Coal-fired power plant essay sample

A fossilfuel power station is a type of power station that burns fossil fuels such as coal, natural gas or petroleum (oil) to produce electricity. Central station fossilfuel power plants are designed on a large scale for continuous operation. In many countries, such plants provide most of the electrical energy used. Fossil fuel power stations have rotating machinery to convert the heat energy of combustion into mechanical energy, which then operates an electrical generator. The prime mover may be a steam turbine, a gas turbine or, in small plants, a reciprocating internal combustionengine. All plants use the energy extracted from expanding gas steam or combustion gases. A very few MHD generators have been built which directly convert the energy of moving hot gas into electricity.[citation needed] Byproducts of thermal power plant operation must be considered in their design and operation. Waste heat energy, which remains due to the finite efficiency of the Carnot, Rankine, or Diesel power cycle, is released directly to the atmosphere, directly to river or lake water, or indirectly to the atmosphere using a cooling tower with river or lake water used as a cooling medium.

The flue gas from combustion of the fossil fuels is discharged to the air. This gas contains carbon dioxide, water vapour, as well as substances such as nitrogen oxides (NOx), sulfur oxides (SOx), mercury, traces of other metals, and, for coalfired plants, fly ash. Solid waste ash from coalfired boilers must also be removed. Some coal ash can be recycled for building materials. [2] Fossil fueled power stations are major emitters of CO2, a greenhouse gas (GHG) which according to a consensus opinion of scientific organisations is a contributor to global warming as it has been observed over the last 100 years. Brown coal emits about 3 times as much CO2 as natural gas, and black coal emits about twice as much CO2 per unit of electric energy. Carbon capture and storage of emissions is not expected to be available on a commercial economically viable basis until government supported legislation is enacted.

Basic concepts

In a fossil fuel power plant the chemical energy stored in fossil fuels such as coal, fuel oil, natural gas or oil shale and oxygen of the airis converted successively into thermal energy, mechanical energy and, finally, electrical energy. Each fossil fuel power plant is a complex, customdesigned system. Construction costs, as of 2004, run to US$1, 300 per kilowatt, or $650 million for a 500 MWeunit[citation needed]. Multiple generating units may be built at a single site for more efficient use of land, natural resources and labour. Most thermal power stations in the world use fossil fuel, outnumbering nuclear, geothermal, biomass, or solar thermal plants. Heat into mechanical energy

The second law of thermodynamics states that any closedloop cycle can only convert a fraction of the heat produced during combustion into mechanical work. The rest of the heat, called waste heat, must be released into a cooler environment during the return portion of the cycle. The fraction of heat released into a cooler medium must be equal or larger than the ratio of absolute temperaturesof the cooling system (environment) and the heat source (combustion furnace). Raising the furnace temperature improves the efficiency but complicates the design, primarily by the selection of alloys used for construction, making the furnace more expensive. The waste heat cannot be converted into mechanical energy without an even cooler cooling system.

However, it may be used in cogenerationplants to heat buildings, produce hot water, or to heat materials on an industrial scale, such as in some oil refineries, plants, andchemical synthesis plants. Typical thermal efficiency for electrical generators in the industry is around 33% for coal and oilfired plants, and 56 – 60% (LHV) forcombinedcycle gasfired plants. Plants designed to achieve peak efficiency while operating at capacity will be less efficient when operating offdesign (i. e. temperatures too low.)[3] The Carnot cycle is the theoretically most efficient closed thermodynamic cycle for conversion of heat energy into useful work, and practical fossilfuel stations cannot exceed this limit. In principle, fuel cells do not have the same thermodynamic limits as they are not heat engines.

