

Electricity generation

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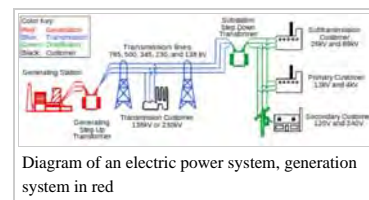
Electricity generation is the process of generating electric power from other sources of primary energy. For electric utilities, it is the first process in the delivery of electricity to consumers. The other processes, electricity transmission, distribution, and electrical power storage and recovery using pumped-storage methods are normally carried out by the electric power industry. Electricity is most often generated at a power station by electromechanical generators, primarily driven by heat engines fuelled by combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. Other energy sources include solar photovoltaics and geothermal power.

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Turbo generator



History

The fundamental principles of electricity generation were discovered during the 1820s and early 1830s by the British scientist Michael Faraday. This method is still used today: electricity is generated by the movement of a loop of wire, or disc of copper between the poles of a magnet. Central power stations became economically practical with the development of alternating current power transmission, using power transformers to transmit power at high voltage and with low loss. Electricity has been generated at central stations since 1882. The first power plants were run on water power or coal,^[1] and today rely mainly on coal, nuclear, natural gas, hydroelectric, wind generators, and petroleum, with supplementary amounts from solar energy, tidal power, and geothermal sources. The use of power-lines and power-poles have been significantly important in the distribution of electricity.

Methods of generating electricity

There are seven fundamental methods of directly transforming other forms of energy into electrical energy.

Static electricity

Static electricity, form the physical separation and transport of charge (examples: triboelectric effect and lightning). It was the first form discovered and investigated, and the electrostatic generator is still used even in modern devices such as the Van de Graaff generator and MHD generators.

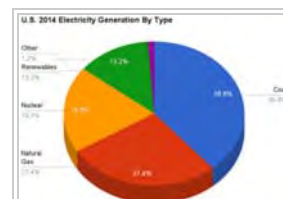
Electromagnetic induction

In Electromagnetic induction, an electric generator, dynamo or alternator transforms kinetic energy into electricity. This is the most used form for generating electricity and is based on Faraday's law. It can be experimented by rotating a magnet within closed loops of a conducting material (e.g. copper wire). Almost all commercial electrical generation is done using electromagnetic induction, in which mechanical energy forces a generator to rotate.

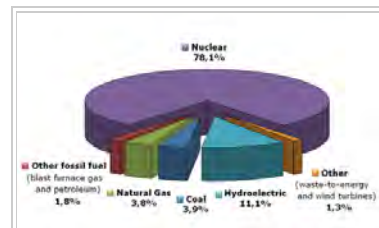
Turbines

Almost all electrical power on Earth is generated with a turbine, driven by wind, water, steam or burning gas. The turbine drives a generator. There are many different methods of developing mechanical energy, including heat engines, hydro, wind and tidal power. Most electric generation is driven by heat engines. The combustion of fossil fuels supplies most of the heat to these engines, with a significant fraction from nuclear fission and some from renewable sources. The modern steam turbine (invented by Sir Charles Parsons in 1884) currently generates about 80% of the electric power in the world using a variety of heat sources. Power sources include:

- Steam
 - Water is boiled by coal burned in a thermal power plant, about 41% of all electricity is generated this way.^[4]
 - Nuclear fission heat created in a nuclear reactor creates steam. Less than 15% of electricity is generated this way.
 - Renewables. The steam is generated by Biomass, Solar thermal energy where solar parabolic troughs and solar power towers concentrate sunlight to heat a heat transfer fluid, which is then used to produce steam, or Geothermal power.
 - Natural gas: turbines are driven directly by gases produced by combustion. Combined cycle are driven by both steam and natural gas. They generate power by burning natural gas in a gas turbine and use residual heat to generate steam. At least 20% of the worlds electricity is generated by natural gas.
- Small turbines can be powered by Diesel engines. This is used for back up generation, usually at low voltages. Most large power grids also use diesel generators, originally provided as emergency back up for a specific facility such as a hospital, to feed power into the grid during certain circumstances.



