.html. Sources: • 1949-2003 and Normals—U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center, Asheville, North Carolina, Historical Climatology Series 5-2. • 2004—Energy Information Administration, Monthly Energy Review, February 2004-January 2005 issues, Table 1.11, which reports data from NOAA, National Weather Service Climate Prediction Center, Camp Springs, Maryland.

13.1 – Geographic Information System (GIS) Maps

A Geographical Information System (GIS) is a computer-based system used to manipulate, manage, and analyze multidisciplinary geographic and related attribute data. The GIS system is composed of hardware, software, data, and expertise. A GIS system allows the user to perform several tasks, including data capture, data management, data manipulation, data analysis, and presentation of results in graphic or report forms.

All information in GIS is linked to a spatial reference used to store and access data. GIS data layers can be recombined or manipulated, and analyzed with other layers of information. The GIS allows identification of relationships between features, within a common layer or across layers – and data can be queried or manipulated based on the tabular and/or the spatial characteristics.

One set of maps (**Figures 13.1, 13.3, 13.5, and 13.7**) illustrates the natural renewable resource for the United States by quality of the resource. The transmission grid and the major load centers are overlaid on the resource maps. The major load centers represent the areas in the United States where the vast majority of electricity demand exists (large metropolitan areas). The maps featured here are simplified to make them easier to read. Higher-resolution resource maps are available online (see **Online Resources** later in this chapter.

One of the challenges facing renewable energy is that, in many cases, areas with excellent renewable energy resources have little demand for electricity – while many major load centers are far from areas with good renewable resources.

The other set of maps (**Figures 13.2, 13.4, 13.6, and 13.8**) shows the installed generating capacity from 1996 through 2005 by state. A number in the state shows generating capacity in MW, and a bar chart in the state shows the generating capacity over time.

Biomass

Biomass power utilizes biomass such as wood, agricultural waste, and yard waste through combustion. The biomass fuel is either directly combusted in a boiler, or gasified and then combusted, or turned into a liquid fuel that can be combusted (see the Biomass section of Chapter 2 for more detail on biomass technologies).

Natural Resource

The majority of biomass resources exist east of the Continental Divide (**Figure 13.1**). Biomass resources are derived from the vegetation. Because the western part of the United States has sparse vegetation, the biomass resource in the Western states is generally poor. The Eastern states have much higher-quality resources; and many major load centers in Eastern states are near areas with excellent biomass resources. Alaska has limited biomass resources, while Hawaii has excellent biomass resources on some of the islands.

Installed Capacity

Biomass-generating capacity was nearly level during the past decade, with a slight decline in the past few years (**Figure 13.2**). The largest states, in terms of generating capacity, are Florida (1,051 MW), California (799 MW), and Maine (788 MW).

Geothermal

Geothermal technologies for power generation utilize heat from underground sources to generate electricity. Plants are currently operating in the Western United States (see the Geothermal section of Chapter 2 for more details on geothermal technologies).

Natural Resource

The majority of high-quality geothermal resources exist in the western part of the United States – and, in particular, the Southwest (**Figure 13.3**). Most of the major load areas in the Eastern states are not near any high-quality geothermal resources. The Western states are more promising, as several of the major load centers are in – or close to – high-quality geothermal resources. A good supply of high-quality geothermal resources exists in sparsely populated areas in the West. Alaska and Hawaii both have some areas with excellent geothermal resources.

Installed Capacity

Geothermal generation is currently located in three Western states (**Figure 13.4**). California is by far the largest (2,802 MW), followed by Nevada (272 MW) and Utah (38MW).

Solar

The two most commonly deployed solar power technologies are photovoltaic (PV) and concentrating solar thermal power (CSP) (see the Solar section of Chapter 2 for more information on solar technologies).

Natural Resource

The southern parts of the United States, and especially the southwest, have the greatest potential for solar energy (**Figure 13.5**). This is determined largely by latitude and weather patterns. Solar resources generally decline in quality, moving east and north from the Southwest. The Northeast, as a whole, generally has moderate-quality solar resources. Alaska has moderate solar resources, while Hawaii has good – to very good – solar resources.

Installed Capacity

This map features concentrating solar thermal power (CSP) generating capacity (**Figure 13.6**). Total CSP-generating capacity is virtually unchanged over the past decade. California has the most CSP generating capacity, by far (418 MW), followed by Arizona (10 MW), New York (0.5 MW), Nevada (0.3 MW), and Pennsylvania (0.3 MW).

Wind

Wind power utilizes naturally occurring wind patterns to drive turbines that generate electricity (see the Wind section of Chapter 2 for more information on wind power technologies).