Coal

The Grand Canal of China allows convenient access to this power station inYangzhou Coal is the most abundant fossil fuel on the planet. It is a relatively cheap fuel, with some of the largest deposits in regions that are relatively stable politically, such as China, India and the United States. This contrasts with natural gas and petroleum, the largest deposits of which are located in the politically volatile Persian Gulf. Solid coal cannot directly replace natural gas or petroleum in most applications, petroleum is mostly used for transportationand the natural gas not used for electricity generation is used for space, water and industrial heating. Coal can be converted to gas or liquid fuel, but the efficiencies and economics of such processes can make them unfeasible.[citation needed] Vehicles or heaters may require modification to use coalderived fuels. Coal can produce more pollution than petroleum or natural gas. As of 2009 the largest coalfired power station is Taichung Power Plant in Taiwan. The world’s most energyefficient coalfired power plant is the Avedøre Power Station inDenmark.[4] Fuel transport and delivery

Big Bend Coal Power Station in Apollo Beach, Florida in the United States.

Coalfired power plants provide about 46% of consumed electricity in the United States. This is the Castle Gate Plant near Helper, Utah. Coal is delivered by highway truck, rail, barge, collier ship or coal slurry pipeline. Some plants are even built near coal mines and coal is delivered by conveyors. A large coaltrain called a “ unit train” may be two kilometers (over a mile) long, containing 130140 cars with 100 short tons of coal in each one, for a total load of over 15, 000 tons. A large plant under full load requires at least one coal delivery this size every day. Plants may get as many as three to five trains a day, especially in “ peak season” during the hottest summer or coldest winter months (depending on local climate) when power consumption is high. A large thermal power plant such as the one in Nanticoke, Ontario stores several million metric tons of coal for winter use when the lakes are frozen. Modern unloaders use rotary dump devices, which eliminate problems with coal freezing in bottom dump cars.

The unloader includes a train positioner arm that pulls the entire train to position each car over a coal hopper. The dumper clamps an individual car against a platform that swivels the car upside down to dump the coal.

Swiveling couplers enable the entire operation to occur while the cars are still coupled together. Unloading a unit train takes about three hours. Shorter trains may use railcars with an “ airdump”, which relies on air pressure from the engine plus a “ hot shoe” on each car. This “ hot shoe” when it comes into contact with a “ hot rail” at the unloading trestle, shoots an electric charge through the air dump apparatus and causes the doors on the bottom of the car to open, dumping the coal through the opening in the trestle. Unloading one of these trains takes anywhere from an hour to an hour and a half. Older unloaders may still use manually operated bottomdump rail cars and a “ shaker” attached to dump the coal. Generating stations adjacent to a mine may receive coal by conveyor belt or massive dieselelectricdrive trucks.

A collier (cargo ship carrying coal) may hold 40, 000 long tons of coal and takes several days to unload. Some colliers carry their own conveying equipment to unload their own bunkers; others depend on equipment at the plant. Colliers are large, seaworthy, selfpowered ships. For transporting coal in calmer waters, such as rivers and lakes, flatbottomed vessels called barges are often used. Barges are usually unpowered and must be moved by tugboats or towboats. For start up or auxiliary purposes, the plant may use fuel oil as well. Fuel oil can be delivered to plants by pipeline, tanker, tank car or truck. Oil is stored in vertical cylindrical steel tanks with capacities as high as 90, 000 barrels (14, 000 m3)’ worth. The heavier no. 5 “ bunker” and no. 6 fuels are typically steamheated before pumping in cold climates. Plants fueled by natural gas are usually built adjacent to gas transport pipelines or have dedicated gas pipelines extended to them. Fuel processing

Coal is prepared for use by crushing the rough coal to pieces less than 2 inches (5 cm) in size. The coal is then transported from the storage yard to inplant storage silos by rubberized conveyor belts at rates up to 4, 000 short tons per hour. In plants that burn pulverized coal, silos feed coal pulverizers (coal mills) that take the larger 2inch (51 mm) pieces, grind them to the consistency of face powder, sort them, and mix them with primary combustion air which transports the coal to the boiler furnace and preheats the coal in order to drive off excess moisture content. A 500 MWe plant may have six such pulverizers, five of which can supply coal to the furnace at 250 tons per hour under full load. In plants that do not burn pulverized coal, the larger 2inch (51 mm) pieces may be directly fed into the silos which then feed either mechanical distributors that drop the coal on a traveling grate or the cyclone burners, a specific kind of combustor that can efficiently burn larger pieces of fuel.

