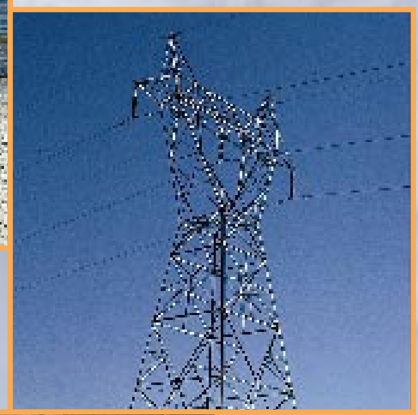
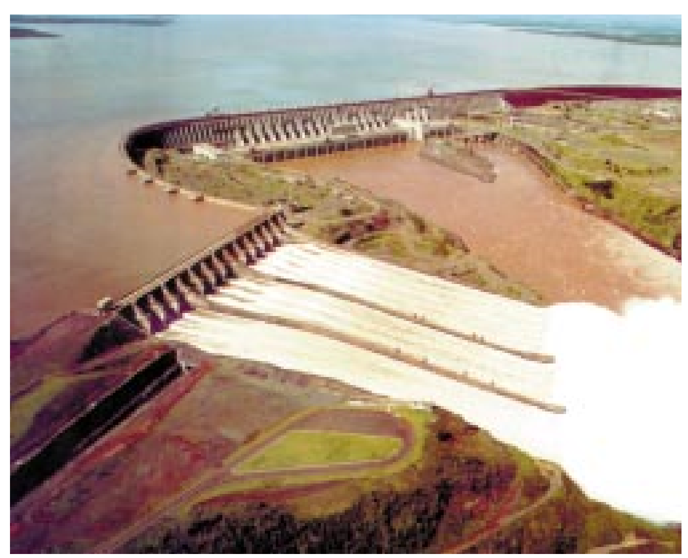
HYDROPOWER

A KEY TO PROSPERITY IN THE GROWING WORLD



Hydropower supplies nearly one-fifth of the world's electricity, second in importance only to fossil fuel-generated electricity (coal, oil, and gas). Hydroelectric power has supplied industry, agriculture, and homeowners with affordable electricity for over 100 years and has been directly linked to prosperity and a higher standard of living worldwide. Classified as a clean, renewable energy source, hydropower reduces the net production of greenhouse gases by displacing other forms of power generation. In contrast to most other renewable sources of electricity, hydropower can supply a significant portion of the world's electricity needs.

- Hydropower is a mature technology, with known costs and benefits.
- Hydropower plants are the most efficient of the major types of power plants.
- Hydropower facilities can respond almost instantaneously to changing electricity demand.
- Hydropower projects provide crucial water management, flood control, and recreational benefits.
- Hydropower emits minimal greenhouse gases and other chemical pollutants.
- Hydropower can be produced as long as the rain falls and rivers flow — it will never run out and does not deplete our natural resources.



Itaipu Dam, Brazil/Paraguay border

FACT

The Itaipu project of Brazil and Paraguay, shown to the right, has attracted more than 9 million visitors from over 50 countries since it was completed in 1983. Its powerhouse produces 12,600 megawatts (MW), almost enough to power all of California.

2000 B.C. Hydropower used by the Greeks to turn water wheels for grinding wheat

1880 Michigan's Grand Rapids Electric Light and Power Company generating electricity with a dynamo belted to a water turbine at the Wolverine Chair Factory, lit up 16 brush-arc lamps

1886 About 45 water-powered electric plants (waterwheels) in Canada and the U.S.

1895 The first hydroelectric generator at Niagara Falls, New York, produces alternating current

1902 First Aswan Dam completed on the Nile River

1910 The Vemork Hydropower Plant in Norway started producing electricity — it was at the time the world's largest

1932 The Dnepr Dam completed — one of the earliest major dams in the Soviet Union

1933 Construction of the Grand Coulee Dam began — it still has more generating capacity than any dam in North America

1940 40% of all electricity generating capacity in the U.S. is provided by hydropower

