Renewable Fuels Module

The NEMS Renewable Fuels Module (RFM) provides natural resources supply and technology input information for forecasts of new central-station U.S. electricity generating capacity using renewable energy resources. The RFM has five submodules representing various renewable energy sources, biomass, geothermal, landfill gas, solar, and wind; a sixth renewable, conventional hydroelectric power, is represented in the Electricity Market Module (EMM).[109]

Some renewables, such as landfill gas (LFG) from municipal solid waste (MSW) and other biomass materials, are fuels in the conventional sense of the word, while others, such as wind and solar radiation, are energy sources that do not involve the production or consumption of a fuel. Renewable technologies cover the gamut of commercial market penetration, from hydroelectric power, which was an original source of electricity generation, to newer power systems using biomass, geothermal, LFG, solar, and wind energy. In some cases, they require technological innovation to become cost effective or have inherent characteristics, such as intermittency, which make their penetration into the electricity grid dependent upon new methods for integration within utility system plans or upon low-cost energy storage.

The submodules of the RFM interact primarily with the Electricity Market Module (EMM). Because of the high level of integration with the EMM, the final outputs (levels of consumption and market penetration over time) for renewable energy technologies are largely dependent upon the EMM.

Projections for residential and commercial grid-connected photovoltaic systems are developed in the end-use demand modules and not in the RFM; see the Distributed Generation and Combined Heat and Power descriptions in the “Commercial Demand Module” section of the report.

Key Assumptions

Nonelectric Renewable Energy Uses

In addition to projections for renewable energy used in central station electricity generation, the *AEO2004* contains projections of nonelectric renewable energy uses for industrial and residential wood consumption, solar residential and commercial hot water heating, blending in transportation fuels, and residential and commercial geothermal (ground-source) heat pumps. Assumptions for their projections are found in the residential, commercial, industrial, and petroleum marketing sections of this report. Additional minor renewable energy applications occurring outside energy markets, such as direct solar thermal industrial applications or direct lighting, off-grid electricity generation, and heat from geothermal resources used directly (e.g., district heating and greenhouses) are not included in the projections.

Electric Power Generation

The RFM considers only grid-connected central station electricity generation. The RFM submodules that interact with the EMM are the central station grid-connected biomass, geothermal, landfill gas, solar (thermal and photovoltaic), and wind submodules, which provide specific data or estimates that characterize that resource. A set of technology cost and performance values is provided directly to the EMM and are central to the build and dispatch decisions of the EMM. The technology cost and performance values are summarized in Table 38 in the chapter discussing the EMM. Overnight capital costs are presented in Table 72 and the assumed capacity factors for new plants in Table 73.

Conventional Hydroelectricity

The Hydroelectric Power Data File in the EMM represents reported plans for new conventional hydroelectric power capacity connected to the transmission grid and reported on Form EIA-860, *Annual Electric Generator Report*, and Form EIA-867, *Annual Nonutility Power Producer Report*. It does not estimate pumped storage hydroelectric capacity, which is considered a storage medium for coal and nuclear power and not a renewable energy use. However, the EMM allows new conventional hydroelectric capacity to be built in addition to reported plans. Converting Idaho National Engineering and Environmental Laboratory information on U.S. hydroelectric potential, the EMM contains regional conventional hydroelectric supply estimates at increasing capital costs. All the capacity is assumed available at a uniform capacity factor of 45 percent. Data maintained for hydropower include the available capacity, capacity factors, and costs (capital, and fixed and variable operating and maintenance). The fossil-fuel heat rate equivalents for hydropower are provided to the report writer for energy consumption calculation purposes only. Because of hydroelectric power's position in the merit order of generation, it is assumed that all available installed hydroelectric capacity will be used within the constraints of available water supply and general operating requirements (including environmental regulations).

Table 72. Overnight Capital Cost Characteristics for Renewable Energy Generating Technologies in Four Cases (2002$/kW)

			Total Overnight Costs[1]			
Technology	Overnight Costs in 2003	Year	**Reference**	**Low Renewable**	**High Renewable**	**DOE Goals**
Geothermal[2]	2,003					
		2005	1,882	1,699	1,851	1,746
		2010	1,685	1,890	1,509	1,174
		2025	2,293	2,524	1,951	1,452
Landfill Gas[3]	1,475					
		2005	1,470	1,470	1,470	1,470
		2010	1,454	1,454	1,454	1,454
		2025	1,404	1,404	1,404	1,404
Photovoltaic[4]	3,961					
		2005	3,889	3,981	2,838	3,370
		2010	3,684	9,934	2,582	1,743
		2025	2,677	3,702	1,817	1,155
Solar Thermal[4]	2,625					
		2005	2,577	2,625	2,553	3,004
		2010	2,458	2,625	2,374	3,091
		2025	2,062	2,577	1,804	2,898
Biomass[5]	1,731					
		2005	1,715	1,869	1,818	1,688
		2010	1,672	1,869	1,690	1,590
		2025	1,460	1,869	1,234	1,287
Wind	1,015					
		2005	1,010	1,015	1,010	977
		2010	1,008	1,015	1,008	888
		2025	998	1,015	986	873

[1]Overnight capital cost (i.e. excluding interest charges), plus contingency, learning, and technological optimism factors, excluding regional multipliers.

