Electric Power Plants

This publication explains issues relevant to the production of electricity for the state of Wisconsin. It addresses basic power plant technologies and fuels, how the state's demand for reliable electricity is fulfilled, and the role the Public Service Commission of Wisconsin (PSC or Commission) plays in ensuring electrical energy needs are met.

Electricity Use and Production Patterns

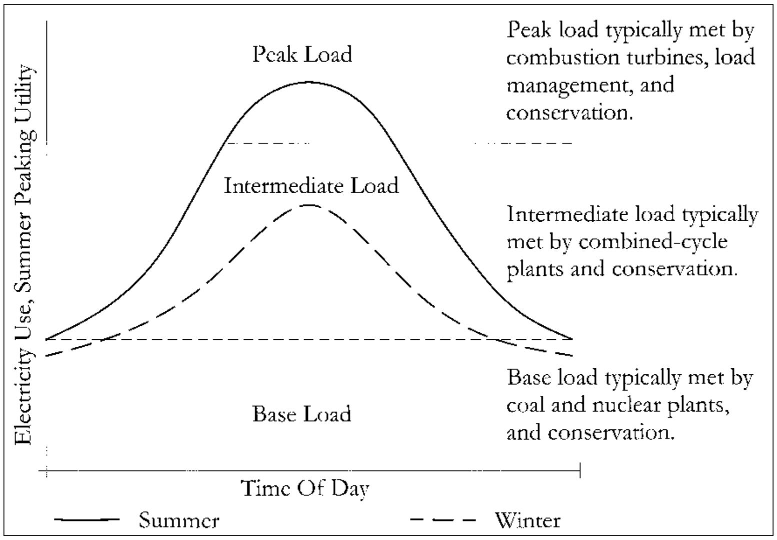
Consumers' demand for electricity changes daily and seasonally. A manufacturing plant assembly line starts and stops throughout the day and week. Air conditioners are turned on and off seasonally. During peak times, the largest amount of electricity is needed (peak load), but a "base load" of electricity is needed year-round. Because electricity cannot be stored easily, utilities must anticipate demand, even on the hottest summer day, and supply enough electricity to meet the demand. Consumption depends predominantly on the time of day and on the season. Utilities meet this demand with in-state power plants and by purchasing electricity from power plants in other states. The balancing of supply and demand is required in order to maintain a reliable electric system without a power interruption to the consumer.

Demand, or need for electricity is the total amount of electricity that consumers use at a particular time and is measured as electrical capacity in kilowatts. 1,000 kilowatts (kW) equals a megawatt (MW). One kW will turn on ten 100-watt light bulbs. Most home air conditioners require two kW to operate. A power plant rated at 1 MW will supply enough energy for 500 to 1,000 homes, simultaneously. Electricity is also needed to supply industrial, commercial, and agriculture portions of the economy. In 2007, Wisconsin had approximately 17,000 MW of generation for meeting the needs of its 5.6 million residents which is approximately three kW of capacity per resident.

Energy use, as opposed to **demand**, is the total amount of measured electricity that consumers use over time. Energy use is typically measured in kilowatt-hours (kWh). A kWh is equal to the energy of 1 kilowatt working for one hour. 1,000 kWh equals a megawatt-hour (MWh). In 2007, the average Wisconsin resident consumed 8,680 kWh of energy per year, according the Wisconsin State Energy Office. Focus on Energy reports that in most Wisconsin households, gas furnaces and water heaters use the most electricity (more than 50 percent), followed by lighting (approximately 8 percent).

Demand or energy use can be divided into "base load," "intermediate load," and "peak load" (see Figure 1). This helps to determine the type and quantity of power plants needed to produce the electricity at the right times. Different types of plants using different fuels or combination of fuels are needed to fulfill one or more of these three types of demand.

Figure 1 Typical Electric Load Curve



The capacity factor of a power plant is the actual output of a plant over a period of time compared to its potential output if it had operated at full nameplate capacity the entire time. It generally relates to how often a plant is run during a year and is expressed as a ratio or a percentage. For instance, new, more efficient coal-fired plants might have a capacity factor of 80 percent because they would be producing electricity 80 percent of the time, while older, less efficient coal-fired plants might have a capacity factor of 40 percent because they would be operated for only 40 percent of the time.