1954 Owens Falls Dam, completed in Uganda, created the world's largest capacity reservoir

1960 Construction on the Aswan High Dam began — the largest construction project on the Nile River (completed in 1971)

1966 The world's first dam to furnish hydroelectric power from ocean tides built on the Rance River, France

1971 Itaipu Dam construction begins between Brazil and Paraguay — the world's largest operating hydroelectric plant

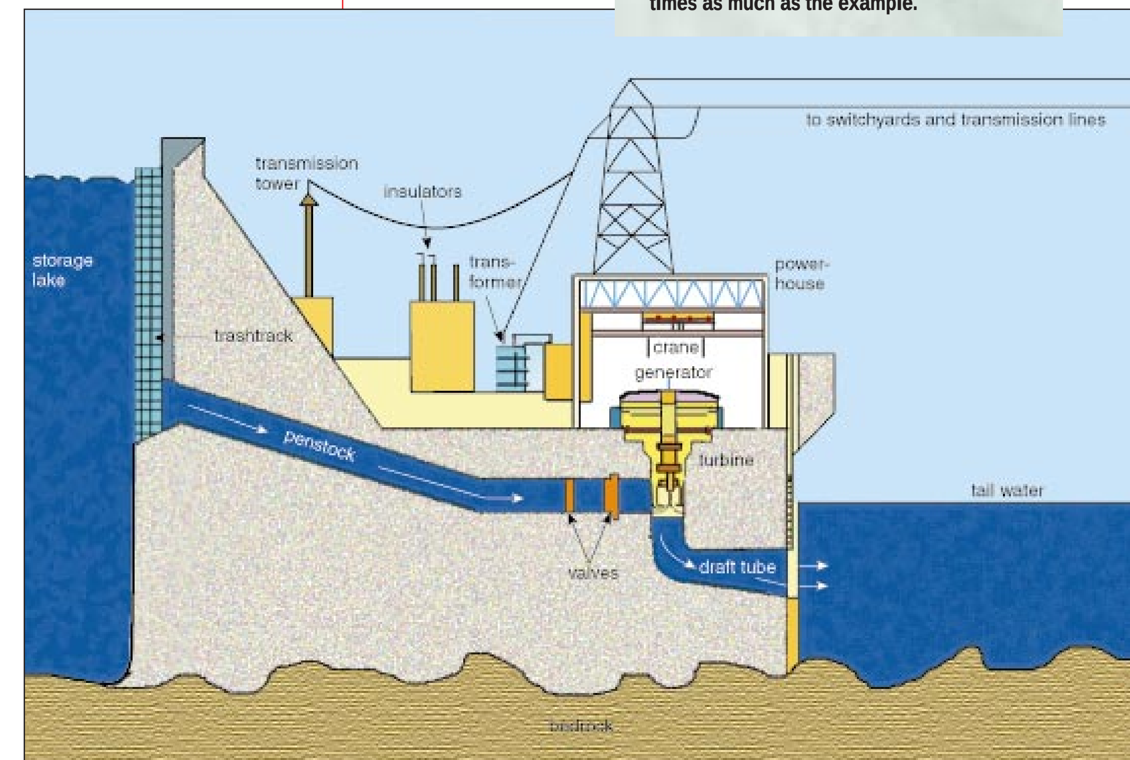
1976 Tarbela Dam in Pakistan completed — the world's largest volume dam outside the U.S.

1986 Worldwide hydropower generation increasing at 2.3% annually (1986 to present)

1993 Approximately 20% of all electricity in the world (2,470 billion kWh) is generated by hydropower

FACT

The power produced by water depends on the flow and the head (height of the fall). A flow of 3 cubic meters per second (100 cubic feet per second) falling 3 meters (10 feet) will produce 113 horsepower. For comparison, the Itaipu Dam has the capacity of nearly 17 million horsepower, or 150,000 times as much as the example.