Natural Resource

The wind resources of the United States fall into two major categories: 1) onshore, and 2) offshore. So far, most of the wind resource assessments focused on onshore wind. Most of the best onshore wind resource is in the Midwestern states (**Figure 13.7**). Many of the major load centers in the Eastern states are not located near good wind resources, while some Western load centers are located close to high-quality wind resources.

Installed Capacity

Wind power is the most consistently growing renewable energy technology among those featured in this chapter (**Figure 13.8**). California is the largest state, in terms of capacity (2,150 MW), with Texas close behind (1,995 MW). Iowa, the third-largest state (836 MW), has less than half the capacity of the largest states. Wind-generating capacity is growing rapidly in many states.

Online Resources

For more GIS information, including dynamic maps, GIS data, and analysis tools – as well as downloadable high-resolution maps – please see the NREL GIS Web site at http://www.nrel.gov/gis

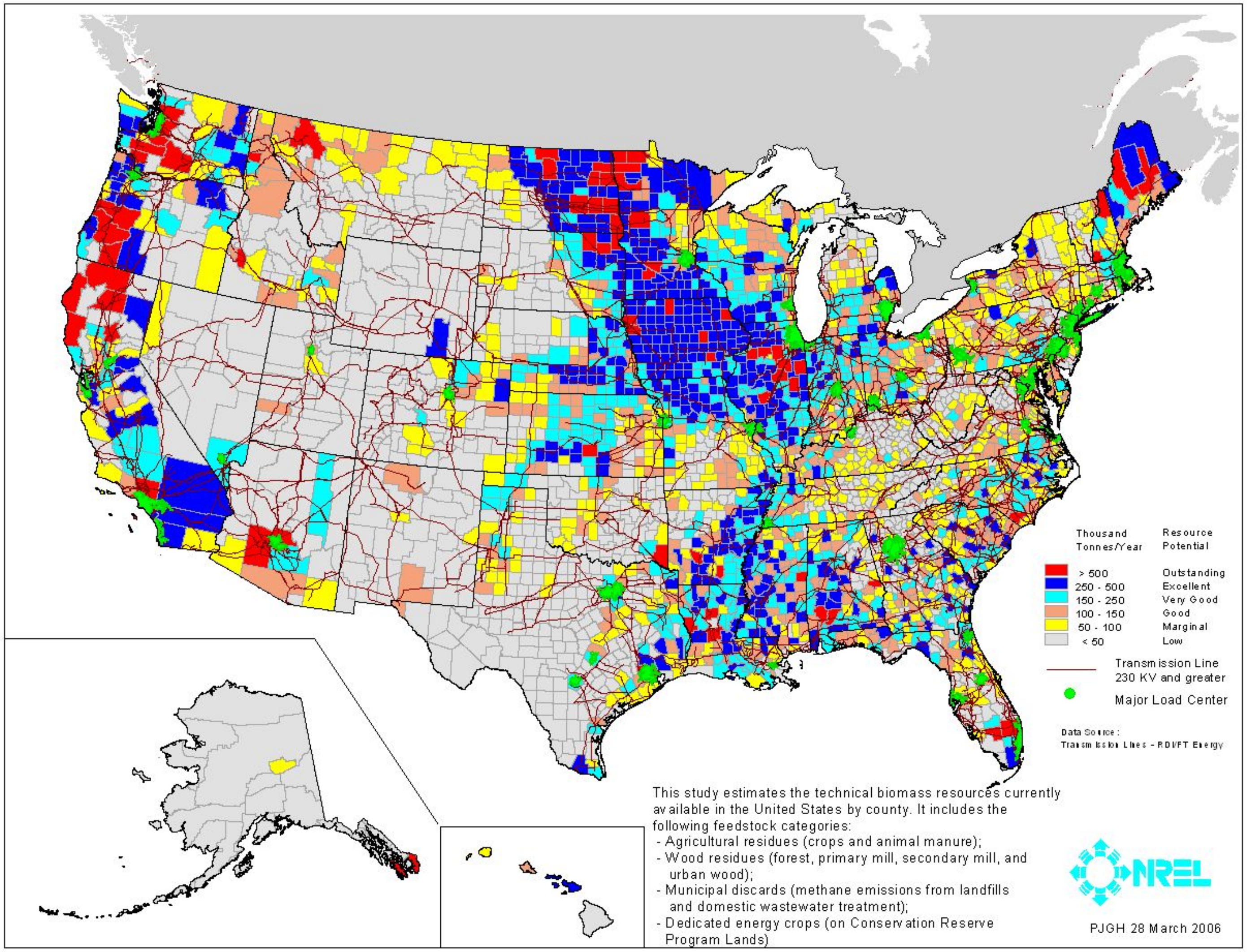