Base load plants provide a base level of electricity to the system and are typically large generating units. In Wisconsin, nuclear energy and coal has powered the state's base load plants. These plants often require a substantial financial investment to build (higher construction cost), but are less expensive to operate over longer periods of time. Base load plants operate almost continuously (approximately 70 to 80 percent of the time), except when down for scheduled maintenance, repairs, or unplanned outages. They take a long time to ramp back up to full capacity and have limited to no ability to vary their output of electricity.

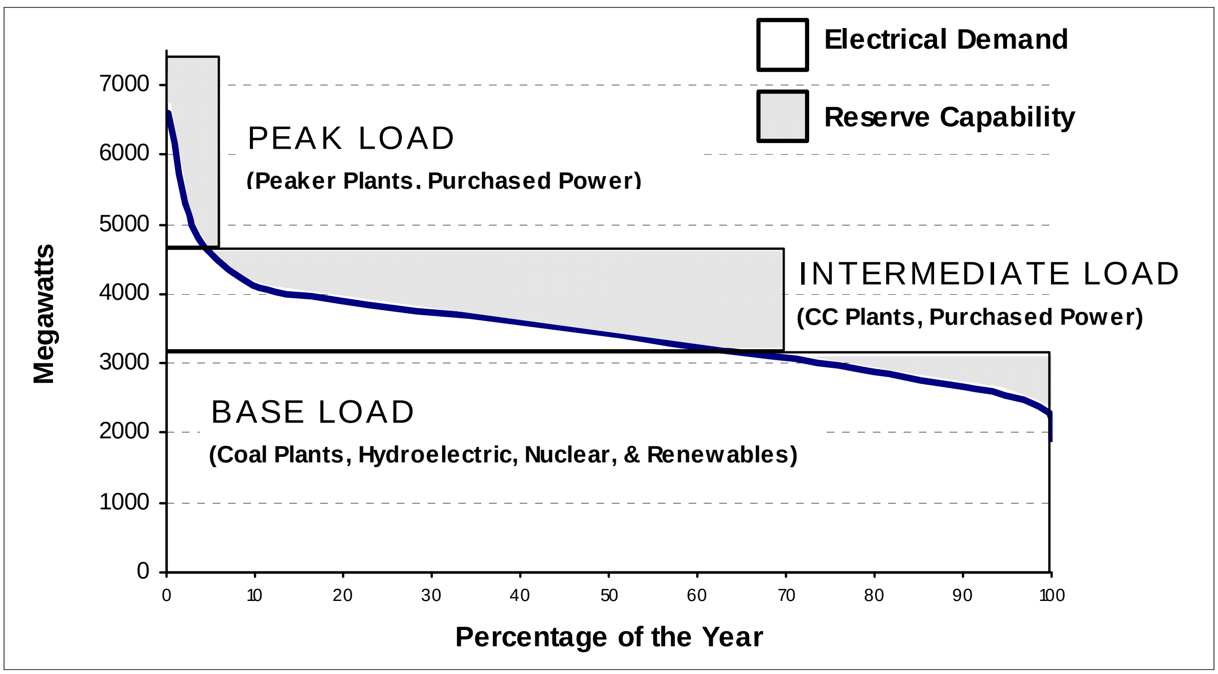
In contrast, plants that satisfy peak demand (peaker plants) are highly responsive to changes in electrical demand. They can be turned off and on relatively quickly. However, they typically operate less than 10 percent of the time. Peaker plants are most often natural gas combustion turbines and are relatively expensive to operate but cost less to build than base load or intermediate load plants.

The cost and flexibility of intermediate load plants fall in between those of base and peak load plants. These plants are designed more specifically for cyclic operation, or they can be older coal plants that have become too expensive to run as base load plants. They normally operate during times of elevated load demand, between 30 and 60 percent of the time. Compared to peaker plants, they are generally more efficient or utilize a cheaper fuel source and, therefore, cost less to operate.

A **reserve margin** is the electric generating capacity the PSC requires utilities to maintain beyond demand to handle unpredicted needs. It is the generation capacity above the annual peak energy requirement. The PSC currently requires utilities to maintain a 15 percent reserve margin in their electric generation planning.