Hydroelectric generation follows a simple concept: water falling under the force of gravity turns the blades of a turbine, which is connected to a generator *(see diagram above)*. Electricity generated by the spinning turbine passes through a transformer and out to transmission lines supplying factories, shops, farms, and homes. The principle and the technique for generating electricity from hydropower remains the same regardless of the size of the project, and plants can be tailor-made to fit a community or a country. For example, a million people in Nepal benefit from "mini/micro" scale hydropower (<2MW-sized) because their rural communities cannot easily gain access to the national grid system. In contrast, the massive Itaipu plant *(shown on the previous page)* supplies 78% of the entire electricity demand in Paraguay and 25% of the demand in Brazil.

HISTORICAL PERSPECTIVES ON HYDROPOWER

The Egyptians and Greeks harnessed the power of river currents to turn wheels and grind grain into flour before 2000 B.C. Romans constructed paddle wheels that turned with the riverflow and lifted water to troughs built above the height of the river. In the Middle Ages, more efficient waterwheels, which used a millrace to shoot water over the top blades of the wheel and produced more power, were built for milling grain.

The first modern turbine design was developed in 1849 by James B. Francis, who built an enclosed waterwheel with adjustable blades or vanes. The vanes deflect the water, and the reaction spins the turbine; the angle of the vanes is changed to increase efficiency. The first hydroelectric generator built at Niagara Falls, New York, in 1895 produced alternating current. The installation at Niagara Falls set the standard for other hydroelectric power installations worldwide.

Waterwheel, Mystic Connecticut

FACT

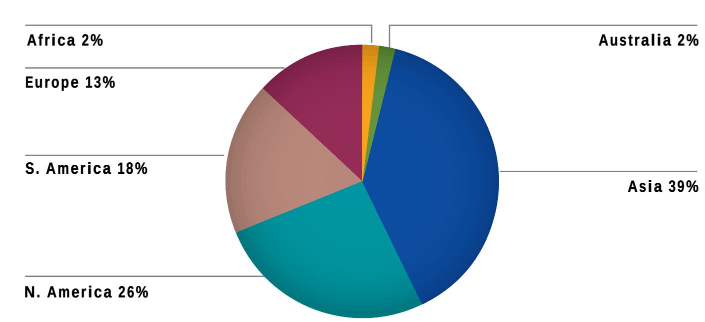
Hydropower supplies virtually all (99.6%) of Norway's electricity. Additional capacity is under construction, and more is planned for the future. Twenty-five countries worldwide depend on hydropower for 90% or more of their electricity needs.

WORLDWIDE HYDROPOWER DEVELOPMENT AND CAPACITY

During the twentieth century, Europe and North America developed much of their hydropower potential. The development of hydropower in these areas accelerated economic growth and contributed to high levels of prosperity. Asia's development of hydropower, particularly in China, eventually exceeded that of North America and Europe in terms of total installed capacity. Asia, South America, and Africa still have vast, untapped reserves of potential hydropower.

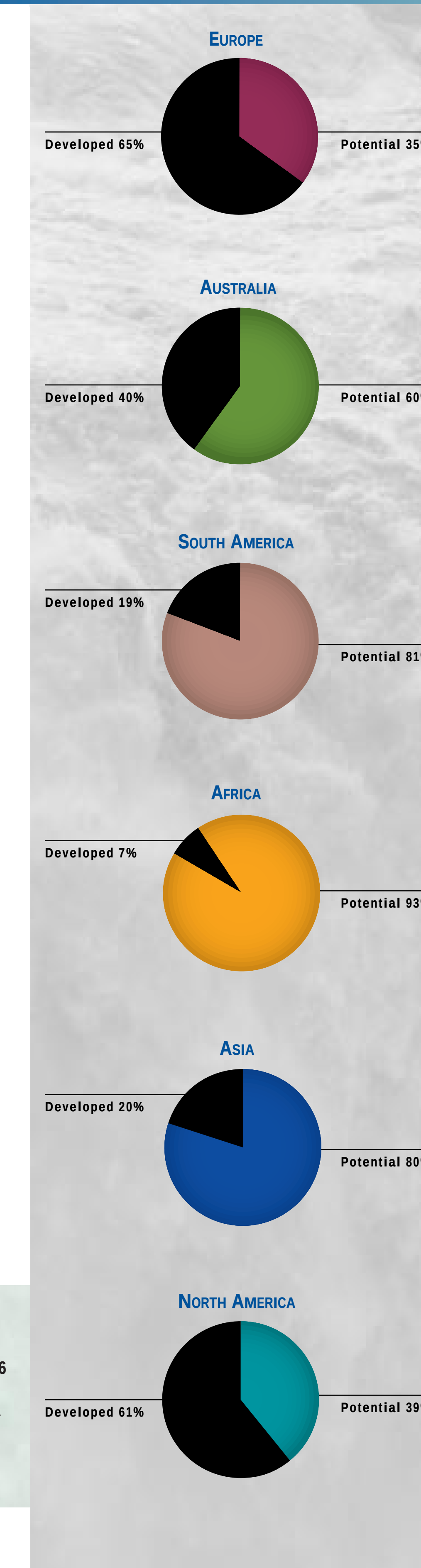
As these pie charts indicate, Europe and North America have already developed more than 60% of their hydropower. In contrast, emerging economies in Asia, South America, and Africa currently utilize only a small portion of their potential hydropower. Africa, for example, has developed only 7% of its potential hydropower resources.