[2]Geothermal costs are specific for each site. The table entries represent the least cost unit available in the specified year in the Northwest Power Pool region, where most of the proposed sites are located.

[3]Provided to show evolution of landfill gas costs through 2025; for landfill gas, assumptions are the same in all four cases.

[5]Costs decline slightly in the Low Renewable case for photovoltaic and solar thermal technologies as technological optimism is factored into initial costs (see pg. 74 in the chapter discussing the EMM). However, there is no learning-by-doing assumed once the optimism factor has been removed.

[5]Biomass initial costs for the Low Renewable and High Renewable cases are higher than initial costs in the Reference case as technological optimism is assumed to apply to the entire plant in the Low and High cases, but only applies to the fuel-handling portion of the plant in the Reference case. The DOE goals case initially uses the reference case capital costs; however, neither technological optimism or learning is applied, and subsequent years' capital costs are directly assigned in the DOE goals case.

Source AEO2004 National Energy Modeling System runs: aeo2004.d101703e (Reference case), eere04.d103103a (DOE Goals case), hiren100.d103103a (High Renewable case), lorenew0.d102703b (Low Renewable case).

Table 73. Capacity Factors[1] for Renewable Energy Generating Technologies in Four Cases

Technology	Year	Reference	Low Renewables	High Renewables	DOE Goals
Geothermal[2]	2005	0.86	0.86	0.86	0.86
	2010	0.87	0.87	0.87	0.87
	2025	0.87	0.87	0.87	0.85
Landfill Gas	2005	0.90	0.90	0.90	0.90
	2010	0.90	0.90	0.90	0.90
	2025	0.90	0.90	0.90	0.90
Photovoltaic	2005	0.24	0.24	0.24	0.24
	2010	0.24	0.24	0.24	0.24
	2025	0.24	0.24	0.24	0.24
Solar Thermal	2005	0.15	0.15	0.15	0.19
	2010	0.15	0.15	0.15	0.23
	2025	0.15	0.15	0.15	0.28
Biomass	2005	0.83	0.83	0.83	0.80
	2010	0.83	0.83	0.83	0.80
	2025	0.83	0.83	0.83	0.80
Wind	2005	0.39	0.37	0.41	0.41
	2010	0.39	0.38	0.41	0.46
	2005	0.41	0.38	0.43	0.48

[1] Capacity factor for units available to be built in specified year.

[2]Geothermal costs are specific for each site. The table entries represent the least cost unit available in the specified year in the Northwest Power Pool region, where most of the proposed sites are located.

Source: AEO2004 National Energy Modeling System runs: aeo2004.d1021703e (Reference Case), eere04.d103103a (DOE Goals case), hiren100.d103103a (High Renewable case), lorenew0.d102703b (Low Reference case)

Capital Costs

The capital costs of renewable energy technologies are modified to represent two phenomena:

- Short-term cost adjustment factors, which increase technology capital costs as a result of a rapid U.S. buildup in a single year, reflecting limitations on the infrastructure (for example, limits on manufacturing, resource assessment, and construction expertise) to accommodate unexpected demand growth. These short-term factors are invoked when demand for new capacity in any year exceeds 50 percent of the prior year's total U.S. capacity. For every 1 percent increase in total U.S. capacity over the previous year exceeding 50 percent, capital costs rise 0.5 percent for wind, 0.33 percent for biomass, and 1 percent for solar technologies.

- For geothermal and wind, higher costs are assumed to result from large cumulative increases in their use, reflecting any or all of three factors: (1) resource degradation, (2) required transmission network upgrades, and (3) competition with other market uses. Presumably, the best resources are used first. Increased use results in the application of less efficient resources (e.g., less accessible, less productive, more difficult to use (e.g, land roughness, slope, terrain variability, or productivity, wind turbulence or wind variability)). Second, as capacity increases, especially for intermittent technologies like wind power, existing local and long-distance transmission networks require upgrading, increasing overall costs. Third, market pressures from competing land uses increase costs as cumulative capacity increases, including competition from agricultural or other production alternatives, residential or recreational use, aesthetics, or from broader environmental preferences. As a result, each EMM region's wind resource estimates are parceled into five cost levels, 0, 20, 50, 100 and 200 percent, respectively. For geothermal, four successive increments incur neither, either, or both of 33 percent increases in the drilling and field cost portions of capital costs and doubling of the relatively small exploration cost component. The size of the resource cost increments varies by technology and region.

For a description of NEMS algorithms lowering generating technologies' capital costs as more units enter service (learning), see "Technological Optimism and Learning" in the EMM chapter of this report. A detailed description of the RFM is provided in the EIA publication, *Renewable Fuels Module of the National Energy Modeling System, Model Documentation 2004*, DOE/EIA-M069(2004) (Washington, DC, 2004).

Solar Electric Submodule

Background

The Solar Electric Submodule (SOLES) currently includes both concentrating solar power (thermal) and photovoltaics, including two solar technologies: 50 megawatt central receiver (power tower) solar thermal (ST) and 5 megawatt single axis tracking-flat plate thin-film copper-indium-diselenide (CIS) photovoltaic (PV) technologies. PV is assumed available in all thirteen EMM regions, while ST is available only in the six Western regions where direct normal solar insolation is sufficient. Capital costs for both technologies are determined by EIA using multiple sources, including 1997 technology characterizations by the Department of Energy's Office of Energy Efficiency and Renewable Energy and the Electric Power Research Institute (EPRI).[110] Most other cost and performance characteristics for ST are obtained or derived from the August 6, 1993, California Energy Commission memorandum, *Technology Characterization for ER 94*; and, for PV, from the Electric Power Research Institute, *Technical Assessment Guide (TAG) 1993*. In addition, capacity factors are obtained from information provided by the National Renewable Energy Laboratory (NREL).

