# Alternative energy sources

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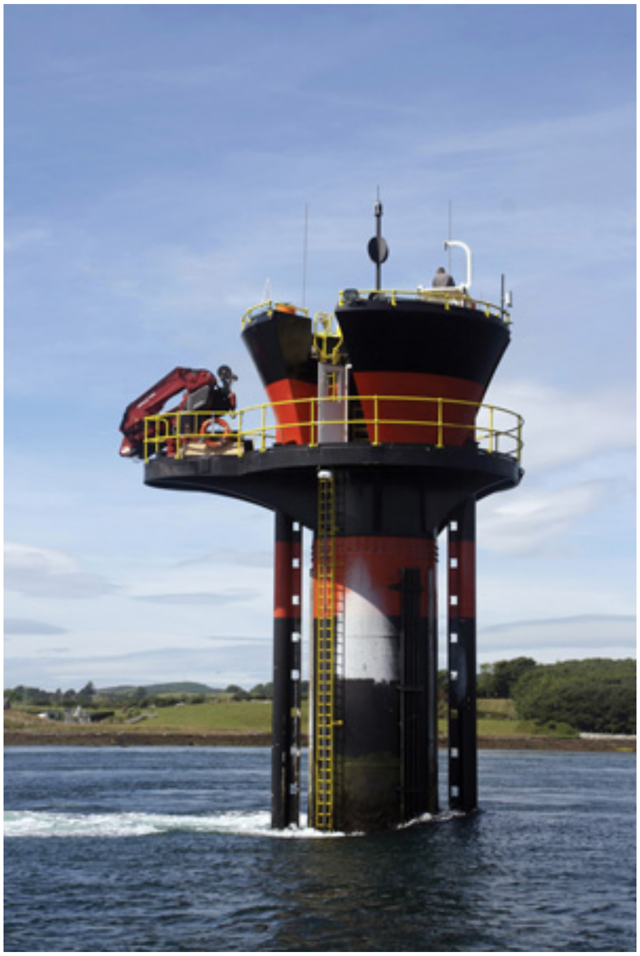
From Opposing Viewpoints in Context



In the second decade of the twenty first century, the idea of alternative energy is generally applied to energy other than conventional non-renewable fossil fuels. Fossil fuels, though actually forming continuously, are considered non-renewable because they are consumed at a much higher rate than they renew. Fossil fuels make up the bulk of the world's current primary energy sources. In 2013, about 33 percent of total global energy consumption came from oil products, followed by coal and natural gas. The United Nations estimates that 60 percent of global energy will come from renewable energy sources by 2070.

Energy consumption is most clearly understood if final energy consumption is distinguished from primary energy consumption. Final energy consumption is energy consumed, not wasted at the point of generation. For example, of all the energy released by burning coal at a coal-fired power plant, only about 40 percent is turned into electricity; the rest is wasted up the chimney as heat. A further 5 percent or so is lost in power lines; so, of the total energy released by fuel-burning at such a plant (usually termed "primary energy"), only about 35 percent reaches end uses and can be counted as final energy consumption. In a heating system for a building, only the energy that heats the building is calculated in final energy consumption; energy that goes up the vent-stack is primary energy consumption but does not heat the house.

Fossil fuels, nuclear power, and large-scale hydroelectric power from dams are all considered conventional energy sources and are contributors to climate change because of carbon dioxide ($CO_2$) emissions in the atmosphere. Other sources are termed "alternative." The main fossil fuels--coal, oil, and natural gas (methane)--provided the vast majority (over 75 percent) of final energy consumption worldwide in the late 2000s--and it is expected to continue to do so into the future. Nuclear reactors provided around 3 percent of final energy consumption, and hydroelectric power from dams also provided about 3 percent. Alternative energy sources, including wind power, active and passive solar systems, biofuel, and geothermal energy, supplied approximately 5 percent of final energy consumption. Due to the depletion of fossil fuel sources as well as the pollution caused by all conventional energy sources, the share of worldwide energy consumption originating from alternative energy sources is growing.