Percentage of current electricity generated by hydropower



FACT

The generation of hydroelectric power worldwide increased by 458 billion kWh between 1986 and 1995, or an average annual growth rate of 2.3%. Canada, the U.S., Brazil, Russia, and China were the five largest producers of hydroelectric power in 1995, accounting for 51% of the world total.



Because of its ability to provide an almost instantaneous response to heavy electricity demand simply by releasing more water, hydropower can augment other energy sources, such as solar and wind energy, that may require supplemental electricity generation. Large-scale displacement of fossil fuel generation by large hydropower projects also significantly reduces greenhouse gas emissions. Large hydropower projects can also foster economic prosperity for millions of people. However, the creation of large reservoirs and infrastructures accompanying large-scale hydropower projects may not fit the priorities of local communities.

Xiuwen Hydropower Station, China

FACT

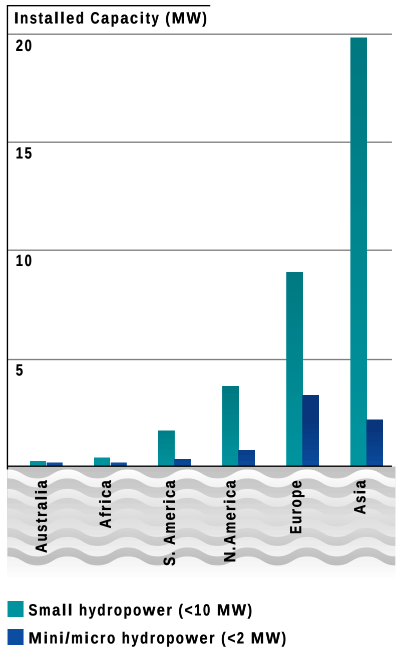
China has numerous hydropower dams, such as the Xiuwen Hydropower Station located on the Maotiaohe River. Like the rest of the Asian continent, China has vast untapped hydropower potential.

Small, locally driven hydropower projects often provide the best means for developing nations to increase access to electricity and improve living standards without incurring local environmental disruption. Many regions, particularly Asia, Europe, and North America, have developed substantial hydroelectric resources with small plants of <10 MW capacity. Developing nations and rural areas possess tremendous potential for small hydropower projects that are quick to plan and build, use low-cost devices and materials, and have minimal local environmental impact.

FACT

Vietnam has approximately 2,500 "micro" hydro-electric power stations (<100kW). These plants serve irrigation and drainage needs and produce electricity for about 200,000 households. The Republic of Guinea has identified 150 "mini" (<2 MW) and "micro" hydro sites; Nigeria plans to develop 700 MW of capacity at 236 different projects.