The three boxes in Figure 2 represent the electric energy provided by a utility's power plants and purchases over the course of a year. Note how the largest box represents the base load plants, while the smallest represents the peak load plants. More energy is obtained from base load generation in any given year. As shown, the utility's electrical demand varies from a base load of approximately 3,000 MW to a peak load of over 6,000 MW. Capacity not used would be ready in reserve.

Figure 2 Electrical Plant Capacities and Types of Load Demand in a Year



Existing Power Generation in Wisconsin

Maintaining reliable and economical electrical generation for the state of Wisconsin depends on sufficient quantities of the right types of power plants operating together in a cost-effective manner. A diversity of energy resources also helps achieve stability of generation and prevents dependence upon a specific fuel. Figure 3 shows a map of major electric generation plants in Wisconsin.

Figure 3 Existing Major Electric Generation Plants

Wisconsin is heavily dependent on fossil fuels, especially coal, for electric power. Figure 4 shows the MW capacity by fuel type as of July 2007. Figure 5 shows the MWs of energy produced by fuel type for 2006. Almost 90 percent of Wisconsin's generating capacity comes from power plants that burn fossil fuels. In 2006, 64 percent of the electricity used in the state came from fossil fuel powered plants located in Wisconsin. In addition, Wisconsin imported 17 percent of its electricity from other states, some of which was also derived from fossil fuels. The difference between capacity and electricity used is more clearly apparent by examining the role of peak and intermediate load plants in the state which burn primarily natural gas. Approximately 40 percent of Wisconsin's non-coal capacity is provided by natural gas-burning plants. However, they actually produced less than 7 percent of Wisconsin's total electricity, in 2006, because they operate only during certain demand periods.

Nuclear power is also an important part of Wisconsin's current electric generation mix. Approximately 10 percent of Wisconsin's generating capacity was powered by nuclear energy in 2007. In 2006, 16 percent of the electricity used in the state came from Wisconsin nuclear power plants. In addition, some of the electricity imported into Wisconsin was generated at nuclear power plants in other states.

Electrical power can also be produced from sources such as hydropower, wind, and other renewable resources. Renewable resources currently provide only a small portion of Wisconsin's electricity (4.3 percent of capacity in 2007 and 2.8 percent of electricity used in 2006). Historically, most renewable energy technologies have not been cost effective when compared to carbon-based fuel technologies because of their high cost to build or lower utilization or capacity factors.

Figure 4 Capacity by Fuel Type as of July 2007 (MW)