Power generated with electricity is only one energy source, although it is a particularly versatile one. Because much fossil fuel is consumed for nonelectric forms of energy (heat and transport), the breakdown of the world electricity supply is differently stated than that for the world energy supply. By 2014 about less than 35 percent of world electricity came from coal, 24 percent from natural gas, 11 percent from nuclear power, 15 percent was from hydropower, and the remainder percent from alternative (renewable) sources such as wind turbines and solar cells.

One of the best sources of information about primary energy (as opposed to final energy) production is the annual *BP Statistical Review of World Energy*. The 2013 edition of that report stated that fossil fuels accounted for about 87 percent of all primary energy produced in the world, compared to 13 percent from renewable resources. These data have long been criticized by some observers, however. For example, U.S. energy expert Amory Lovins (1947-), a prominent figure in expert debates around nuclear power, alternative energy, and energy efficiency starting in the 1970s, has argued that the statistics collected are based primarily on large electric utilities and the regions they serve. They fail to account for areas remote from major power grids, which are more likely to use solar energy, wind energy, or other sources. When these areas are taken into consideration, Lovins, who is also the chief scientist at the Rocky Mountain Institute, has stated that alternative energy sources contribute a larger proportion to the total primary energy used in the United States, and perhaps elsewhere in the world. Animal manure, furthermore, is widely used as an energy source in India, parts of China, and much of Africa, and when this is taken into account the percentage of the worldwide contribution that alternative sources make to primary energy production could rise even higher yet.

Now considered an alternative energy source, wind power is one of the earliest forms of energy harvested mechanically by humankind. Wind is caused by the uneven heating of the earth's surface by the sun, and so (like wave and tidal power) is considered an indirect form of solar power. The kinetic energy of wind--the energy that a moving air mass has by virtue of its motion--is proportional to the square of wind velocity, and the energy that a wind turbine (windmill generator) can *extract* from wind is proportional to the cube of velocity, so the ideal location for a windmill generator is an area with constant and relatively fast winds. In most locations, wind speed rises (up to a point) with height, and turbulence from ground roughness decreases--also a crucial consideration. Modern turbines are therefore placed on high towers, typically about 200 feet (60 m) above the ground.

An efficient wind turbine can produce 175 watts per square meter of propeller blade area at a height of 75 feet (25 m); in fact, turbines being installed today are much higher than this, and so intercept more wind and produce more power per unit of blade area. In 2013, the cost of generating one kilowatt hour of wind power was said to be about four cents, as compared to five cents for hydropower and fifteen cents for nuclear power. (Disagreement exists about this estimate because of tax incentives often given to wind facilities.) Because of low capital costs, low fuel costs, rapid construction, and zero pollution, global wind-generation capacity was growing exponentially from the late 1990s to the end of the 2000s, and continues a rapid increase. From 2000 to 2012, global wind capacity increased from 17.4 GW (gigawatts) in 2000 to 59.1 GW in 2005 to 197.7 GW in 2010 to 282.4 GW in 2012. The nation with the highest wind energy production per capita in 2012 was Denmark (693 GW/person), followed by Spain (469 GW/person), Portugal (386 GW/person), and Ireland (355 GW/person). The United States ranked ninth in the world at 150 GW/person.

Solar energy can be utilized either directly as heat or indirectly by converting it to electrical power using photovoltaic cells or steam-turbine plants. Windows and collectors alone are considered passive systems; an active solar system uses a fan, pump, or other machinery to transport the heat generated from the sun. Greenhouses and solariums are the most common examples of the passive use of solar energy, with glass windows allowing entrance to sunlight but restricting the heat from escaping. In most climates, buildings can be made entirely self-sufficient in heating and cooling through use of superinsulation and passive solar heat collection. Flat-plate collectors that use fluid circulating over a dark surface to collect solar energy are another direct solar-thermal method, often mounted on rooftops. These collectors can provide from one-third to all of the energy required for space heating, depending on climate and overall building efficiency. In 2013, the nations with the largest solar power generating capacity per capita were Germany, Italy, Belgium, and the Czech Republic. The United States ranked twentieth on that list.