U.S. 2014 Electricity Generation By Type.^[2]



Sources of electricity in France in 2006;^[3] nuclear power was the main source.

- Water Energy is captured from the movement of water. From falling water, the rise and fall of tides or ocean thermal currents. Each driving a water turbine to produce approximately 16% of the world's electricity. The Perth Wave Energy Project is an early production, submerged buoy, electrical power and direct desalination installation supplying power to HMAS Stirling in Western Australia.
- The windmill was a very early wind turbine. In a solar updraft tower wind is artificially produced. Before 2010 less than 2% of the world's electricity was produced from wind.

Electrochemistry

Electrochemistry is the direct transformation of chemical energy into electricity, as in a battery. Electrochemical electricity generation is important in portable and mobile applications. Currently, most electrochemical power comes from batteries.^[5] Primary cells, such as the common zinc-carbon batteries, act as power sources directly, but many types of cells are used as storage systems rather than primary generation systems. Open electrochemical systems, known as fuel cells, can be used to extract power either from natural fuels or from synthesized fuels. Osmotic power is a possibility at places where salt and fresh water merges.

Photovoltaic effect

The photovoltaic effect is the transformation of light into electrical energy, as in solar cells. Photovoltaic panels convert sunlight directly to electricity. Although sunlight is free and abundant, solar electricity is still usually more expensive to produce than large-scale mechanically generated power due to the cost of the panels. Low-efficiency silicon solar cells have been decreasing in cost and multijunction cells with close to 30% conversion efficiency are now commercially available. Over 40% efficiency has been demonstrated in experimental systems.^[6] Until recently, photovoltaics were most commonly used in remote sites where there is no access to a commercial power grid, or as a supplemental electricity source for individual homes and businesses. Recent advances in manufacturing efficiency and photovoltaic technology, combined with subsidies driven by environmental concerns, have dramatically accelerated the deployment of solar panels. Installed capacity is growing by 40% per year led by increases in Germany, Japan, and the United States.

Thermoelectric effect

Thermoelectric effect is the direct conversion of temperature differences to electricity, as in thermocouples, thermopiles, and thermionic converters.

Piezoelectric effect

The Piezoelectric effect generates electricity from the mechanical strain of electrically anisotropic molecules or crystals. Researchers at the United States Department of Energy's Lawrence Berkeley National Laboratory have developed a piezoelectric generator sufficient to operate a liquid crystal display using thin films of M13 bacteriophage.^[8] Piezoelectric devices are used for power generation from mechanical strain, particularly in power harvesting.

Nuclear transformation

Nuclear transformation is the creation and acceleration of charged particles (examples: betavoltaics or alpha particle emission). The direct conversion of nuclear potential energy to electricity by beta decay is used only on a small scale. In a full-size nuclear power plant, the heat of a nuclear reaction is used to run a heat engine. This drives a generator, which converts mechanical energy into electricity by magnetic induction. Betavoltaics are a type of solid-state power generator which produces electricity from radioactive decay. Fluid-based magnetohydrodynamic (MHD) power generation has been studied as a method for extracting electrical power from nuclear reactors and also from more conventional fuel combustion systems.

Economics of generation and production of electricity

The selection of electricity production modes and their economic viability varies in accordance with demand and region. The economics vary considerably around the world, resulting in widespread selling prices, e.g. the price in Venezuela is 3 cents per kWh while in Denmark it is 40 cents per kWh. Hydroelectric plants, nuclear power plants, thermal power plants and renewable sources have their own pros and cons, and selection is based upon the local power requirement and the fluctuations in demand. All power grids have varying loads on them but the daily minimum is the base load, supplied by plants which run continuously. Nuclear, coal, oil and gas plants can supply base load.

Thermal energy is economical in areas of high industrial density, as the high demand cannot be met by renewable sources. The effect of localized pollution is also minimized as industries are usually located away from residential areas. These plants can also withstand variation in load and consumption by adding more units or temporarily decreasing the production of some units. Nuclear power plants can produce a huge amount of power from a single unit. However, recent disasters in Japan have raised concerns over the safety of nuclear power, and the capital cost of nuclear plants is very high. Hydroelectric power plants are located in areas where the potential energy from falling water can be harnessed for moving turbines and the generation of power. It is not an economically viable source of production where the load varies too much during the annual production cycle and the ability to store the flow of water is limited.