Assumptions

- Capacity factors for solar technologies are assumed to vary by time of day and season of the year, such that nine separate capacity factors are provided for each modeled region, three for time of day and for each of three broad seasonal groups (summer, winter, and spring/fall). Regional capacity factors vary from national averages. The current reference case solar thermal annual capacity factor for California, for example, is assumed to average 40 percent; California's current reference case PV capacity factor is assumed to average 24.6 percent.

- Because solar technologies are more expensive than other utility grid-connected technologies, early penetration will be driven by broader economic decisions such as the desire to become familiar with a new technology or environmental considerations. Minimal early years' penetration is included by EIA as "floor" additions to new generating capacity (see "Supplemental and Floor Capacity Additions" below).

- Solar resources are well in excess of conceivable demand for new capacity; therefore, energy supplies are considered unlimited within regions (at specified daily, seasonal, and regional capacity factors). Therefore, solar resources are not estimated in NEMS. In the seven regions where ST technology is not modeled, the level of direct, normal insolation (the kind needed for that technology) is insufficient to make that technology commercially viable through 2025.

- NEMS represents the Energy Policy Act of 1992 (EPACT) permanent 10-percent investment tax credit for solar electric power generation by tax-paying entities.

Wind-Electric Power Submodule

Background

Because of limits to windy land area, wind is considered a finite resource, so the submodule calculates maximum available capacity by Electricity Market Module Supply Regions. The minimum economically viable wind speed is about 14 mph, and wind speeds are categorized into three wind classes according to annual average wind speed. The RFM tracks wind capacity (megawatts) within a region and moves to the next best wind class when one category is exhausted. For *AEO2004*, wind resource data on the amount and quality of wind per EMM region come from the National Renewable Energy Laboratory for 23 states[111] and a Pacific Northwest Laboratory study and a subsequent update for the remainder.[112] The technological performance, cost, and other wind data used in NEMS are derived by EIA from consultation with industry experts.[113] Maximum wind capacity, capacity factors, and incentives are provided to the EMM for capacity planning and dispatch decisions. These form the basis on which the EMM decides how much power generation capacity is available from wind energy. The fossil-fuel heat rate equivalents for wind are used for energy consumption calculation purposes only.

Assumptions

- Only grid-connected (utility and nonutility) generation is included. The forecasts do not include off-grid or distributed electric generation.

- In the wind submodule, wind supply is constrained by three modeling measures, addressing (1) average wind speed, (2) distance from existing transmission lines, and (3) resource degradation, transmission network upgrade costs, and market factors.

- Available wind resource is reduced by excluding all windy lands not suited for the installation of wind turbines because of: excessive terrain slope (greater than 20 percent); reservation of land for non-intrusive uses (such as National Parks, wildlife refuges, and so forth); inherent incompatibility with existing land uses (such as urban areas, areas surrounding airports and water bodies, including offshore locations); insufficient contiguous windy land to support a viable wind plant (less than 5 square kilometers of windy land in a 100 square kilometer area). Half of the wind resource located on military reservations, U.S. Forest Service land, state forested land, and all non-ridge-crest forest areas are excluded from the available resource base to account for the uncertain ability to site projects at such locations. These assumptions are detailed in the Draft Final Report to EIA on *Incorporation of Existing Validated Wind Data into NEMS*, November 2003.

- Wind resources are mapped by distance from existing transmission capacity among three distance categories, within (1) 0-5, (2) 5-10, and (3) 10-20 miles on either side of the transmission lines. Additional transmission costs are added to the resources further from the transmission lines. Transmission costs vary by region and distance from transmission lines, ranging from $8.80 per kW to $94 per kW (2002$).

- Capital costs for wind technologies are assumed to increase in response to (1) declining natural resource quality, such as terrain slope, terrain roughness, terrain accessibility, wind turbulence, wind variability, or other natural resource factors, (2) increasing cost of upgrading existing local and network distribution and transmission lines to accommodate growing quantities of intermittent wind power, and (3) market conditions, such as the increasing costs of alternative land uses, including aesthetic or environmental reasons. Capital costs are left unchanged for some initial share, then increased 20, 50, 100 percent, and finally 200 percent, to represent the aggregation of these factors. Proportions of total wind resources in each category vary by EMM region. For all thirteen EMM regions, 1.2 percent of windy land is available with no cost increase, 1.8 percent is available with a 20 percent cost increase, 3.2 percent is available with a 50 percent cost increase, 3.2 percent is available with a 100 percent cost increase, and almost 91 percent of windy land is assumed to be available with a 200 percent cost increase.

- Depending on the EMM region, the cost of competing fuels, and other factors, wind plants can be built to meet system capacity requirements or as a "fuel saver" to displace generation from existing capacity. For wind to penetrate as a fuel saver, its total capital and fixed operations and maintenance costs minus applicable subsidies must be less than the variable operating costs, including fuel, of the existing (non-wind) capacity. When competing in the new capacity market, wind is assigned a capacity credit that declines based on its estimated contribution to regional reliability requirements.