Small and Mini/Micro-Scale Hydropower



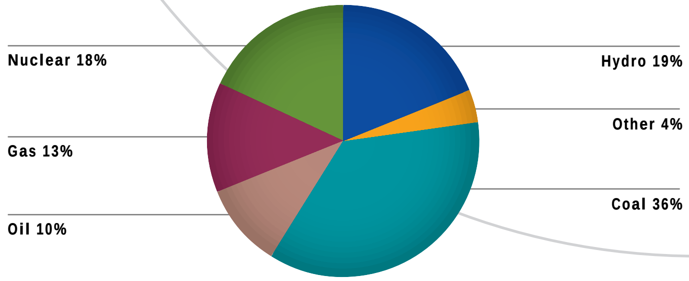
HOW WILL HYDROPOWER MEET THE NEEDS OF A GROWING WORLD?

Not only does hydropower supply one-fifth of the world's electricity supply, it far exceeds the capacity of any other renewable energy resource.

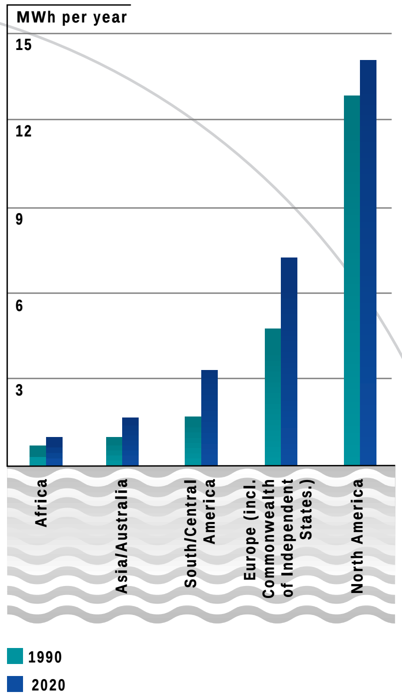
- Hydropower produced 22 times more electricity world-wide in 1995 than geothermal, solar, and wind power combined.
- Hydropower is even more important for emerging economies: hydropower produced 31% of the electricity in developing nations in 1987.

Despite the dominance of fossil fuels in terms of total electricity generated worldwide *(shown by the pie chart below)*, more than 60 countries currently use hydroelectricity for 50% or more of their electricity needs. Most of the installed hydroelectric capacity resides in North America, Brazil, Russia, China, and Europe. Most of the potential hydropower, however, exists in less developed regions in Asia, South and Central America, and Africa.

World Electricity Supply



Electricity Demand Per Capita



Demand for electricity worldwide is expected to increase as emerging economies modernize and developed nations continue along paths of economic growth and prosperity. Some forecasters predict total electricity demand in the world will double between 1990 and 2020, reflecting a growth rate of slightly more than 2% per year over 30 years. As shown in the graph above, tremendous differences in electricity demand per capita exist among regions of the world. The growth rates of per capita electricity demand are expected to be greatest in South and Central America, Asia, and Africa. Fortunately, the potential hydropower available to generate electricity in those rapidly growing regions of the world is also the greatest.

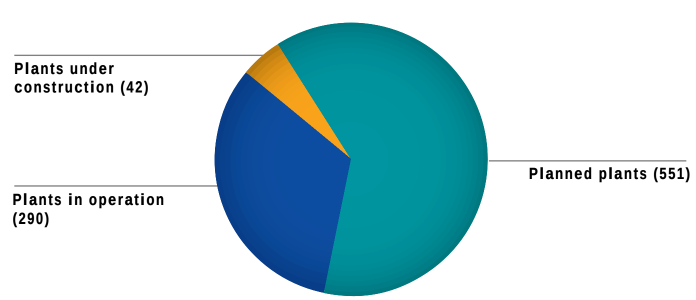
Numappara Pumped Storage Plant, Japan

FACT

Japan currently has 38 pumped storage plants in operation, including the Numappara Pumped Storage Plant shown above. In addition, it has 8 under construction and 440 potential new sites.