Figure 13.1. Biomass Resources, Transmission, and Load Centers

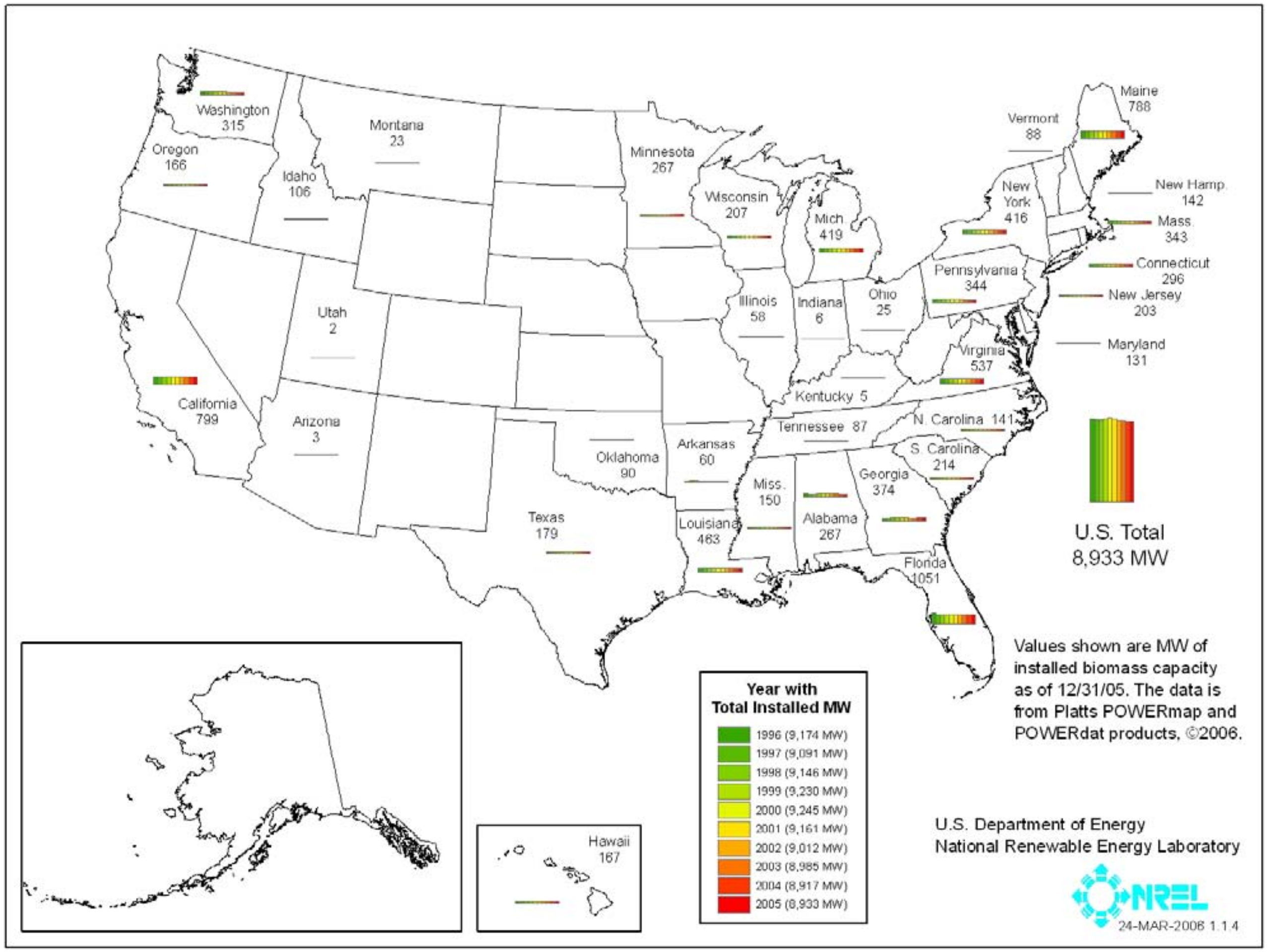


Figure 13.2. Installed Biomass Generating Capacity

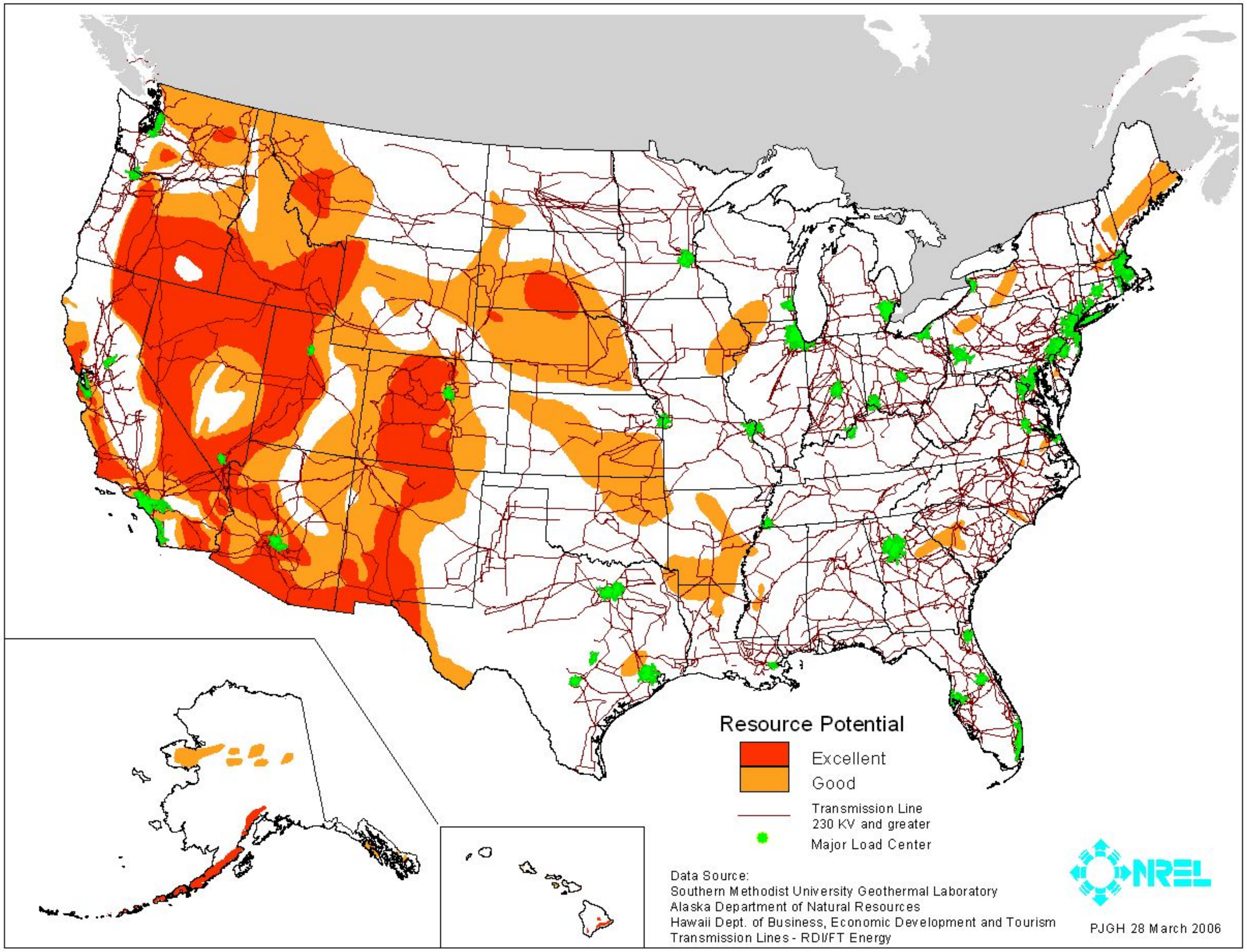


Figure 13.3. Geothermal Resources, Transmission, and Load Centers