- Because of downwind turbulence and other aerodynamic effects, the model assumes an average spacing between turbine rows of 5 rotor diameters and a lateral spacing between turbines of 10 rotor diameters. This spacing requirement determines the amount of power that can be generated from wind resources and is factored into requests for generating capacity by the EMM.

- Capacity factors are assumed to increase to a national average of 43 percent in the best wind class resulting from taller towers, more reliable equipment, and advanced technologies. Capacity factors for each wind class are calculated as a function of overall wind market growth. The capacity factors are assumed to be limited to about 45 percent for an average Class 6 site. As better wind resources are depleted, capacity factors are assumed to go down.

- *AEO2004* does not allow plants constructed after 2003 to claim the Federal Production Tax Credit (PTC), a 1.8 cent per kilowatt-hour tax incentive that expired on December 31, 2003. Wind plants are assumed to depreciate capital expenses using the Modified Accelerated Cost Recovery Schedule with a 5-year tax life.

Geothermal-Electric Power Submodule

Background

The Geothermal-Electric Submodule (GES), represents the generating capacity and output potential of 51 hydrothermal resource areas in the Western United States based on estimates provided in 1999 by DynCorp Corporation and subsequently modified by EIA.[114] Hot dry rock resources are not considered cost effective until after 2025 and are therefore not modeled in the GES. Both dual flash and binary cycle technologies are represented. The GES distributes the total capacity for each site within each EMM region among four increasing cost categories, with the lowest cost category assigned the base estimated costs, the next assigned higher (double) exploration costs, the third assigned a 33 percent increase in drilling and field costs, and the highest assigned both double exploration and 33 percent increased drilling and field costs. Drilling and field costs vary from site to site but are roughly half the total capital cost (along with plant costs) of new geothermal plants; exploration costs are a relatively minor additional component of capital costs. All quantity-cost groups in each region are assembled into increasing-cost supplies. When a region needs new generating capacity, all remaining geothermal resources available in that region at or below an avoided cost level determined in the EMM are submitted (in three increasing cost subgroups) to compete with other technologies for selection as new generating supply. Geothermal capital costs decline with learning. For estimating costs for building new plants, new dual-flash capacity – the lower cost technology - is assigned an 80 percent capacity factor, whereas binary plants are assigned a 95 percent capacity factor; both are assigned an 87 percent capacity factor for actual generation.

To realistically reflect capacity availability through 2025 at each of the 51 geothermal sites, each site's potential is limited to about 100 megawatts for each of four cost levels. Second, annual maximum capacity builds are established for each site, reflecting industry practice of expanding development gradually. For the reference case, each site is permitted a maximum development of 25 megawatts per year through 2015 and 50 megawatts per year thereafter; for the high renewables and DOE goals cases, the 50 megawatt annual limit applies to all years.

Assumptions

- Existing and identified planned capacity data are obtained directly by the EMM from Forms EIA-860A (utilities) and EIA-860B (nonutilities) and from supplemental additions (See Below).

- The permanent investment tax credit of 10 percent available in all forecast years based on the EPACT applies to all geothermal capital costs.

- Plants are not assumed to retire unless their retirement is reported to EIA. Geysers units are not assumed to retire but instead are assigned the 35 percent capacity factors reported to EIA reflecting their reduced performance in recent years.

- Capital and operating costs vary by site and year; values shown in Table 38 in the EMM chapter are indicative of those used by EMM for geothermal build and dispatch decisions.

Biomass Electric Power Submodule

Background

Biomass consumed for electricity generation is modeled in two parts in NEMS. Capacity in the wood products and paper industries, the so-called captive capacity, is included in the industrial sector module as cogeneration. Generation by the electricity sector is represented in the EMM, with capital and operating costs and capacity factors as shown in Table 38 in the EMM chapter, as well as fuel costs, being passed to the EMM where it competes with other sources. Fuel costs are provided in sets of regional supply schedules. Projections for ethanol are produced by the Petroleum Market Module (PMM), with the quantities of biomass consumed for ethanol decremented from, and prices obtained from, the EMM regional supply schedules.

Assumptions

- Existing and planned capacity data are obtained from Forms EIA-860A and EIA-860B.

- The conversion technology represented, upon which the costs in Table 38 in the EMM chapter are based, is an advanced gasification-combined cycle plant that is similar to a coal-fired gasifier. Costs in the reference case were developed by EIA to be consistent with coal gasifier costs. Short-term cost adjustment factors are used.

- Biomass cofiring can occur up to a maximum of 15 percent of fuel used in coal-fired generating plants.

Fuel supply schedules are a composite of four fuel types: forestry materials, wood residues, agricultural residues and energy crops. The first three are combined into a single supply schedule for each region which does not change over the forecast. Energy crops data are presented in yearly schedules from 2010 to 2025 in combination with the other material types for each region. The forestry materials component is made up of logging residues, rough rotten salvable dead wood, and excess small pole trees.[115] The wood residue component consists of primary mill residues, silvicultural trimmings, and urban wood such as pallets, construction waste, and demolition debris that are not otherwise used.[116] Agricultural residues are wheat straw and corn stover only, which make up the great majority of crop residues.[117] Energy crops data are for hybrid poplar, willow, and switchgrass grown on crop land, pasture land, or on Conservation Reserve lands.[118] The maximum amount of resources in each supply category is shown in Table 74.