A significant and growing portion of the hydroelectric capacity worldwide is devoted to pumped storage facilities that are designed solely to provide power during peak loads. Pumped storage facilities offer significant flexibility to supplement other electricity supplies. During off-peak hours, such as the early morning hours, excess electricity produced by conventional power plants is used to pump water from lower- to higher-level reservoirs. During periods of highest demand, the water is released from the upper reservoir through turbines to generate electricity. The combined use of pumped storage facilities with other types of electricity generation creates large cost savings through more efficient utilization of base-load plants. As the chart below illustrates, the number of pumped storage plants planned and under construction is more than double the number of plants currently operating.

Worldwide Use of Pumped Storage Plants



THE IMPORTANCE OF HYDROPOWER ADVANTAGES & DISADVANTAGES

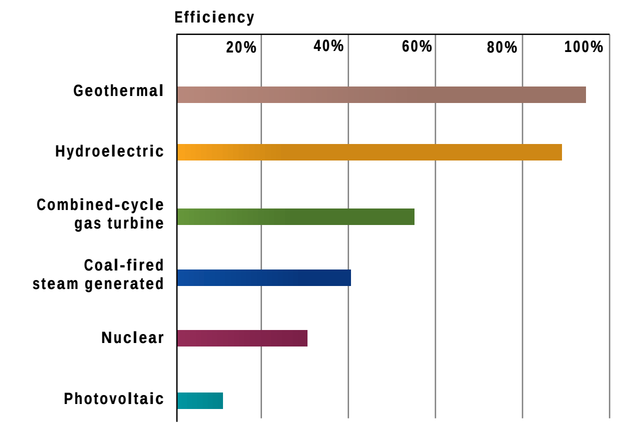
FACT

A recent agreement among industrialized nations signed in Kyoto, Japan, will require nations to limit greenhouse gas emissions below 1990 levels over the next 10 to 15 years. As demand for electricity grows, the agreement will place enormous pressure on countries to maintain economic growth and prosperity by seeking other, nonpolluting sources of electricity generation.

Hydropower generation is much better suited to meet demands for peak loads than are steam-electric units. The ability to start quickly and adjust to rapid changes in load adjustments make hydroelectric plants particularly suitable for responding to peak loads. If operating at less than full load, hydroelectric power plants can often respond very rapidly to sudden demands for increased power.

Operating hydropower plants emit minimal amounts of airborne pollutants. As countries grapple with reducing emissions of greenhouse gases, hydropower can provide a significant energy alternative and displace other, more polluting forms of electricity generation. Other positive influences of hydropower generation include flood control; navigational improvements on waterways; and vast recreational opportunities for boating, swimming, fishing, and wildlife enthusiasts.

Comparing Efficiencies of Electricity Generation



Hydropower has several advantages over most other sources of electrical power, including a high level of reliability, very low operating costs, and the ability to easily adjust to load changes. Also, hydropower does not contribute to air pollution, and reservoirs can also be used for recreation, water supply, and flood control. However, like all electricity options, hydropower involves trade-offs. Hydropower dams can cause environmental problems, such as modification of fish habitat through altering of stream and lake levels. While careful planning and operation of hydropower facilities can minimize environmental damage, environmental costs may prohibit the development of hydropower in some areas.

Advantages of Hydropower	Disadvantages of Hydropower
Renewable resource	High initial cost of facilities
Fuel Saver	Precipitation dependent
Flexible to meet load	Changes in stream flows
Efficient	Inundation of land and wildlife habitat
Reliable and durable	Loss or modification of fish habitat
Low operation and maintenance costs	Fish entrainment and passage restriction
Proven Technology	Changes in reservoir and stream water quality
No Atmospheric pollutants	

FACT

A 1% improvement in the efficiency of existing U.S. power plants will produce enough power to supply 283,000 households, saving the energy equivalent of more than 5 million barrels of oil per year.

HYDROPOWER: ELECTRICITY AND MORE

Hydropower projects produce prime outdoor recreation opportunities. Storage reservoirs create areas for boating, fishing, water skiing, and swimming. Reaches of the river below dams also provide fishing, rafting, canoeing, and other stream-related recreation. Lands surrounding hydropower projects often offer additional benefits, including camping, picnicking, hiking, and environmental and cultural resources education and interpretation.

Hoover Dam, U.S.A.