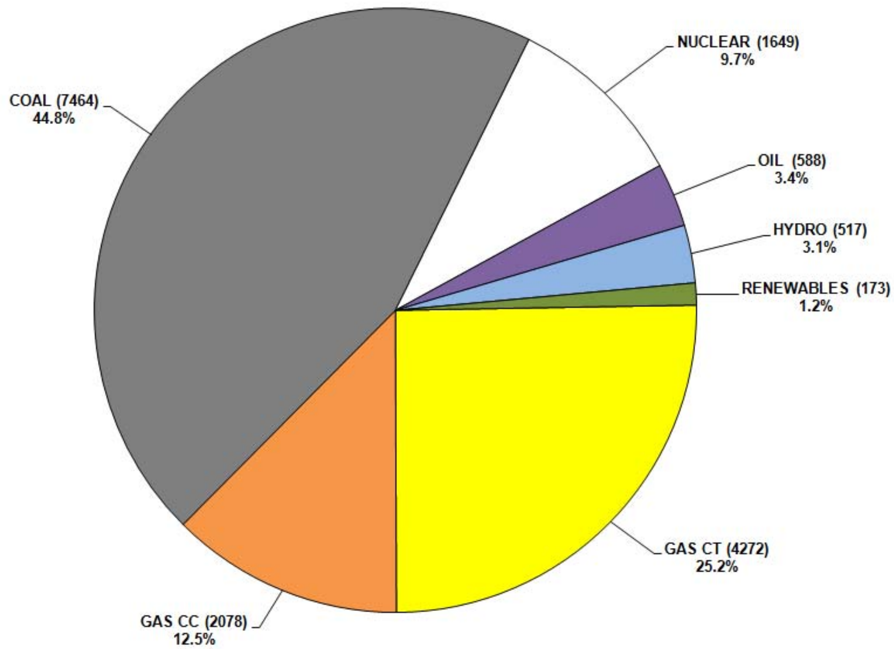
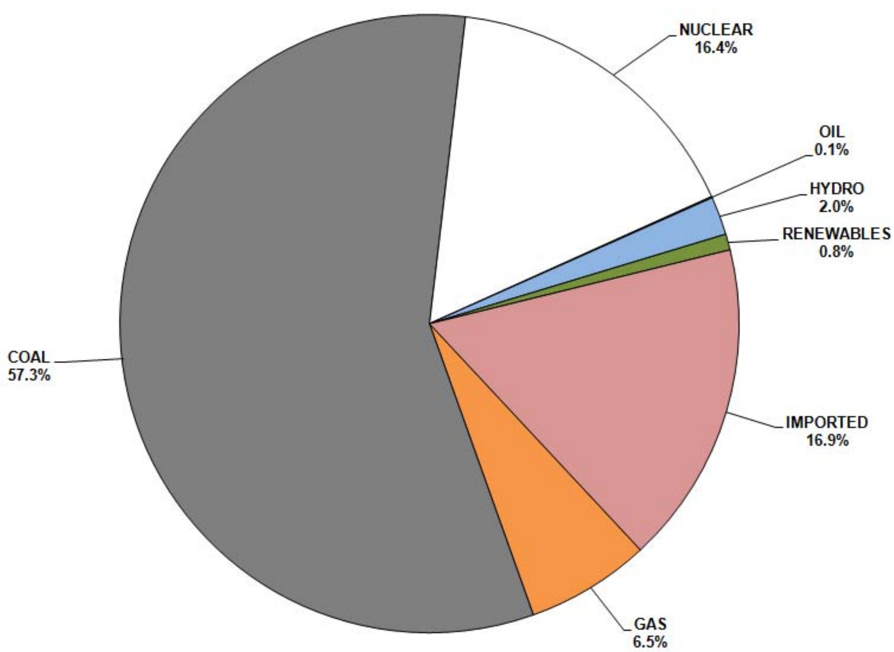


Figure 5 Actual Generation by Fuel in 2006 (MWh)