Landfill-Gas-to-Electricity Submodule

Background

Landfill-gas-to-electricity capacity competes with other technologies using supply curves that are based on the amount of "high", "low", and "very low" methane producing landfills located in each EMM region. An average cost-of-electricity for each type of landfill is calculated using gas collection system and electricity generator costs and characteristics developed by EPA's "Energy Project Landfill Gas Utilization Software" (E-PLUS).[119]

Assumptions

- Gross domestic product (GDP) and population are used as the drivers in an econometric equation that establishes the supply of landfill gas.

- Recycling is assumed to account for 35 percent of the total waste stream by 2005 and 50 percent by 2010 (consistent with EPA's recycling goals).

Table 74. U.S. Biomass Resources, by Region and Type, 2025
(Trillion Btu)

	Forest Resources	Urban Wood Waste/ Mill Residue	Energy Crops	Agricultural Residue	Total
1. ECAR	363	156	183	407	1,110
2. ERCOT	29	45	78	57	210
3. MAAC	44	50	19	28	142
4. MAIN	125	36	112	439	712
5. MAPP	191	39	398	946	1,573
6. NPCC/NY	40	63	59	3	165
7. NPCC/NE	81	50	38	0	170
8. SERC/FL	32	42	4	0	79
9. SERC	342	307	217	61	927
10. SPP	225	138	387	264	1,014
11. NWP	414	180	0	53	647
12. W/RA	105	30	6	54	195
13. W/CNV	43	94	0	23	161
Total US	**2,036**	**1,231**	**1,501**	**2,335**	**7,103**

Sources: Urban Wood Wastes/Mill Residues: Antares Group Inc., *Biomass Residue Supply Curves for the U.S (updated),* prepared for the National Renewable Energy Laboratory, June 1999; all other biomass resources: Oak Ridge National Laboratory, personal communication with Marie Walsh, August 20, 1999.

- The waste stream is characterized into three categories: readily, moderately, and slowly decomposable material.
- Emission parameters are the same as those used in calculating historical methane emissions in the EIA's *Emissions of Greenhouse Gases in the United States 2002.*[120]
- The ratio of "high", "low", and "very low" methane production sites to total methane production is calculated from data obtained for 156 operating landfills contained in the Government Advisory Associates METH2000 database.[121]
- Cost-of-electricity for each site was calculated by assuming each site to be a 100-acre by 50-foot deep landfill and by applying methane emission factors for "high", "low", and "very low" methane emitting wastes.

Legislation

Energy Policy Act of 1992 (EPACT)

The RFM includes the investment tax and energy production credits established in the EPACT for the appropriate energy types. EPACT provides a renewable electricity production tax credit (PTC) of 1.5 cents per kilowatt-hour for electricity produced by wind, applied to plants that become operational between January 1, 1994, and June 30, 1999; *AEO2004* includes extension of the PTC (adjusted for inflation to 1.8 cents) through December 31, 2003, as provided in section 507 of the Tax Relief Extension Act of 1999 as well as by the Job Creation and Worker Assistance Act of 2002. The credit extends for 10 years after the date of initial operation. EPACT also includes provisions that allow an investment tax credit of 10 percent for solar and geothermal technologies that generate electric power. This credit is represented as a 10-percent reduction in the capital costs in the RFM.

Alternative Renewable Technology Cases

Three cases examine the effect on energy supply using alternative assumptions for cost and performance of non-hyrdo, non-landfill gas renewable energy technologies. The Low Renewable case examines the effect if technology costs were to remain at current levels. The High Renewable case examines the effect if technology energy costs were reduced by 2025 to 10 percent below Reference case values. The DOE Goals case examines the effect of using cost and performance assumptions approximating published goals of the relevant program offices of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy (DOE/EE).

The Low Renewables case does not allow "learning-by-doing" effects to reduce the capital cost of biomass, geothermal, solar, or wind technologies beyond 2004 levels. The construction of the first four units of biomass integrated gasification combined cycle units, utility-scale photovoltaic plants, or solar thermal plants are still assumed to reduce the technological optimism factor associated with those technologies. All other parameters remain the same as in the Reference case.

The High Renewables case assumes that the non-hydro, non-landfill gas renewable technologies are able to reduce their overall cost-of-energy produced in 2025 by 10 percent from the Reference case. Because the cost of supply of renewable resources is assumed to increase with increasing utilization (that is, the renewable resource supply curves are upwardly sloping), the cost reduction is achieved by targeting the reduction on the "marginal" unit of supply for each technology in 2025 for the Reference case (that is, the next resource available to be utilized in the Reference case in 2025). This has the effect of reducing costs for the entire supply (that is, shifting the supply curve downward by 10 percent). As a result of the overall reduction in costs, more supply may be utilized, and a unit from higher on the supply curve may result in being the marginal unit of supply in the High Renewable case. Thus the actual market-clearing cost-of-energy for a given renewable technology may not differ by much from the Reference case, although that resource is able to supply more energy than in the Reference case. These cost reductions are achieved gradually through "learning-by-doing", and are only fully realized by 2025.