- Hydropower is the most important source of renewable energy in the world.
- Hydropower has furnished electricity to the world for over a century, making it a proven, reliable technology.
- Some of the oldest hydropower projects have supplied electricity for more than 100 years and are still going strong.
- Hydroelectric power still represents one of the most inexpensive ways to generate power.
- Small, mini-, and micro-scale hydropower projects can be tailor-made to provide power and minimize environmental and social impacts.
- Most importantly, all hydropower projects are clean, renewable sources of energy.

GLOSSARY

ALTERNATING CURRENT	An electrical current in which the electrons flow in alternate directions. For example, in North American electrical grids, the flow reversal is governed at 60 cycles per second (hertz).
BASELOAD	In a demand sense, a load that varies only slightly in level over a specified time period. In a supply sense, a plant that operates most efficiently at a relatively constant level of generation.
CAPACITY	The maximum sustainable amount of power that can be produced by a generator or carried by a transmission facility at any instant.
COMBINED CYCLE	The combination of a gas turbine and steam turbine in an electric generating plant. The waste heat from the first turbine cycle provides the heat energy for the second turbine cycle.
DIRECT CURRENT	An electrical current in which the electrons flow continuously in one direction. Direct current is used in specialized applications in commercial electricity generation, transmission, and distribution systems.
DISCHARGE	The volume of water flowing at a given time, usually expressed in cubic meters/feet per second.
GENERATION	The act or process of producing electrical energy from other forms of energy. Also refers to the amount of electrical energy so produced.
GENERATOR	A machine that converts mechanical energy into electrical energy.
HEAD	The vertical height of water in a reservoir above the turbine. The more head, the more gravitational force that is exerted on the turbine, and the more power that can be produced.
HYDROELECTRIC	The production of electrical power through use of the gravitational force of falling water.
KILOWATT (kW)	A unit of electrical power equal to 1,000 watts (equivalent to about 1.3 horsepower).
KILOWATT-HOUR (kWh)	A basic unit of electrical energy equivalent to one kilowatt of power used for one hour.
LOAD	The amount of electrical power or energy delivered or required at any specified point or points on a system.
MEGAWATT (MW)	A megawatt is one million watts, a measure of electrical power.
MEGAWATT-HOUR (MWh)	A unit of electrical energy equivalent to one megawatt of power used for one hour. Gigawatt-hour (GWh) and Terawatt-hour (TWh) are one billion and one trillion watts of power used for one hour.
OFFPEAK HOURS	Period of relatively low demand for electrical energy, as specified by the supplier (such as the middle of the night).
PEAK LOAD	The maximum electricity demand in a stated period of time. It may be the maximum instantaneous load or the maximum average load within a designated period of time.
PHOTOVOLTAIC	The direct conversion of sunlight to electrical energy through the effects of solar radiation on semiconductor materials.
PUMPED STORAGE PLANT	A hydroelectric power plant that generates electrical energy to meet peak load by using water pumped into a storage reservoir during off-peak periods.
RENEWABLE RESOURCE	A power source that is continuously or cyclically renewed by nature. A resource that uses solar, wind, hydro, geothermal, biomass, or similar sources of energy.
RESERVE CAPACITY	Generating capacity used to meet unanticipated demands for power or to generate power in the event normal generating resources are not available.
RESERVOIR STORAGE	The volume of water in a reservoir at a given time.
STORAGE RESERVOIRS	Reservoirs that have space for retaining water from springtime snow melts. Retained water is released as necessary for multiple uses — power production, fish passage, irrigation, and navigation.
THERMAL POWER PLANT	A facility that uses heat to power an electric generator. The heat may be supplied by burning coal, oil, natural gas, biomass or other fuel; by nuclear fission; or by solar or geothermal sources.
TRANSMISSION GRID	An interconnected system of transmission lines and associated equipment for the transfer of electrical energy in bulk between points of supply and points of demand.
TURBINE	Machinery that converts kinetic energy of a moving fluid, such as falling water, to mechanical power, which is then converted to electrical power by an attached generator.
WATT	Basic unit of electrical power.

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