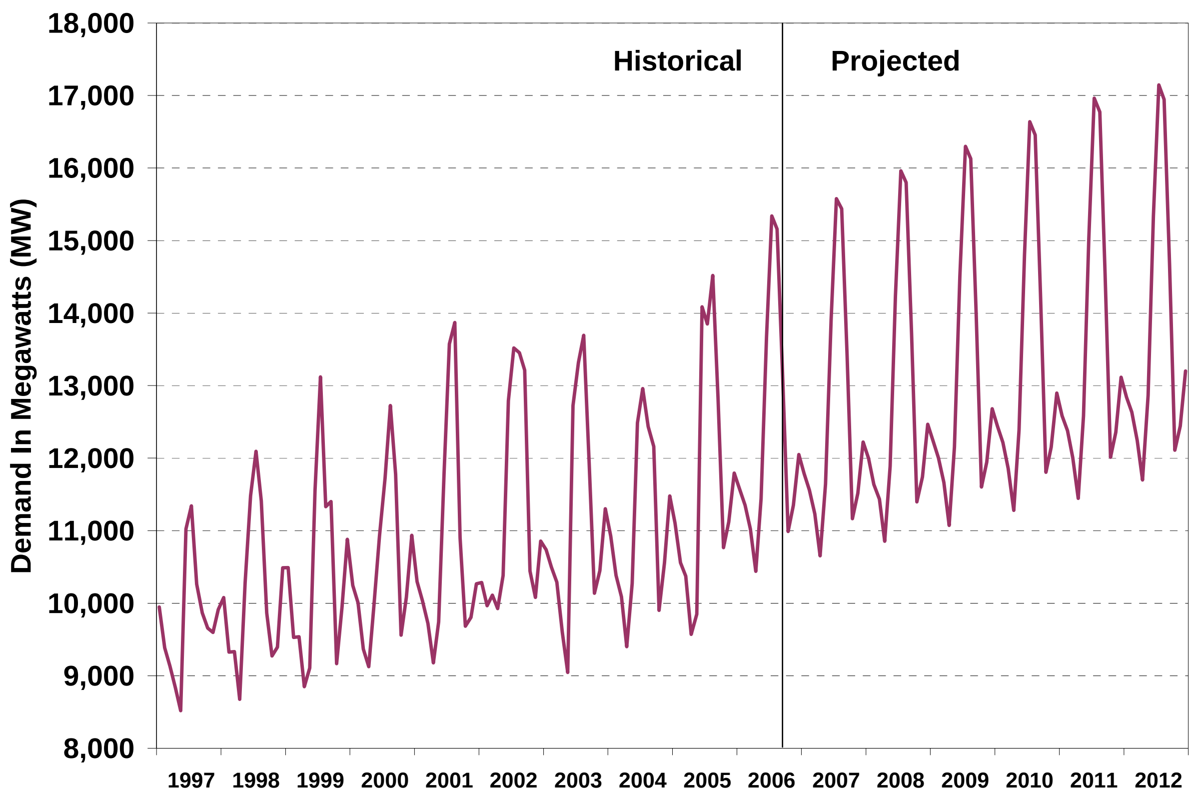
New Generation Plants in Wisconsin

Wisconsin is in a multi-year expansion period for electric generation that has expanded in-state generation capacity by over 5,000 MW through 2009. New wind generation will likely continue to add to this capacity.

The bulk of Wisconsin's electric generation is still produced by plants that are more than 25 years old. In 2002, the average date of construction of the largest generating plants was 1978. Some of Wisconsin's plants are over 40 years old. Older less efficient power plants are more costly to operate, have greater environmental impacts, and are likely to operate less in the future. Depending on several factors, they may be retired. If and when these plants are retired, new plants must be built to satisfy the state's growing demand for electricity.

Recently, Wisconsin's population has been increasing approximately 1 percent per year; and, electric demand is anticipated to increase approximately 1 percent per year, as well. Electricity usage is continuously monitored and could increase or decrease as a result of new customers, business growth, changes in consumer consumption, and changes in weather conditions. Figure 6 illustrates the historical and forecasted seasonal fluctuations in electrical demand. Peaks are shown to occur during the summer months with reduced demand occurring during the remainder of the year. Growth in electric demand must be met either by importing electricity or building new power generation plants.

Figure 6 Historical Monthly Peaks of Electrical Demand in Wisconsin since 1997 and Forecasted Monthly Peaks



Common Types of Power Plants

Different power plant fuels, technologies, and combinations of the two are used to generate electricity to meet specific load demands. Each technology and fuel has attributes that are both positive and negative. The majority of Wisconsin's electricity is generated through the use of coal combustion, natural gas combustion, and nuclear energy.

In the majority of power plants, electricity is generated by transforming chemical energy in the fuel into mechanical energy which turns a rotary engine or turbine. The turbine drives an electric generator that produces electricity.

Renewable energy sources such as wind are playing an increasing role in meeting the energy needs of the utilities. Like other states, Wisconsin has adopted renewable energy laws designed to increase the use of renewable fuels. Wisconsin's present law requires 10 percent of the state's energy to be supplied by renewable resources by the year 2015. This percentage may be raised in the near future.

Coal as Fuel

Coal power plants produce electricity by burning pulverized coal mixed with extremely hot air. Resulting high-pressure steam turns a turbine which drives an electric generator that produces the electricity. Coal plants have high construction costs, but relatively low fuel costs. Coal plants are base-load plants because they generate electricity continuously, except during maintenance and repairs. The design capacity of coal plants can range from small to very large (over 600 MW).

Although coal is inexpensive, burning coal releases significant levels of sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon dioxide (CO_2), particulate matter (PM), and mercury into the air. Environmental concerns surrounding the use of coal to produce energy include global warming, acid rain, regional and local health issues, and the impacts of coal transport and ash disposal. The goal of newer coal combustion technologies has been to reduce the environmental impacts. Significant community impacts can also result from the transport and handling of the coal (roads, trains, and barges), the need for a sizeable workforce, and a requirement for large quantities of cooling water.

Natural Gas as Fuel

Natural gas also can be burned in a boiler to heat water for steam that turns a steam turbine to generate electricity. The price of natural gas can be volatile which leads to increased electricity prices for consumers. The burning of natural gas releases fewer sulfur, mercury, and particulate air emissions than coal. Compared to similarly sized coal plants, natural gas plants release 50 percent less CO_2. The greatest emissions are NOx emissions which can be minimized with various control technologies.