For biomass, geothermal, and solar technologies, this cost reduction is achieved by a reduction in overnight capital costs sufficient to achieve the 10 percent targeted reduction in cost-of-energy. As a result, the supply of biomass fuel is increased by 10 percent at every price level. For geothermal, the capital cost of the lowest-cost site available in the year 2000 (Roosevelt Hot Springs) is reduced such that if it were available for construction in 2025, it would have a 10 percent lower cost-of-energy in the High Renewable case than the cost-of-energy it would have in 2025 were it available for construction in the Reference case. For solar technologies (both photovoltaic and solar thermal power), the resource is assumed to be unlimited and the reductions in cost-of-energy are achieved strictly through capital cost reduction.

Observation of wind energy markets indicates that improvements in performance (as measured by capacity factor) have, in recent years, dominated reductions in capital cost as a means of reducing cost-of-energy. Therefore, in the High Renewables case, wind capital costs are assumed to decline at the same rate relative to market growth as in the Reference case, but the rate of improvement in capacity factor is increased to meet the 10 percent targeted cost reduction. Other assumptions within NEMS are unchanged from the Reference case.

The DOE Goals case uses assumptions designed to correspond to those in the year 2020 Technologies Databook.[122] These assumptions, summarized previously in Table 72 and Table 73, include:

- Biomass: In the DOE Goals case, capital costs are modified from reference case values such that they are similar to those in the *Power Technologies Databook* costs for biomass gasification by 2025. To reflect greater optimism for biomass fuels, biomass supplies are increased 10 percent across all price steps for the four types of biomass. Fixed operations and maintenance costs are reduced about 14 percent to be consistent with *Power Technologies Databook* costs. Biomass capacity factors are unchanged from the reference case.

- Geothermal: In the DOE Goals case, EIA assumes that (1) capital costs for all 51 sites in 2000 match higher EIA rather than *Power Technologies Databook* estimates for this "base" year, (2) EIA assumptions for capital costs decline at a rate sufficient to match *Power Technologies Databook* estimates by 2010, meaning that DOE Goals case assumptions remain higher than DOE/EE assumed costs through 2009 and (3) the lowest cost geothermal site available in 2000 (Roosevelt Hot Springs), would, if available for selection in 2020 (decision year), meet the 2020 *Power Technologies Databook* capital cost goal in that year, about 36 percent below its current $1,900 per kilowatt ($2002) cost. Finally, because each of the 51 sites is separately priced, EIA applies the rate (rather than amounts) of capital cost decline necessary for Roosevelt Hot Springs to meet these requirements to all other 50 sites. Overall, each site's capital cost declines by 3 percentage points per decision year from 2000-2010, and by 0.6 percentage point per year from 2011-2020, using the capital cost weights:

Decision Year	Weight
2000	1.00
2005	0.85
2010	0.70
2015	0.67
2020	0.64
2025	0.64

Least cost geothermal sites result from the interaction of (a) baseline cost estimates for each site, (b) cost adjustment factors, and (c) increased costs as least-cost units are taken and higher cost sites are chosen. Therefore, in the DOE Goals case results, actual 2020 marginal capital costs by 2020 will not necessarily be lower than in the reference case but will instead show greater quantities of geothermal available and chosen before attaining the higher marginal costs.

In the DOE Goals case, geothermal capacity factors and fixed operations and maintenance costs (O&M) are unchanged from the reference case.

- Photovoltaics (Central Station): EIA assumes reduced capital and operations and maintenance costs, corresponding to utility scale flat plate "Thin Film" technology in the *Power Technologies Databook.* Performance is assumed unchanged from the reference case.

- Solar Thermal: In the DOE Goals case, EIA assumes increased initial capital costs compared to the Reference case, with significantly improved performance (as measured by capacity factor); in addition, operations and maintenance costs are reduced. This corresponds with the Central Receiver (Solar Power Tower) technology in the *Power Technologies Databook*, which incorporates, at additional cost, increasing levels of thermal energy storage in the forecast years. To reflect the improved dispatch characteristics of integrated thermal storage, the capacity credit for solar thermal technologies in this case is set equal to the regional capacity factor during the peak load period.

- Wind: EIA assumes reduced capital and operations and maintenance costs, with increased performance (as measured by capacity factor) in all wind classes. The maximum allowable capacity factor for high-wind speed locations (Class 6) is set to 58 percent, and the growth rate parameters are increased to allow the model to achieve capacity factor goals specified in the EE *Power Technologies Databook* for 2020. The *Power Technologies Databook* represents the capital cost of wind turbines for high-wind speed areas (Class 6) and low-wind speed areas (Class 4) improving at different rates. To represent a single capital cost for all wind installations within NEMS, the average *Power Technologies Databook* capital cost for Class 6, Class 5 (the mean of the Class 4 and Class 6 values), and Class 4 was calculated, as weighted by the best available wind class in each region. That is, if 4 of 13 regions had only Class 4 sites available, 7 regions had Class 5 sites available, and 2 regions had Class 6 sites available, Class 4 costs would be given a weight of 0.31, Class 5 costs a weight of 0.54, and Class 6 costs a weight of 0.15 in averaging the three costs. Fixed operation and maintenance costs are set to correspond to levels indicated in the *Power Technologies Databook*. Because costs are assumed to decline (or increase, in the case of Solar Thermal) based on the exogenous cost trajectory of the *Power Technologies Databook*, the normal learning function of the EMM does not apply to these capacity types. Thus cost targets are achieved regardless of actual market penetration.