Photovoltaic cells are made of semiconductor materials such as silicon. These cells are capable of absorbing part of sunlight to produce a direct electric current with about 14 percent efficiency, which is to say about 14 percent of the energy in the sunlight is converted to electricity. In the laboratory, efficiencies of over 40 percent have been achieved, and such work will eventually raise the efficiency of commercially available cells. The cost of producing photovoltaic power is about four dollars a watt: that is, a system capable of producing 1,000 watts in bright sunshine costs about $4,000 to install. However, thin-film cells and other technologies are being perfected that are steadily reducing photovoltaic costs. Photovoltaics are now being used economically in lighthouses, boats, cars, and in rural villages and other remote areas. Large solar systems (producing approximately 20 million watts) are being installed in Europe, the United States, and elsewhere as quickly as the solar industry can meet the demand for photovoltaic cells. Rooftop photovoltaics are also being installed rapidly. These have the advantage that they produce power where it is to be used and use land that has already been developed for buildings, rather than covering wild land with solar cell arrays.

Geothermal energy is the heat generated in the interior of Earth by radioactive elements. Earth's interior radioactive material is so dilute that it does not pose a radiation threat. Like solar energy, it can be used directly as heat or indirectly to generate electricity. Geothermal steam is classified as either dry (without water droplets), or wet (mixed with water). When it is generated in certain areas containing corrosive sulfur (S) compounds, it is known as sour steam; and when generated in areas that are free of sulfur, it is known as sweet steam. Geothermal energy can be used to generate electricity by the flashed steam method, in which high temperature geothermal brine is used as a heat exchanger to convert injected water into steam. The produced steam is used to turn a turbine. When geothermal wells are not hot enough to create steam, a fluid that evaporates at a much lower temperature than water, such as isobutane ($C_4H_{10}$) or ammonia ($NH_3$), can be placed in a closed system in which the geothermal heat provides the energy to evaporate the fluid and run the turbine.

There are at least seventy countries worldwide that utilize geothermal energy, including the United States, Mexico, Italy, Iceland, Japan, and Russia. Geothermal energy can, in some cases, have more environmental impact than solar or wind energy. Depending on the type of geothermal resource being exploited, it can contribute to air pollution; it can also emit dissolved salts and, in some cases, toxic heavy metals such as mercury (Hg) and arsenic (As).

Though there are several ways of extracting energy from the ocean, the most promising are the harnessing of tidal power, wave power, and ocean thermal energy conversion. The power of ocean tides is based on the difference between high and low water. Traditionally, it was thought that for tidal power to be effective the differences in height need to be very great, more than 15 feet (4.6 m), and there are only a few places in the world where such differences exist. These include the Bay of Fundy (on Canada's east coast) and a few sites in China. However, most tide-power projects do not rely on such extreme geography. More modest tides can be harnessed by impounding high tides behind dams and then letting the water run out through turbines at low tide, or by installing underwater turbines resembling windmills in places where coastal and seafloor shapes cause strong tidal currents to run. For instance, since early 2007, Verdant Power, headquartered in Arlington, Virginia, has operated a pilot project in the East River of New York City. It is considered the first major tidal-power project in the United States. Technologies are also being developed for harvesting energy from ocean waves--not the crashing waves seen at the shore, but swells out to sea. The rise-and-fall motion of a float, for example, can be used to compress air that runs a generator, whose power output can be conveyed to shore through cables.

Ocean thermal energy conversion utilizes temperature differences rather than tides and waves. Ocean temperature is stratified, especially near the tropics, and the process takes advantage of this fact by using a fluid with a low boiling point, such as ammonia. The vapor from the fluid drives a turbine, and cold water from lower depths is pumped up to condense the vapor back into liquid. The electrical power generated by this method can be shipped to shore or used to operate a floating plant such as a cannery.

Other sources of alternative energy are being exploited at various scales. These include harnessing the energy in biomass through the production of wood from trees or the production of ethanol ($C_2H_6O$) from crops such as sugarcane, corn, or switchgrass (*Panicum virgatium*). Scientific research studies are being employed to determine efficient and cost-effective ways of deriving energy from biomass. Methane ($CH_4$) gas can be generated from the anaerobic breakdown of organic waste in sanitary landfills and from wastewater treatment plants. With the cost of garbage disposal rapidly increasing, the burning of garbage is becoming a viable option as an energy source. Whether trash incineration can be rendered safe by air pollution controls is, however, disputed.