There are two main natural gas power plant types combustion turbine and combined-cycle.

Combustion turbine (CT) plants typically burn natural gas. CT facilities burn fuel and compressed air to create a very hot gas. The hot gas turns a turbine connected to a generator to produce electricity. CTs have relatively low construction costs but are more expensive to operate. Their efficiency is typically low, approximately 28-30 percent. Because of these traits, CTs are commonly constructed as peak load plants and used only during periods of peak demand such as in the summer, when cooling appliances require high amounts of energy very quickly.

Combined-cycle (CC) plants include CTs as part of their overall technology. However, a CC plant is more efficient than a CT plant because the rejected hot gases of the CT are not vented to the atmosphere like in a CT plant, but are used to produce steam for a second electric generator. By combining the gas and steam cycles, CC power plants convert approximately 40 to 50 percent of fuel energy into electrical energy. Construction and operating costs are between those of coal plants and those of CTs. CC power is commonly used to run intermediate load plants, operating more hours than a peaking plant.

Nuclear Power

Nuclear plants are fueled by the splitting of uranium atoms under high temperatures. The dividing atoms create heated water and steam that turn a turbine that drives an electric generator. Like most coal plants, they are used to satisfy base load demand because they operate continuously. Nuclear plants are expensive to build but are the most inexpensive source of electricity overall to operate.

Air emissions are not an issue with nuclear plants. The main concern is safety involving the storage and management of highly radioactive nuclear fuel. At this time, no new nuclear plants may be built in Wisconsin. As per Wis. Stat. § 196.493, the Commission cannot issue a Certificate of Public Convenience and Necessity (CPCN) for a new nuclear plant until a federally licensed facility is built with adequate capacity to dispose of the high-level nuclear waste from all the nuclear power plants operating in Wisconsin. Currently, the Federal Department of Energy is in the process of preparing an application to obtain a Nuclear Regulatory Commission (NRC) license to proceed with construction of a long-term repository at Yucca Mountain in Nevada.

As a temporary alternative, the NRC has authorized the use of on-site, dry cask storage of spent fuel. Fuel removed from the reactor is placed in a pool of water to remove the heat from the fuel. The spent fuel pools at Wisconsin's nuclear facilities were sized to store spent fuel for only five to seven years, at which point the new fuel was to be shipped off-site to a long-term repository. Dry casks are built to store spent fuel that can be removed from the spent fuel pools in the plants. The casks are stored on a special pad out-of-doors. The casks are designed to hold fuel until the long-term repository is available.

Power Plants Using Renewable and Recycled Resources

Renewable resources generate electricity without using conventional fuels such as coal, natural gas, oil, and uranium. Renewable resource generation plants can be small and dispersed throughout the electric system or can be large and centralized. They can burn renewable fuels or avoid combustion altogether. Four types of renewable energy plants are described below.

Hydroelectric Power

Hydroelectric plants use falling water to turn a turbine that drives a generator to produce electricity. Sizes range from large, utility-owned dams on major rivers to small locally-owned dams on small streams. Hydroelectric power plants have high construction costs, but are long-lived with very low energy costs. Plant capacity can range from a few kW to hundreds of MW. They operate typically as base load units because they run continuously. Small hydropower plants exist along the Wisconsin, Chippewa, Flambeau, and Wolf Rivers, among others. This renewable resource appears fully developed at this time.

Hydroelectric power plants produce no air emissions. Their main environmental impacts are related to the flooding of the landscape upstream, changing flows within the stream banks downstream, dividing the stream into separated pools, and damaging or killing young fish. The barriers created by dams constrain fish and other species to specific pools, impacting their ability to survive and reproduce. The turbines have the potential to damage or kill young fish if they are not filtered aside on the upstream side of the dam.

Wind Power

Wind energy is converted to electricity when wind passes by blades mounted on a rotating shaft. As the wind moves the blades, the rotation of the shaft turns a generator that produces electricity. Three factors affect wind machine power, the length and design of the blades, air density, and wind velocity. Longer blades produce more power output. Cold air is denser, which means it has more force, or ability to turn the blades (approximately 20 percent more). In general, as elevations increase, wind turbines will encounter greater wind velocities.

