15.12: Energy from Wind and Water

Moving fluids are rich sources of energy that can be tapped, usually by turbines linked to electrical generators. Moving water and blowing winds are energy-rich fluids that have some similarities as energy sources so they are considered together in this section. Both are renewable and both are indirect means of harnessing solar energy — winds produced by the uneven heating of air masses and water carried by the solar-powered hydrologic cycle. Both are among the oldest sources of energy, such as wind used to propel sailing ships and waterwheels used for centuries to grind grain. And both are among the newest sources of energy — winds with technologically advanced wind turbines and water through ingenious devices such as those used to capture the energy of moving water in ocean tides.

Favorable Winds

As the sun heats air masses unevenly, winds are generated that can be tapped as an indirect form of solar energy. Wind power is undergoing rapid growth in a number of countries and has become competitive in cost with more conventional sources in some areas. In parts of Europe, California, Wyoming, and other locations, the sight of wind-powered generators mounted on towers has become common (Figure 15.15). In 2009 world wind power capacity increased by 31%reaching a capacity of 158 gigawatts. During 2009 China's wind power capacity doubled from 12GW to 25 GW and the U.S. capacity grew by 10 GW to 35 GW total capacity. This gave the U.S.the largest wind power capacity of any nation in the world, though rapidly being overtaken by China.

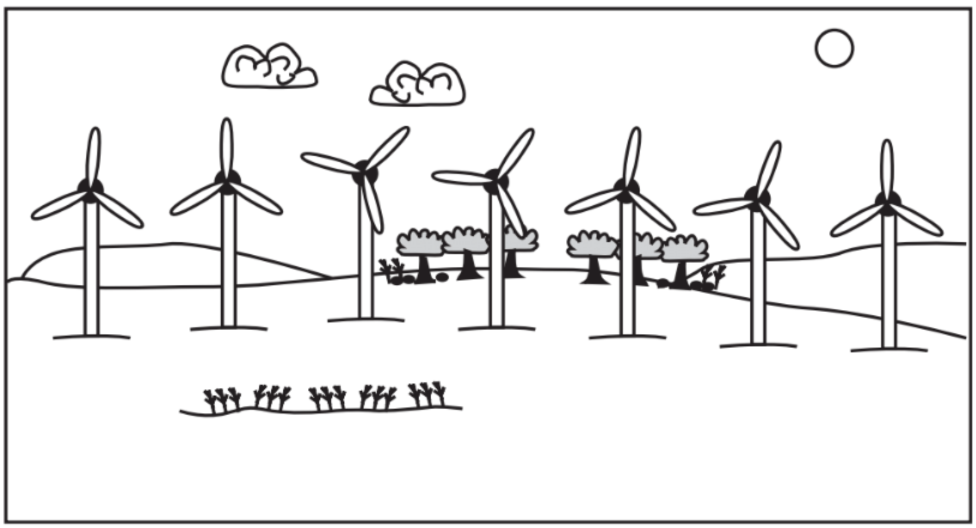

Figure 15.15. Wind-powered electrical generators mounted on towers are becoming increasingly common sights in the world in areas where consistent wind makes this nonpolluting source of renewable energy practical.

Modern wind turbines are generally large and sophisticated machines with diameters of 40 to 50 meters and rated between 0.5 to 2 megawatts. The largest turbines available as of 2010 were rated at 7 MW. Wind turbines are designed to operate consistently at varying wind speeds, to respond to changing wind direction, and to operate over a wide range of temperatures. Provision is made for electrical resistance heating of turbine blades in cold climates where ice accumulation is likely.

Offshore locations with turbines firmly anchored to the sea bed offer several advantages for production of wind power including generally consistent winds in coastal areas and lack of conflict with uses of land. The largest offshore wind power project to date began operation off the coast of southeast England in September 2010. This facility operated by Vattenfall, a Swedish energy company, has 100 turbines each 115 meters tall, and produces up to 300 megawatts of electricity, enough to power 200,000 homes

Energy from Moving Water

Various means of harnessing the energy of moving water have been used since ancient times with water-powered sailing vessels and waterwheels driven by flowing water for grinding grain known in ancient Greece and Rome. Waterwheels up to 50 horsepower were developed in the Middle Ages and were widely applied to grist mills, sawmills, and leather, textile, and machine shop operations in Colonial America. These sources suffered from problems due to irregular water flow and freezing during winter so that many of these facilities were abandoned when steam engines became widely available in the early 1800s.

A renaissance in waterpower occurred in the late 1800s when it became practical to drive electrical generators with water. Starting with the first hydroelectric plant in the U.S. on the Fox River near Appleton, Wisconsin, in 1882, hydroelectric power driven by sophisticated power turbines grew rapidly in the U.S. and throughout the world. By 1980 hydroelectric power composed 25% of world electricity production and 5% of total world energy generation. Norway generates essentially all of its electric power and about 50% of its total energy from hydroelectric sources.