Due to advancements in technology, and with mass production, renewable sources other than hydroelectricity (solar power, wind energy, tidal power, etc.) experienced decreases in cost of production, and the energy is now in many cases cost-comparative with fossil fuels. Many governments around the world provide subsidies to offset the higher cost of any new power production, and to make the installation of renewable energy systems economically feasible. However, their use is frequently limited by their intermittent nature. If natural gas prices are below \$3 per million British thermal units, generating electricity from natural gas is cheaper than generating power by burning coal.^[9]

Production

The production of electricity in 2009 was 20,053TWh. Sources of electricity were fossil fuels 67%, renewable energy 16% (mainly hydroelectric, wind, solar and biomass), and nuclear power 13%, and other sources were 3%. The majority of fossil fuel usage for the generation of electricity was coal and gas. Oil was 5.5%, as it is the most expensive common commodity used to produce electrical energy. Ninety-two percent of renewable energy was hydroelectric followed by wind at 6% and geothermal at 1.8%. Solar photovoltaic was 0.06%, and solar thermal was 0.004%. Data are from OECD 2011-12 Factbook (2009 data).^[10]



Large dams such as Three Gorges Dam in China can provide large amounts of hydroelectric power; it has a 22.5 GW capability.



Large dams such as Hoover Dam can provide large amounts of hydroelectric power; it has 2.07 GW capability.



A coal-fired power plant in Laughlin, Nevada U.S.A. Owners of this plant ceased operations after declining to invest in pollution control equipment to comply with pollution regulations.^[7]



Wind turbines usually provide electrical generation in conjunction with other methods of producing power.

Source of Electricity (World total year 2008)

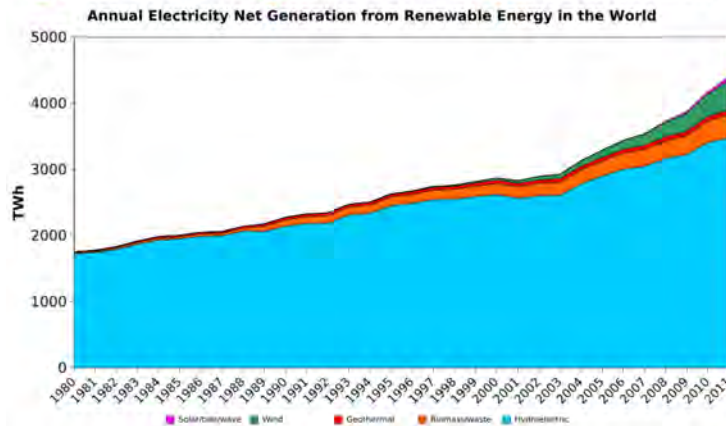
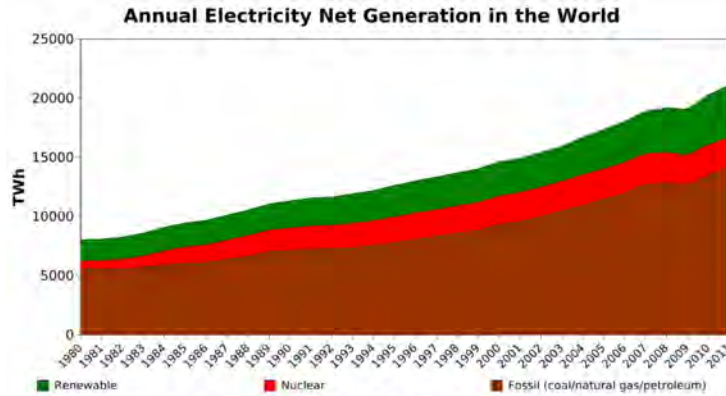
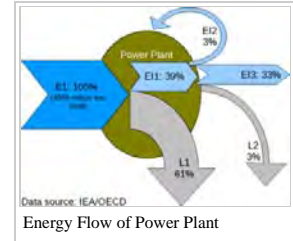
-	Coal	Oil	Natural Gas	Nuclear	Renewables	other	Total
Average electric power (TWh/year)	8,263	1,111	4,301	2,731	3,288	568	20,261
Average electric power (GW)	942.6	126.7	490.7	311.6	375.1	64.8	2311.4
Proportion	41%	5%	21%	13%	16%	3%	100%