Ethanol and methanol (CH3OH) are produced from biomass and used in transportation; in Brazil, all gasoline is sold with at least 20 percent ethanol from sugar cane (in the United States, a 10 percent corn-ethanol blend is common). However, production of fuel ethanol has been criticized both as a net-energy consumer (or poor net-energy producer) and also as injurious to the world's poor population. In early 2008, for example, food shortages gripped much of the world, with riots against high prices becoming more common in some poor countries. Food prices worldwide had risen 83 percent since 2005, according to the World Bank. Although there were a number of causes for rising prices, including a drought in Australia that lowered production of rice, the main food of over one-half the world's population, food experts agreed that the push to raise crops for ethanol biofuel for vehicles was part of the problem. Biofuel manufacturers compete directly with food buyers in the market for corn, and high demand for biofuel crops causes growers to switch acreage away from food production. The result is higher food prices, which some of the world's poorest simply cannot pay.

Hydrogen could be a valuable aid in utilizing energy from renewable sources if problems of supply and storage can be solved. Its only combustion by-products are water and heat, and it can be combined with oxygen in battery-like devices termed fuel cells to generate electricity directly with high efficiency. Also, despite a bad reputation, it is not nearly as explosive as gasoline vapor; hydrogen disperses rapidly when released, rather than pooling near the ground. Some alternative-energy advocates visualize a hydrogen economy in which windmills, solar cells, and other renewable energy sources produce hydrogen by cracking water molecules (hydrogen and oxygen), a process known as electrolysis. The hydrogen would then provide clean fuel for vehicles as well as electricity from fuel cells to smooth the output of variable sources such as wind and sun. To date, the difficulty of producing affordable fuel cells and hydrogen slows the deployment of hydrogen technologies.

Of all alternative energy sources, energy conservation or efficiency is perhaps the most important. In practice, improving efficiency is in most settings a far cheaper way to provide an additional unit of energy service than is buying the output of new generating capacity, whether wind, nuclear, coal, or other. Efficiency improvements such as thicker insulation and re-design of industrial machines also entails relatively small levels of pollution or material use compared to generating the energy that the efficiency displaces. Therefore, energy efficiency is the best way to meet energy demands without adding to air and water pollution and the other harms entailed by generating various kinds of energy.

Strictly speaking, conservation and efficiency are not sources of energy: One cannot light a house on pure efficiency. However, in a developed energy economy with opportunities for increased efficiency, ways to use energy more effectively compete directly with energy supply. That is, one can spend a dollar to buy an additional unit of energy to accomplish a certain task, such as lighting a building, or one can pay for efficiency to do the same job with less energy. One reason the United States survived the energy crises of the 1970s was that it was able to curtail a small fraction of its immense energy waste. Relatively easy lifestyle alterations, vehicle improvements, building insulation, and more efficient machinery and appliances have significantly reduced their potential energy demand. Experts have estimated that it is possible to double the efficiency of electric motors, triple the intensity of light bulbs, quadruple the efficiency of refrigerators and air conditioners, and quintuple the gasoline mileage of automobiles. Because of rising gas prices, the popularity and technology of hybrid vehicles in terms of improvements in their efficient use of electricity continues to grow, which also results in decreasing pollution and its effects on global warming. Moreover, most efficiency improvements make buildings more comfortable, appliances quieter and more reliable, and businesses more profitable; efficiency does not equate to darkness, cold, and discomfort. The U.S. government offers tax breaks for the purchase of hybrid cars and the installation of energy-efficient appliances, windows, insulation, doors, and heating and cooling units as well as installation of solar energy generators such as solar panels and water heaters.

Alternative energy sources are being developed rapidly to meet energy needs, but demand for energy is also growing, leading to uncertainty and concern about future supply. In the early 2010s, despite investment in alternative energy, coal-burning--the dirtiest form of fossil-fuel energy and a major contributor to global climate change--was one of the fastest-growing sources of energy worldwide. However, although enormous investments in new technology and equipment will be needed and potential supplies are uncertain, there is reasonable hope for an energy-abundant future based primarily on renewable sources and efficient end-use. In the United States in 2013, nuclear energy contributed 19 percent to all non-fossil fuel energy produced in the country, followed by seven percent by hydroelectric sources, and five percent by other renewable sources.

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# Further Readings

## Resources

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