The morphology of the geosphere has a strong influence on the potential for hydroelectric power generation, which is favored by mountainous terrain and large river valleys. Abundant rainfall and snowmelt are also important factors. China has about 1/10 of the world's potential for hydroelectric energy and its enormous Tree Gorges installation on the Yangtze River is the world's largest. The reservoir for this power source has been impounded with a 185-meter high, 1,300-m long dam located at the end of a number of steep canyons holding a body of water that extends for 630 km with an average width of 1.2 km. When fully operational, this massive installation will have 32 generating units and a capacity of 22.5 gigawatts, equivalent to 22 large coal-fired powerplants.

With the hydrologic cycle continuously pumping water into it, hydroelectric power is certainly sustainable, and prevents release of greenhouse gases. Bodies of water impounded to provide power can serve as water supplies for agriculture, municipalities, and industries. The potential exists to practice aquaculture in reservoirs by raising fish and freshwater shrimp(prawns). On the negative side, the development of hydroelectric power can present some serious environmental problems. In the modern era construction of a large power reservoir displaces significant numbers of people (more than 1 million for China's Three Gorges project), alters river flow, changes aquatic ecology, and fills once scenic valleys with water. In several significant cases dams have been removed from rivers to restore their valleys to their former state.

Water Energy without Dams

Hydrokinetic and **wave energy conversion** devices are being developed to harvest the kinetic energy of moving water in natural streams, tidal estuaries, ocean currents, and constructed waterways free of dams. A typical such device consists of a turbine with relatively large and widely spaced blades coupled directly to a generator that is fixed in a river or other water current. Such a device can be anchored directly to a river bed or attached to bridge supports.

Another source of energy from moving water is that from tides, changing levels of seawater resulting from the gravitational pull of the sun and moon. Tidal energy is feasible as demonstrated by the 240 megawatt tidal power station that has operated reliably in the Rance estuary region of France since it was constructed in 1966. This facility has about 1/4 the capacity of a standard 1,000MW coal-fired or nuclear plant. Several other small installations have been built including an 18MW experimental unit at Annapolis Royal, Canada. Tidal electricity generating stations suffer from the disadvantage that sufficient water flows to generate electricity only about 10 hours per day. Nevertheless, the amount of energy potentially available from tides is enormous and it is completely renewable.

An interesting way of harnessing water energy is **pressure-retarded osmosis** in which saline ocean water and fresh water are separated by a water-permeable membrane and the flow of water through the membrane from the fresh water to the saline water side builds pressure in the latter that can be harnessed to produce electricity. Pressure-retarded osmosis is illustrated in Figure15.16. Although the process operates on a continuous basis it is shown as a stepwise process in Figure 15.16 to illustrate the operating principle. The world's first osmotic plant, a demonstration unit with a minuscule capacity, went into operation in Tofte, Norway, in November, 2009. Pressure-retarded osmosis plants can be located in almost any of the huge number of locations worldwide where fresh water flows into the sea.

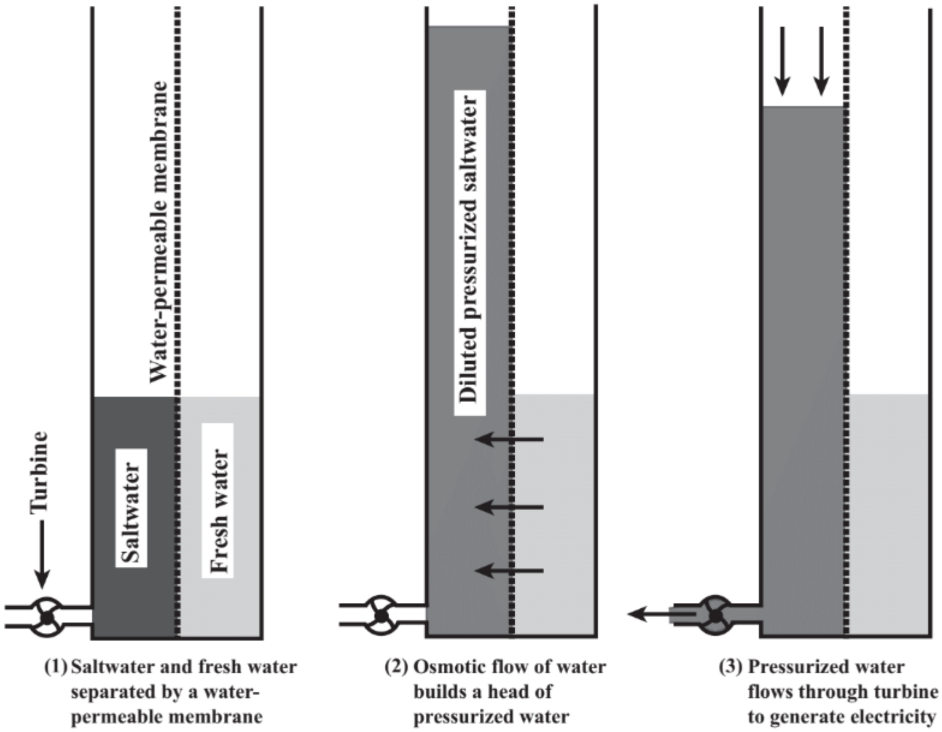

Figure 15.16. Illustration of the principle of pressure-retarded osmosis power generation that is based on the difference in osmotic pressure between saltwater and fresh water. Although it is shown here as a stepwise process, this mode of power generation operates on a continuous basis.