Current wind plant sizes range from small-scale wind machines (50 kW) to large-scale "wind farms" (over 100 MW). The current typical capacity of individual turbines is approximately 1.5MW. Wind power has high construction costs but low operating costs. Turbines operate approximately 90 percent of the time, but have an effective capacity factor of only 20 to 35 percent, depending on location. Wind power is not affected by fuel prices, but is dependent on constant high wind speeds. Without constant winds, predictable power generation becomes an issue when comparing this technology to other sources of electrical generation. Wind power has low environmental impacts (no air or water emissions), but concerns have been raised over aesthetics, noise, shadow flicker, and mortality to birds and bats. Additionally, transmission lines often need to be built to connect the large rural wind farms to the electrical grid and load centers.

Solar - Photovoltaic Power

Photovoltaic (PV) cells convert sunlight directly into electricity. PV panels, consisting of multiple PV cells can be used in small groups on rooftops or as part of a system for producing large amounts of electrical power. The amount of energy produced by a PV system depends upon the amount of sunlight available. The intensity of sunlight varies by season of the year, time of day, and the degree of cloudiness. Use of solar power in Wisconsin may be limited by our relatively large number of overcast days.

Currently, PV-generated power is less expensive than conventional power technologies where the load is small or the area is too difficult to serve by electric utilities. The initial construction costs of solar power may be very high, but the production costs are very low. Recent technological breakthroughs may further reduce this cost. Compared to traditional methods of electric generation, solar power has few environmental concerns. The primary impacts for larger systems are related to land use and aesthetics and may be resolved through appropriate siting.

Biomass Power

Biomass power plants burn recently-grown plant materials as opposed to fossil fuels. Solid biomass can be burned like coal to produce steam. It can also be gasified and burned like natural gas. More common biomass fuels include waste wood and dedicated crops. Biogas also is a form of biomass, consisting of methane and other combustible gases that can be used in a conventional engine or gas turbine to turn an electric generator. Biogas can be generated from on-farm anaerobic manure digestion, landfill gas collection, and wastewater treatment plant gas collection.

Air emissions from biomass combustion are generally less than those from coal or natural gas. Like coal or natural gas combustion, biomass combustion produces CO2, an important greenhouse gas.

Biomass can also emit lower amounts of NOx, produce less ash than coal, and release significantly less toxic material such as mercury. A closed methane digestion system that burns biogas on a farm or landfill would reduce the amount of methane (a greenhouse gas) lost to the atmosphere. However, it would release emissions similar to those released by natural gas-burning CT or CC facilities, but in smaller quantities. Environmental impacts vary with the type of biomass fuel used, although most fuels will have impacts related to transport (truck or rail) and storage. Biomass technologies are continuing to improve.

The Role of the Public Service Commission

The PSC of Wisconsin has primary authority over most power plant construction. The PSC is a state agency comprised of three commissioners and staff. The three commissioners act as a decision-making body. The PSC determines whether or not projects can be built, where they should be built, and under what conditions. Construction of any power plant of 100 MW or more requires a Certificate of Public Convenience and Necessity (CPCN) from the PSC. Utility projects 100 MW or less requires a Certificate of Authority (CA). The Department of Natural Resources (DNR) is responsible for issuing permits and approvals for air emissions, dredging, water discharges, and waste disposal. The DNR also reviews the CPCN application for impacts to wetlands, rivers, protected habitats, and threatened/endangered species and assists with PSC staff analyses. Other state and federal agencies are responsible for enforcing additional regulations.

The PSC considers many aspects of a power plant application. These considerations include the cost and need for the proposed plants, its location, its community and environmental impacts, and a review of project alternatives. Public involvement is solicited in the form of meetings, hearings, and public comment periods. For larger projects, an environmental impact statement (EIS) is prepared by the PSC or jointly with the DNR. The public's comments and testimony aid the Commission in making a decision that either approves, denies, or modifies the power plant application. The PSC has the authority to order additional environmental protections or mitigation measures.

The Public Service Commission of Wisconsin is an independent state agency that oversees more than 1,100 Wisconsin public utilities that provide natural gas, electricity, heat, steam, water and telecommunication services.

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