Steamelectric

Main article: Thermal power station

Most electric power made from fossil fuel is produced by thermal power stations. Reciprocating steam engines fell out of use rapidly after the first steam turbines were introduced around 1906.

Gas turbine plants

480 megawatt GE H series power generation gas turbine

Currant Creek Power Plant near Mona, Utah is a natural gas fired electrical plant. One type of fossil fuel power plant uses a gas turbine in conjunction with aheat recovery steam generator (HRSG). It is referred to as a combined cyclepower plant because it combines the Brayton cycle of the gas turbine with theRankine cycle of the HRSG. The thermal efficiency of these plants has reached a record heat rate of 5690 Btu/(kW·h), or just under 60%, at a facility in Baglan Bay, Wales.[5] The turbines are fueled either with natural gas, syngas or fuel oil. While more efficient and faster to construct (a 1, 000 MW plant may be completed in as little as 18 months from start of construction), the economics of such plants is heavily influenced by the volatile cost of fuel, normally natural gas.

The combined cycle plants are designed in a variety of configurations composed of the number of gas turbines followed by the steam turbine. For example, a 31 combined cycle facility has three gas turbines tied to one steam turbine. The configurations range from (11), (21), (31), (41), (51), to (61)[citation needed] Simplecycle or open cycle gas turbine plants, without a steam cycle, are sometimes installed as emergency or peaking capacity; their thermal efficiency is much lower. The high running cost per hour is offset by the low capital cost and the intention to run such units only a few hundred hours per year. Other gas turbine plants are installed in stages, with an open cycle gas turbine the first stage and additional turbines or conversion to a closed cycle part of future project plans.

Reciprocating engines

Diesel engine generator sets are often used for prime power in communities not connected to a widespread power grid. Emergency (standby) power systems may use reciprocating internal combustion engines operated by fuel oil or natural gas. Standby generators may serve as emergency power for a factory or data center, or may also be operated in parallel with the local utility system to reduce peak power demand charge from the utility. Diesel engines can produce strong torque at relatively low rotational speeds, which is generally desirable when driving an alternator, but diesel fuel in longterm storage can be subject to problems resulting from water accumulation and chemical decomposition. Rarely used generator sets may correspondingly be installed as natural gas or LPG to minimize the fuel system maintenance requirements. Sparkignition internal combustion engines operating on gasoline (petrol), propane, or LPG are commonly used as portable temporary power sources for construction work, emergency power, or recreational uses. Reciprocating external combustion engines such as the Stirling engine can be run on a variety of fossil fuels, as well as renewable fuels or industrial waste heat. Installations of Stirling engines for power production are relatively uncommon.

Environmental impacts

The Mohave Power Station, a 1, 580 MW coal power station near Laughlin, Nevada, out of service since 2005 due to environmental restrictions[6] See also: Environmental impact of the coal industry

The world’s power demands are expected to rise 60% by 2030.[7] In 2007 there were over 50, 000 active coal plants worldwide and this number is expected to grow.[8] In 2004, the International Energy Agency (IEA) estimated that fossil fuels will account for 85% of the energy market by 2030.[7] World organizations and international agencies, like the IEA, are concerned about the environmental impact of burning fossil fuels, and coal in particular. The combustion of coal contributes the most to acid rain and air pollution, and has been connected with global warming. Due to the chemical composition of coal there are difficulties in removing impurities from the solid fuel prior to its combustion. Modern day coal power plants pollute less than older designs due to new “ scrubber” technologies that filter the exhaust air in smoke stacks; however emission levels of various pollutants are still on average several times greater than natural gas power plants. In these modern designs, pollution from coalfired power plants comes from the emission of gases such as carbon dioxide, nitrogen oxides, and sulfur dioxide into the air. Acid rain is caused by the emission of nitrogen oxides and sulfur dioxide.