data source IEA/OECD

Total energy consumed at all power plants for the generation of electricity was 4,398,768 ktoe (kilo ton of oil equivalent) which was 36% of the total for primary energy sources (TPES) of 2008.

Electricity output (gross) was 1,735,579 ktoe (20,185 TWh), efficiency was 39%, and the balance of 61% was generated heat. A small part (145,141 ktoe, which was 3% of the input total) of the heat was utilized at co-generation heat and power plants. The in-house consumption of electricity and power transmission losses were 289,681 ktoe. The amount supplied to the final consumer was 1,445,285 ktoe (16,430 TWh) which was 33% of the total energy consumed at power plants and heat and power co-generation (CHP) plants.^[11]

Historical results of production of electricity

































Production by country

The United States has long been the largest producer and consumer of electricity, with a global share in 2005 of at least 25%, followed by China, Japan, Russia, and India. As of Jan-2010, total electricity generation for the 2 largest generators was as follows: USA: 3992 billion kWh (3992 TWh) and China: 3715 billion kWh (3715 TWh).

List of countries with source of electricity 2008

Data source of values (electric power generated) is IEA/OECD.^[12] Listed countries are top 20 by population or top 20 by GDP (PPP) and Saudi Arabia based on CIA World Factbook 2009.^[13]

Composition of Electricity by Resource (TWh per year 2008)

Country's electricity sector	Fossil Fuel					Nuclear	rank	Renewable								Bio other*	total	rank
	Coal	Oil	Gas	sub total	rank			Hydro	Geo Thermal	Solar PV*	Solar Thermal	Wind	Tide	sub total	rank			
World total	8,263	1,111	4,301	13,675	-	2,731	-	3,288	65	12	0.9	219	0.5	3,584	-	271	20,261	-
Proportion	41%	5.5%	21%	67%	-	13%	-	16%	0.3%	0.06%	0.004%	1.1%	0.003%	18%	-	1.3%	100%	-
 China	2,733	23	31	2,788	2	68	8	585	-	0.2	-	13	-	598	1	2.4	3,457	2
 India	569	34	82	685	5	15	12	114	-	0.02	-	14	-	128.02	6	2.0	830	5
 USA	2,133	58	1011	3,101	1	838	1	282	17	1.6	0.88	56	-	357	4	73	4,369	1
 Indonesia	61	43	25	130	19	-	-	12	8.3	-	-	-	-	20	17	-	149	20
 Brazil	13	18	29	59	23	14	13	370	-	-	-	0.6	-	370	3	20	463	9
 Pakistan	0.1	32	30	62	22	1.6	16	28	-	-	-	-	-	28	14	-	92	24
 Bangladesh	0.6	1.7	31	33	27	-	-	1.5	-	-	-	-	-	1.5	29	-	35	27
 Nigeria	-	3.1	12	15	28	-	-	5.7	-	-	-	-	-	5.7	25	-	21	28
 Russia	197	16	495	708	4	163	4	167	0.5	-	-	0.01	-	167	5	2.5	1,040	4
 Japan	288	139	283	711	3	258	3	83	2.8	2.3	-	2.6	-	91	7	22	1,082	3
 Mexico	21	49	131	202	13	9.8	14	39	7.1	0.01	-	0.3	-	47	12	0.8	259	14
 Philippines	16	4.9	20	40	26	-	-	9.8	11	0.001	-	0.1	-	21	16	-	61	26
 Vietnam	15	1.6	30	47	25	-	-	26	-	-	-	-	-	26	15	-	73	25
 Ethiopia	-	0.5	-	0.5	29	-	-	3.3	0.01	-	-	-	-	3.3	28	-	3.8	30
 Egypt	-	26	90	115	20	-	-	15	-	-	-	0.9	-	16	20	-	131	22
 Germany	291	9.2	88	388	6	148	6	27	0.02	4.4	-	41	-	72	9	29	637	7
 Turkey	58	7.5	99	164	16	-	-	33	0.16	-	-	0.85	-	34	13	0.22	198	19
 DR Congo	-	0.02	0.03	0.05	30	-	-	7.5	-	-	-	-	-	7.5	22	-	7.5	29
 Iran	0.4	36	173	209	11	-	-	5.0	-	-	-	0.20	-	5.2	26	-	215	17
 Thailand	32	1.7	102	135	18	-	-	7.1	0.002	0.003	-	-	-	7.1	23	4.8	147	21
 France	27	5.8	22	55	24	439	2	68	-	0.04	-	5.7	0.51	75	8	5.9	575	8
 UK	127	6.1	177	310	7	52	10	9.3	-	0.02	-	7.1	-	16	18	11	389	11
 Italy	49	31	173	253	9	-	-	47	5.5	0.2	-	4.9	-	58	11	8.6	319	12
 South Korea	192	15	81	288	8	151	5	5.6	-	0.3	-	0.4	-	6.3	24	0.7	446	10
 Spain	50	18	122	190	14	59	9	26	-	2.6	0.02	32	-	61	10	4.3	314	13
 Canada	112	9.8	41	162	17	94	7	383	-	0.03	-	3.8	0.03	386	2	8.5	651	6
 Saudi Arabia	-	116	88	204	12	-	-	-	-	-	-	-	-	-	-	-	204	18
 Taiwan	125	14	46	186	15	41	11	7.8	-	0.004	-	0.6	-	8.4	21	3.5	238	16
 Australia	198	2.8	39	239	10	-	-	12	-	0.2	0.004	3.9	-	16	19	2.2	257	15
 Netherlands	27	2.1	63	92	21	4.2	15	0.1	-	0.04	-	4.3	-	4.4	27	6.8	108	23
Country	Coal	Oil	Gas	sub total	rank	Nuclear	rank	Hydro	Geo Thermal	Solar PV	Solar Thermal	Wind	Tide	sub total	rank	Bio other	Total	rank