Because costs are assumed to decline (or increase, in the case of Solar Thermal) based on the exogenous cost trajectory of the *Power Technologies Databook*, the normal learning function of the EMM does not apply to these capacity types. Thus, cost targets are achieved regardless of actual market penetration.

For both the High Renewables and DOE Goals cases, demand-side improvements are also assumed in the renewable energy technology portions of residential and commercial buildings, industrial processes, and refinery fuels modules. Details on these assumptions can be found in the corresponding sections of this report.

Supplemental and Floor Capacity Additions

In addition to capacity projected through the use of the EMM and RFM, including 6.7 gigawatts additional renewables in the electric power sector, 4.3 gigawatts added in the large end-use heat and power sector, and another 900 megawatts in the small end-use sector, *AEO2004* also includes 4,362 megawatts additional renewables generating capacity identified by EIA as entering service through 2025 (Supplemental Additions). Summarized in Table 75 and detailed in Table 76, some of the capacity represents mandated new capacity required by state laws, EIA estimates for expected new capacity under state-enacted renewable portfolio standards (RPS), estimates of winning bids in California's renewables funding program (Assembly Bill 1890), expected new capacity under known voluntary programs, such as "green marketing" efforts, and other publicly stated plans. The additions do not include off-grid or distributed photovoltaics or hydroelectric power.

Table 75. Post-2001 Supplemental Capacity Additions (Megawatts, Net Summer Capability)

Rationale	Biomass	Conventional Hydro-electric	Geothermal	Landfill Gas	Solar Thermal	Solar Photovoltaic	Wind	Total
Mandates[1]	47.5	0.0	0.0	9.0	0.0	0.0	921.7	969.2
RenewablePortfolio Standards	254.2	0.0	675.5	148.2	107.6	6.4	748.9	1940.8
California AB1890[2]	0.0	21.0	0.0	19.5	0.0	0.0	181.6	222.1
Other Reported Plans[3]	42.1	0.0	58.8	87.4	0.0	1.0	1040.1	1229.4
Total	343.8	21.0	734.3	255.1	107.6	7.4	2892.3	4361.5

[1]includes mandates and goals.

[2]Partially supported by funding under California Assembly Bill 1890.

[3]Other non mandated plans, including "green marketing" efforts and other activities known to EIA.

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting, based on publicly available information about specific projects, state renewable portfolio standards, and other plans.

For *AEO2004*, expectations for planned new capacity from state RPS are significantly reduced from expectations in *AEO2003* in recognition of some states' ongoing successful reliance on existing capacity or other measures (including exemptions) rather than on new additions. However, *AEO2004* also includes expectations of significantly more planned non-mandated new wind capacity than in *AEO2003*, ostensibly reflecting wind power's becoming increasingly competitive (albeit with incentives) and possible wind industry interest in marketing renewable energy credits in RPS, "green power," and other markets

In addition to the Supplemental Additions, projections also include 75.5 megawatts of central station thermal-electric and 332.5 megawatts central station photovoltaic (PV) generating capacity ("Floors") assumed by EIA to be installed for reasons in addition to least-cost electricity supply.

Table 76. Planned U.S. Central Station Generating Capacity Using Renewable Resources[1]

Technology	Plant Identification	Program[2]	State	Net Summer Capability (Megawatts)	On-Line Years
Biomass (Including mass-burn waste)	Gulf States Paper	Commercial	Alabama	14.8	2002
	Env. Forest Solutions	Commercial	Arizona	2.9	2003
	APS Biiomass I	RPS	Arizona	2.9	2004
	California RPS	RPS	California	87.1	2004-2008
	Connecticut RPS	RPS	Connecticut	47.5	2007-2009
	Jacobs Energy	Commercial	Illinois	0.6	2003
	Massachusetts (varioius)	RPS	Massachusetts	64.5	2003-2009
	Ware Cogeneration	Commercial	Massachusetts	7.8	2003
	Fibromin Poultry Litter	Mandate	Minnesota	47.5	2006
	New Jersey (various)	RPS	New Jersey	4.8	2004-2008
	Nevada (various)	RPS	Nevada	47.5	2006, 2009
	Aberdeen	Commercial	Washington	16.0	2003
Landfill Gas	California (various)	Commercial	California	19.6	2003
	California (various)	AB1890	California	19.5	2003-2005
	California (various)	RPS	California	87.1	2004-2008
	SW Alachua	Commercial	Florida	2.4	2003
	Illinois (various)	Commercial	Illinois	9.2	2003, 2004
	Bavarian Waste	Commercial	Kentucky	4.8	2003
	Plainville	Commercial	Massachusetts	5.3	2003
	Massachusetts (various)	RPS	Massachusetts	28.8	2003-2009
	Oaks	Commercial	Maryland	4.6	2003
	Grand Blanc	Commercial	Michigan	0.8	2003
	New Jersey (various)	RPS	New Jersey	4.8	2004-2008
	New York (various)	Commercial	New York	4.9	2003
	Palmetto.	Commercial	North Carolina	4.8	2003
	Texas (various)	Commercial	Texas	25.6	2003
	Texas (variouis)	RPS	Texas	21.8	2003
	Virginia (various)	Commercial	Virginia	5.5	2004
	Essex Junction	Commercial	Vermont	0.1	2003
	Wisconsin (various)	RPS	Wisconsin	5.8	2003, 2004
Geothermal	Salton Sea Unit 6	RPS	California	175.8	2006
	Four Mile Hill	Commercial	California	47.4	2007
	California (various)	RPS	California	219.1	2004-2008
	Animas	Commercial	New Mexico	1.0	2003
	Empire	Commercial	Nevada	1.0	2003
	Desert Peak II, III	RPS	Nevada	38.4	2005
	Hot Sulphur Springs	RPS	Nevada	23.8	2005
	Nevada (various)	RPS	Nevada	228.0	2003-2015