These gases may be only mildly acidic themselves, yet when they react with the atmosphere, they create acidic compounds such as sulfurous acid, nitric acid and sulfuric acid which fall as rain, hence the term acid rain. In Europe and the U. S. A., stricter emission laws and decline in heavy industries have reduced the environmental hazards associated with this problem, leading to lower emissions after their peak in 1960s.

Main article: Carbon dioxide

Electricity generation using carbon based fuels is responsible for a large fraction of carbon dioxide (CO2) emissions worldwide and for 34% of U. S. manmade carbon dioxide emissions in 2010. In the U. S., 70% of electricity generation is produced from combustion of fossil fuels.[10] Of the fossil fuels, coal is more carbon intensive than oil or natural gas, resulting in greater volumes of carbon dioxide emissions per unit of electricity generated. In 2010, coal contributed about 81% of CO2 emissions from generation and contributed about 45% of the electricity generated in the

United States.[11] In 2000, the carbon intensity of U. S. coal thermal combustion was (2249 lbs/MWh.[12]) while the carbon intensity of U. S. oil thermal generation was (1672 lb/(MW·h)[13] or 211 kg/GJ) and the carbon intensity of U. S. natural gas thermal production was 1135 lb/(MW·h) (143 kg/GJ).[14])

The Intergovernmental Panel on Climate Change (see IPCC) states that carbon dioxide is a greenhouse gas and that increased quantities within the atmosphere will " very likely" lead to higher average temperatures on a global scale (global warming); concerns regarding the potential for such warming to change the global climate prompted IPCC recommendations calling for large cuts to CO2emissions worldwide.[15] Emissions may be reduced through more efficient and higher combustion temperature and through more efficient production of electricity within the cycle. Carbon capture and storage (CCS) of emissions from coalfired power stations is another alternative but the technology is still being developed and will increase the cost of fossil fuelbased production of electricity. CCS may not be economically viable, unless the price of emitting CO2 to the atmosphere rises. Particulate matter

Another problem related to coal combustion is the emission of particulates that have a serious impact on public health. Power plants remove particulate from the flue gas with the use of a bag house or electrostatic precipitator. Several newer plants that burn coal use a different process, Integrated Gasification Combined Cycle in which synthesis gas is made out of a reaction between coal and water. The synthesis gas is processed to remove most pollutants and then used initially to power gas turbines. Then the hot exhaust gases from the gas turbines are used to generate steam to power a steam turbine. The pollution levels of such plants are drastically lower than those of “ classic” coal power plants.[16] Particulate matter from coalfired plants can be harmful and have negative health impacts. Studies have shown that exposure to particulate matter is related to an increase of respiratory and cardiac mortality.[17] Particulate matter can irritate small airways in the lungs, which can lead to increased problems with asthma, chronic bronchitis, airway obstruction, and gas exchange.[17] There are different types of particulate matter, depending on the chemical composition and size.

The dominant form of particulate matter from coalfired plants is coal fly ash, but secondary sulfate and nitrate also comprise a major portion of the particulate matter from coalfired plants.[18] Coal fly ash is what remains after the coal has been combusted, so it consists of the incombustible materials that are found in the coal.[19] The size and chemical composition of these particles affects the impacts on human health.[17][18] Currently coarse (diameter greater than 2. 5 μm) and fine (diameter between 0. 1 μm and 2. 5 μm) particles are regulated, but ultrafine particles (diameter less than 0. 1 μm) are currently unregulated, yet they pose many dangers.[17] Unfortunately much is still unknown as to which kinds of particulate matter pose the most harm, which makes it difficult to come up with adequate legislation for regulating particulate matter.[18] There are several methods of helping to reduce the particulate matter emissions from coalfired plants. Roughly 80% of the ash falls into an ash hopper, but the rest of the ash then gets carried into the atmosphere to become coalfly ash.[19] Methods of reducing these emissions of particulate matter include: 1. a baghouse