Solar PV* is Photovoltaics **Bio other*** = 198TWh (Biomass) + 69TWh (Waste) + 4TWh (other)

Environmental concerns

Variations between countries generating electrical power affect concerns about the environment. In France only 10% of electricity is generated from fossil fuels, the US is higher at 70% and China is at 80%.^[12] The cleanliness of electricity depends on its source. Most scientists agree that emissions of pollutants and greenhouse gases from fossil fuel-based electricity generation account for a significant portion of world greenhouse gas emissions; in the United States, electricity generation accounts for nearly 40% of emissions, the largest of any source. Transportation emissions are close behind, contributing about one-third of U.S. production of carbon dioxide.^[14] In the United States, fossil fuel combustion for electric power generation is responsible for 65% of all emissions of sulfur dioxide, the main component of acid rain.^[15] Electricity generation is the fourth highest combined source of NOx, carbon monoxide, and particulate matter in the US.^[16] In July 2011, the UK parliament tabled a motion that "levels of (carbon) emissions from nuclear power were approximately three times lower per kilowatt hour than those of solar, four times lower than clean coal and 36 times lower than conventional coal".^[17]

Lifecycle greenhouse gas emissions by electricity source.^[18]

Technology	Description	50th percentile (g CO ₂ /kWh _e)
Hydroelectric	reservoir	4
Wind	onshore	12
Nuclear	various generation II reactor types	16
Biomass	various	18
Solar thermal	parabolic trough	22
Geothermal	hot dry rock	45
Solar PV	Polycrystalline silicon	46
Natural gas	various combined cycle turbines without scrubbing	469
Coal	various generator types without scrubbing	1001

See also

- Cost of electricity by source
- World energy consumption: the total energy used by all of human civilization.
- Distributed generation
- Electric power transmission
- Cogeneration: the use of a heat engine[1] or power station to generate electricity and useful heat at the same time.

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