Table 76. Planned U.S. Central Station Generating Capacity Using Renewable Resources (Continued)

Technology	Plant Identification	Program[2]	State	Net Summer Capability (Megawatts)	On-Line Years
Conventional Hydroelectric	El Dorado Irrigation	AB1890	California	21.0	2003
Central Station Photovoltaics	Springerville (various)	RPS	Arizona	6.4	2003-2010
	Del Mar Fairgrounds	Commercial	California	1.0	2003
Solar Thermal	Saguaro	RPS	Arizona	1.0	2005
	Wellton-Mohawk	RPS	Arizona	33.3	2005
	California (various)	RPS	California	2.23	2004-2008
	Eldorado Solar Thermal	RPS	Nevada	47.5	2005
	Nevada RPS	RPS	Nevada	23.8	2011
Wind	Solano I Expansion	Commercial	California	10.0	2003
	High Winds LLC	AB1890	California	161.8	2003
	Windland II	AB1890	California	19.8	2003
	California (various)	RPS	California	338.7	2004-2008
	Gobblers Knob	Commercial	Colorado	162.0	2003
	Lamar Light	Commercial	Colorado	4.5	2004
	Lenox Wind	Commercial	Iowa	0.8	2003
	Wall Lake	Commercial	Iowa	0.7	2003
	Flying Cloud	Commercial	Iowa	43.5	2003
	Mendota Hills	Goal	Illinois	50.4	2003
	Massachusetts (various)	RPS	Massachusetts	68.2	2008-2009
	13 Small Sites	Mandate	Minnesota	24.7	2003
	Moraine	Mandate	Minnesota	51.0	2003
	Chanarambie Power	Mandate	Minnesota	85.5	2003
	Buffalo Ridge (Small)	Mandate	Minnesota	60.0	2004-2007
	Minnesota (Small)	Mandate	Minnesota	102.0	2008-2010
	FPL Austin	Mandate	Minnesota	100.0	2000
	EnXco Chandler Hills	Mandate	Minnesota	200.0	2007
	PPM Lincoln Countyu	Mandate	Minnesota	150.0	2007
	Xcel	Mandate	Minnesota	100.0	2010
	FPL Basin	Commercial	North Dakota	40.0	2003
	Dickey County	Commercial	North Dakota	21.0	2003
	Dakota I	Commeercial	North Dakota	19.5	2003
	New Jersey (various	RPS	New Jersey	20.0	2007-2008
	New Mexico Wind	Commercial	New Mexico	204.0	2003
	Nevada (various)	RPS	Nevada	60.0	2013-2015
	Bowling Green	Commrcial	Ohio	3.6	2003
	Okla. Wind Energy Ctr.	Commercial	Oklahoma	102.0	2003
	Blue Canyon	Commercial	Oklahoma	74.3	2003
	Apeasay	Commercial	oregon	0.03	2003
	Eurkus Combine Hills	Commercial	Oregon	41.0	2003
	FPL Stateline Expansion	Commeercial	Pennsylvania	40.0	2003

Table 76. Planned U.S. Central Station Generating Capacity Using Renewable Resources (Continued)

Technology	Plant Name	Program[2]	State	Net Summer Capacity (Megawatts)	On-Line Years
	Meyersdale	Commercial	Pennsylvania	30.0	2003
	Pocono Waymart	RPS (Goal)	Pennsylvania	64.5	2003
	Rosebud	Commercial	South Dakota	0.8	2003
	FPL SD Wind Energy	Conmercial	South Dakota	40.5	2003
	Sweetwater I	Commercial	Texas	37.5	2003
	Green Mtn, Brazos	RPS	Texas	160.0	2003
	Cielo Austin Energy	Commercial	Texas	25.0	2004
	Stateline Expansion II	Commercial	Washington	15.6	2003
	Nine Canyon Wind II	Commercial	Washington	15.6	2003
	Unita County Wind	Commercial	Wyoming	144.0	2003

[1]includes reported information and EIA estimates for goals, mandates, renewable portfolio standards (RPS), and California Assembly Bill 1890 required renewables.

[2]RPS" represents state renewable portfolio standards; "AB 1890" represents California Assembly Bill 1890; "Mandate" identifies other forms of identified state legal requirements; "Commercial" identifies other new capacity, not know by EIA to be required, including "green marketing" efforts and other voluntary programs and plans. Publicly available information does not always specify whether a project is mandated or a commercial build.

Note: Publicly available information does not always specify whether a project is mandated or a commercial build.

Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

Notes and Sources

[109]   For a comprehensive description of each submodule, see Energy Information Administration, Office of Integrated Analysis and Forecasting, Model Documentation, Renewable Fuels Module of the National Energy Modeling System, DOE/EIA-M069(2002), (Washington, DC, January 2002).

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