2. an electrostatic precipitator (ESP)
3. cyclone collector

The baghouse has a fine filter that collects the ash particles, electrostatic precipitators use an electric field to trap ash particles on highvoltage plates, and cyclone collectors use centrifugal force to trap particles to the walls.[19] A recent study indicates that sulfur emissions from fossil fueled power stations in China may have caused a 10year lull in global warming (19982008)[20] Radioactive trace elements

Coal is a sedimentary rock formed primarily from accumulated plant matter, and it includes many inorganic minerals and elements which were deposited along with organic material during its formation. As the rest of the Earth's crust, coal also contains low levels ofuranium, thorium, and other naturally occurring radioactive isotopes whose release into the environmentleads to radioactive contamination. While these substances are present as very small trace impurities, enough coal is burned that significant amounts of these substances are released. A 1, 000 MW coalburning power plant could have an uncontrolled release of as much as 5. 2 metric tons per year of uranium (containing 74 pounds (34 kg) of uranium235) and 12. 8 metric tons per year of thorium.[21] In comparison, a 1, 000 MW nuclear plant will generate about 30 short tons of highlevel radioactive solid packed waste per year.[22] It is estimated that during 1982, US coal burning released 155 times as much uncontrolled radioactivity into the atmosphere as the Three Mile Island incident.[23]

The collective radioactivity resulting from all coal burning worldwide between 1937 and 2040 is estimated to be 2, 700, 000 curies or 0. 101 EBq.[21] It should also be noted that during normal operation, the effective dose equivalent from coal plants is 100 times that from nuclear plants.[21] But it is also worth noting that normal operation is a deceiving baseline for comparison: just the Chernobyl nuclear disaster released, in iodine131 alone, an estimated 1. 76 EBq .[24] of radioactivity, a value one order of magnitude above this value for total emissions from all coal burned within a century. But at the same time, it shall also be understood that the iodine131, the major radioactive substance which comes out in accident situations has a half life of just 8 days. Hence, it is not going to cause as much as damage as the uranium and thorium which are released from coalfired power plants which have much higher halflives. Also, the risk of exposure to I131 can largely be mitigated by the consumption of iodine tablets. Water and air contamination by coal ash

A study released in August 2010 that examined state pollution data in the United States by the organizations Environmental Integrity Project, the Sierra Club and Earthjustice found that coal ash produced by coalfired power plants dumped at sites across 21 U. S. states has contaminated ground water with toxic elements. The contaminants including the poisons arsenic and lead.[25] Arsenic has been shown to cause skin cancer, bladder cancer and lung cancer, and lead damages the nervous system.[26] Coal ash contaminants are also linked to respiratory diseases and other health and developmental problems, and have disrupted local aquatic life.[25]

Coal ash also releases a variety of toxic contaminants into nearby air, posing a health threat to those who breath in fugitive coal dust. [26] Currently, the EPA does not regulate the disposal of coal ash; regulation is up to the states and the electric power industry has been lobbying to maintain this status quo. Most states require no monitoring of drinking water near coal ash dump sites. The study found an additional 39 contaminated U. S. sites and concluded that the problem of coal ashcaused water contamination is even more extensive in the United States than has been estimated. The study brought to 137 the number of ground water sites across the United States that are contaminated by power plantproduced coal ash.[25] Mercury contamination

Main article: Mercury (element)

U. S. government scientists tested fish in 291 streams around the country for mercury contamination. They found mercury in every fish tested, according to the study by the U. S. Department of the Interior. They found mercury even in fish of isolated rural waterways. Twenty five percent of the fish tested had mercury levels above the safety levels determined by the U. S. Environmental Protection Agency for people who eat the fish regularly. The largest source of mercury contamination in the United States is coalfueled power plant emissions.