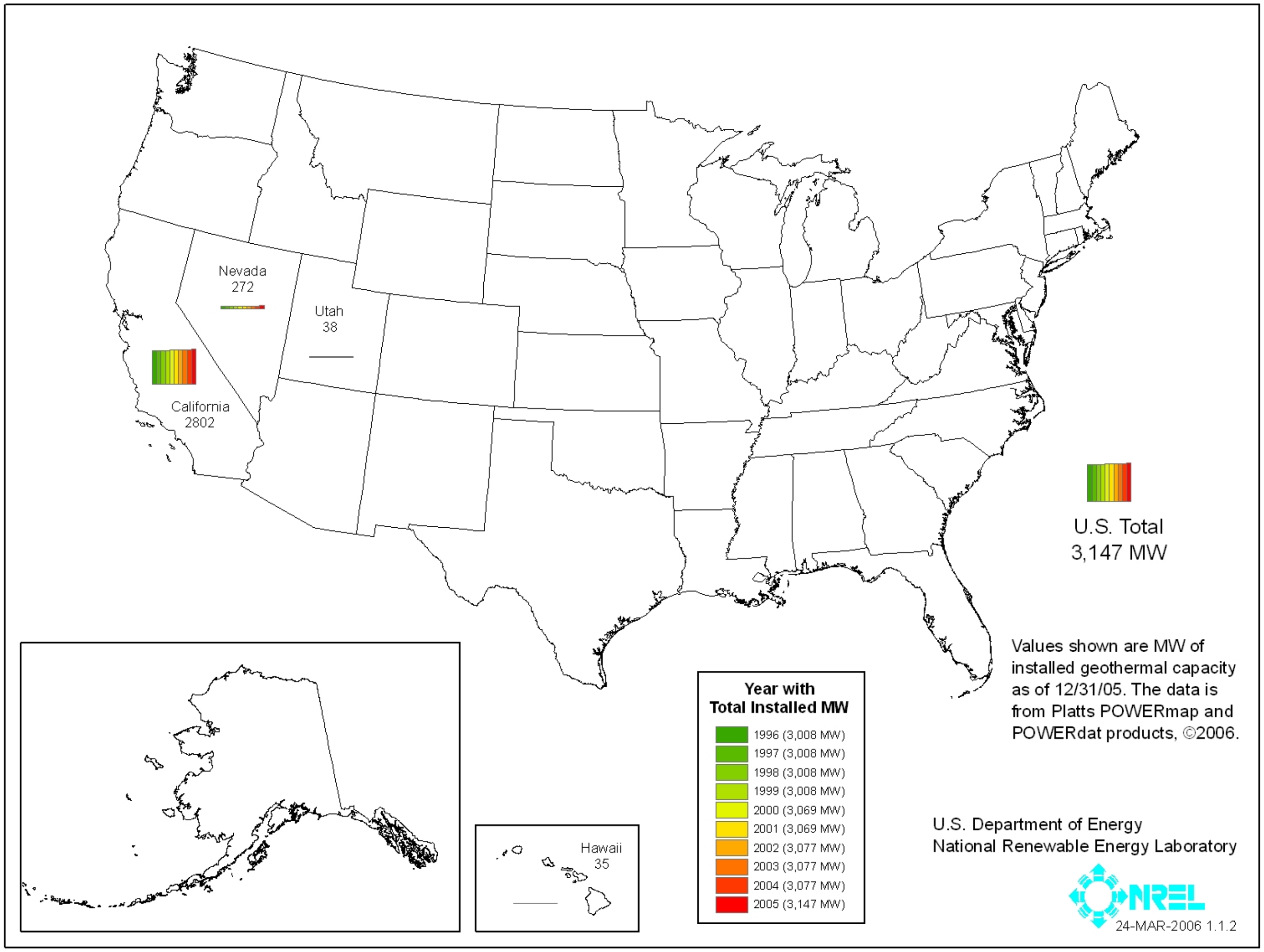


Figure 13.4. Installed Geothermal Generating Capacity

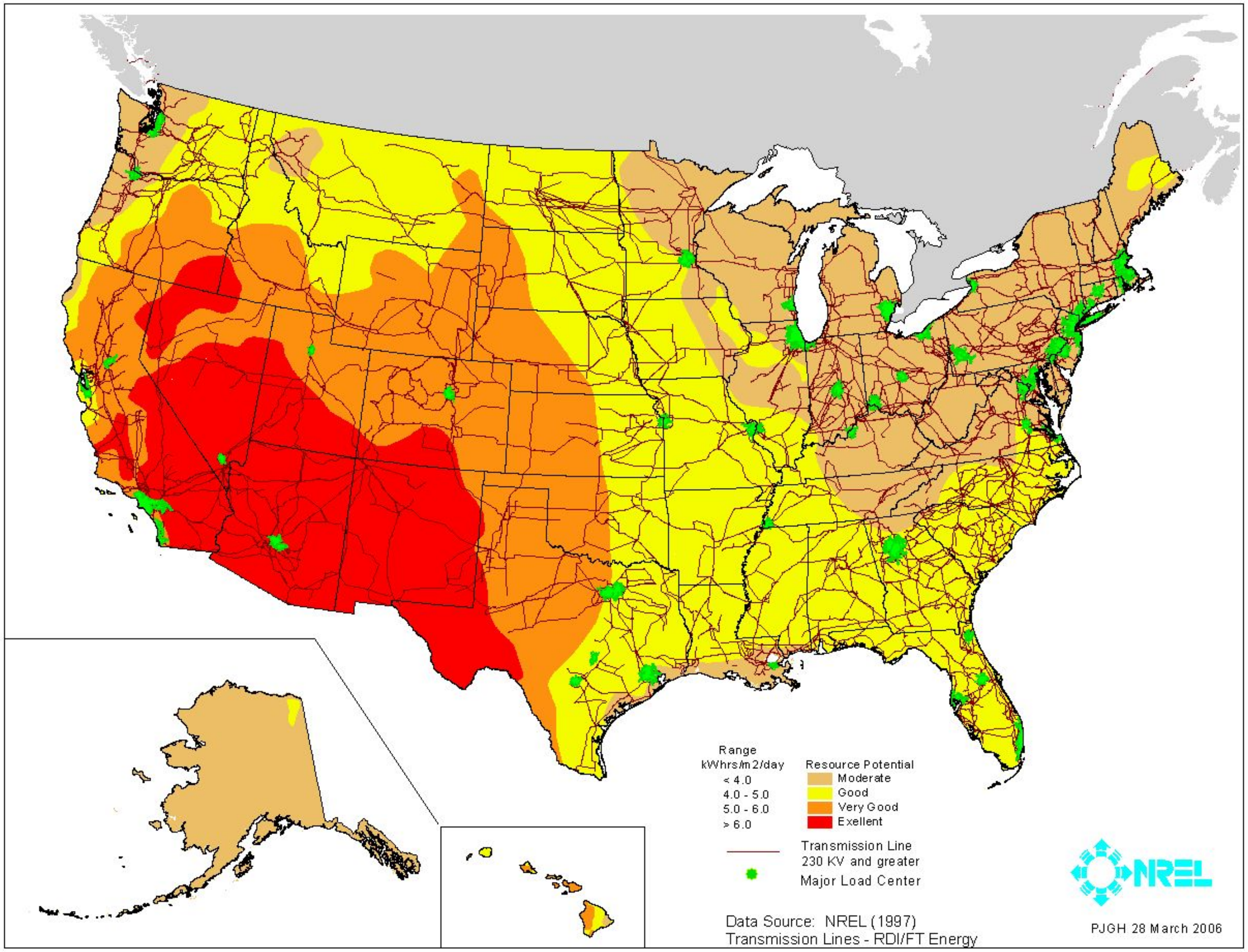


Figure 13.5. Direct Normal Solar Resources, Transmission, and Load Centers

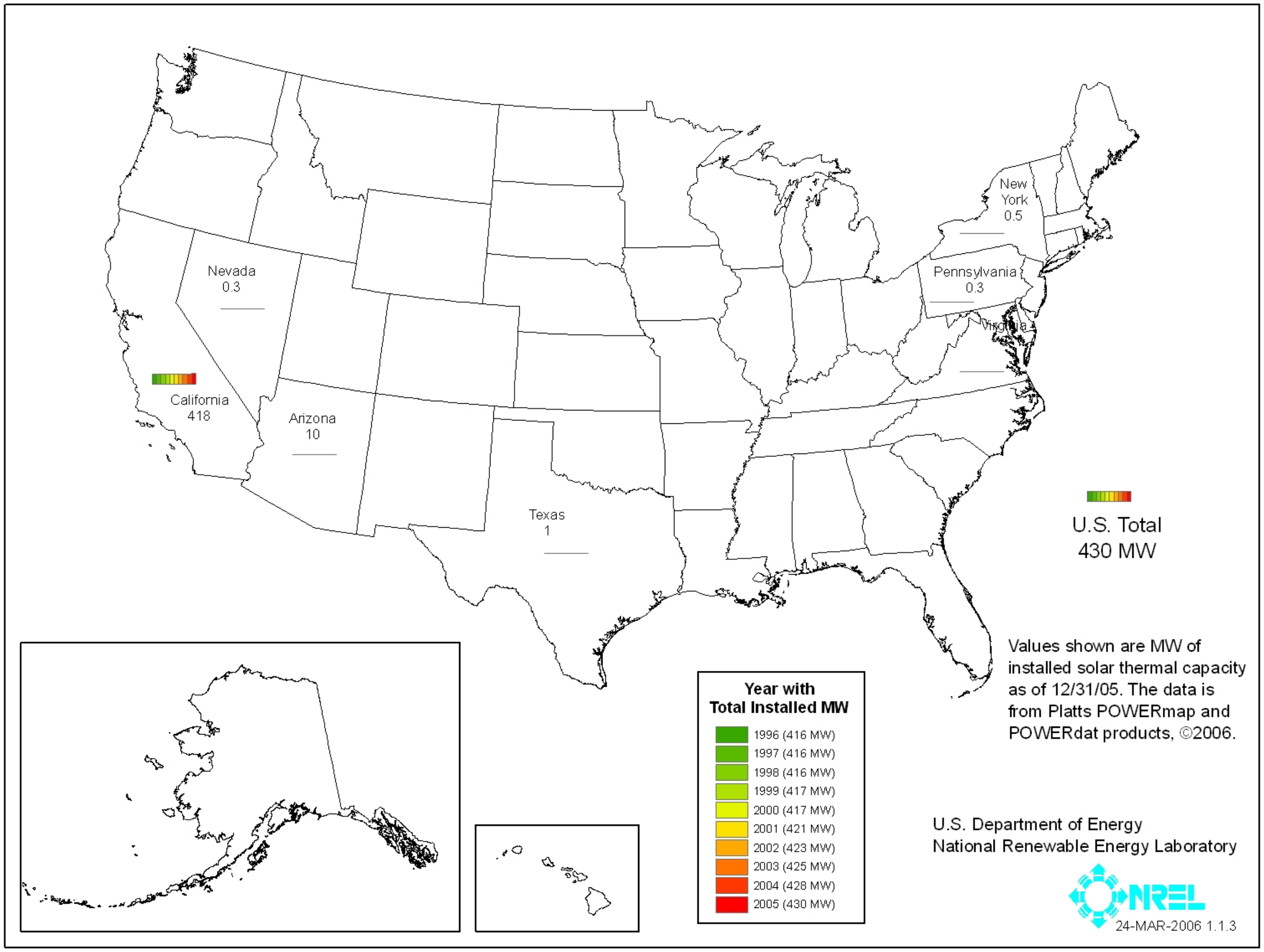


Figure 13.6. Installed CSP Generating Capacity

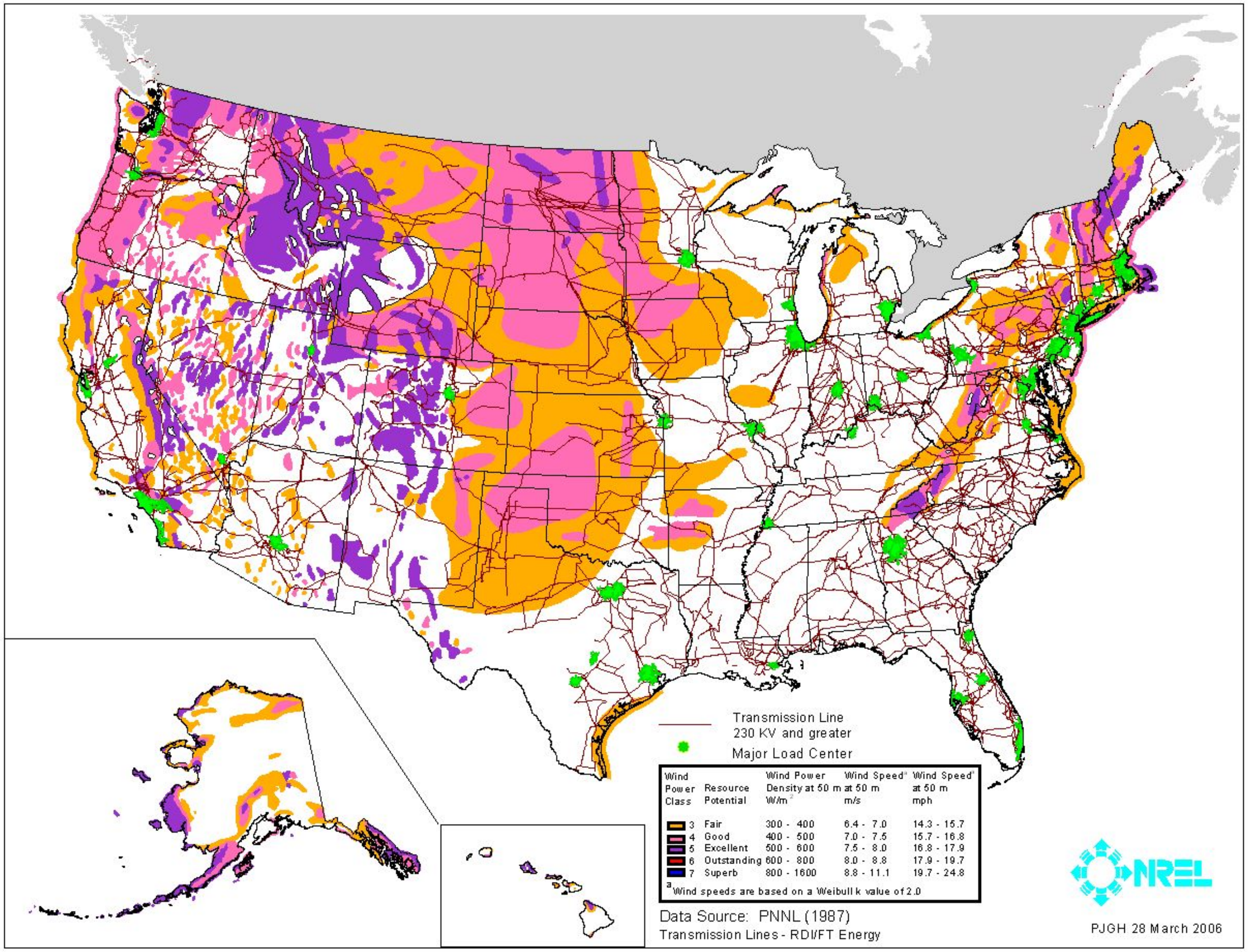


Figure 13.7. Wind Resources, Transmission, and Load Centers

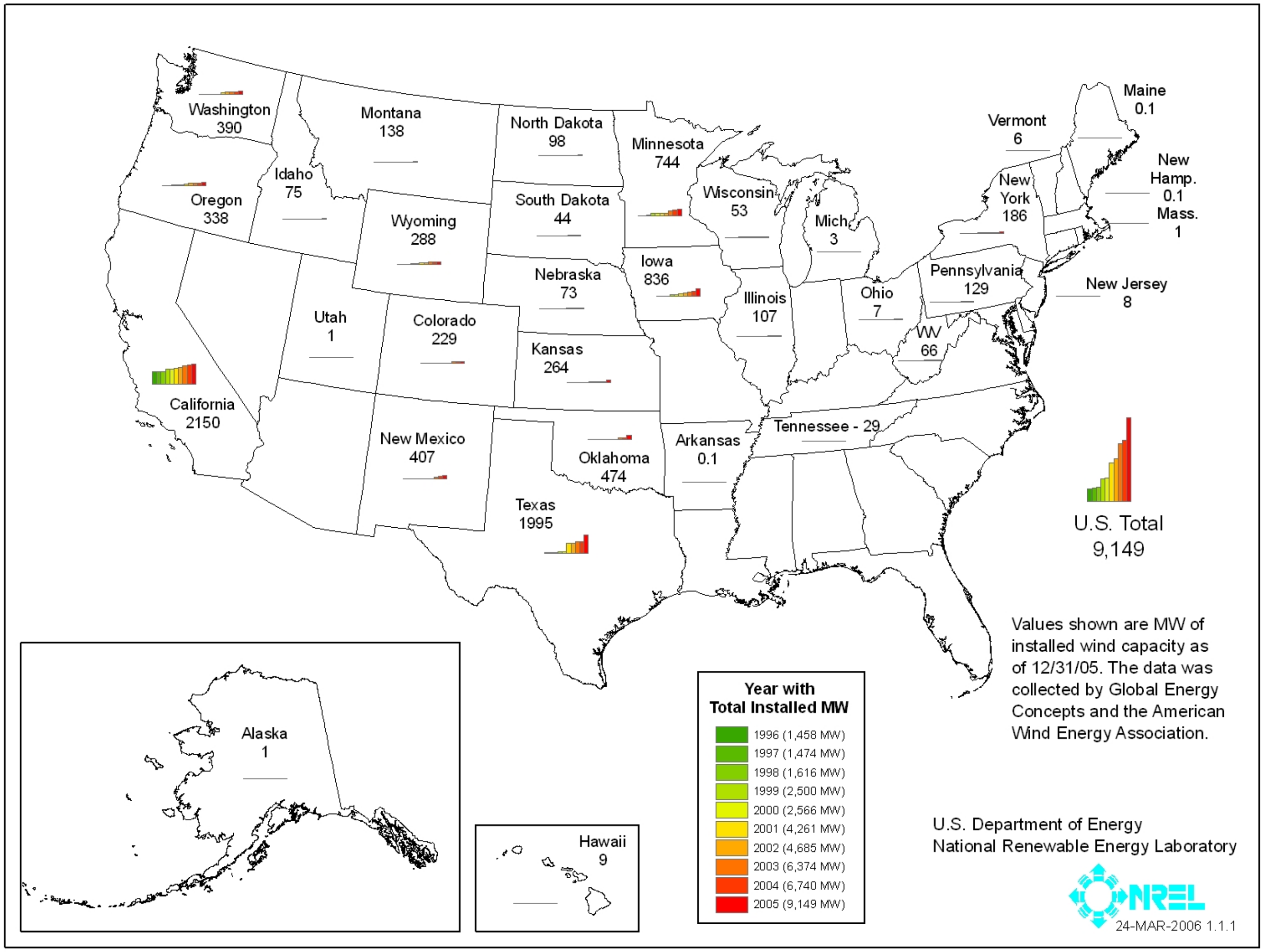


Figure 13.8. Installed Wind Generating Capacity

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