Program : **B.Tech**

Subject Name: **Energy & Environmental Engineering**

Subject Code: **ES-301**

Semester: **3rd**

Unit 1

Introduction to Energy Science:

Introduction to energy systems and resources; Introduction to Energy, sustainability & the environment; Overview of energy systems, sources, transformations, efficiency, and storage; Fossil fuels (coal, oil, oil-bearing shale and sands, coal gasification) - past, present & future, Remedies & alternatives for fossil fuels - biomass, wind, solar, nuclear, wave, tidal and hydrogen; Sustainability and environmental trade-offs of different energy systems; possibilities for energy storage or regeneration (Ex. Pumped storage hydro power projects, superconductor-based energy storages, high efficiency batteries)

Energy

Energy is the capacity to do work and is required for life processes. An energy resource is something that can produce heat, power life, move objects, or produce electricity. Matter that stores energy is called a fuel. Human energy consumption has grown steadily throughout human history. Early humans had modest energy requirements, mostly food and fuel for fires to cook and keep warm. In today's society, humans consume as much as 110 times as much energy per person as early humans. Most of the energy we use today comes from fossil fuels (stored solar energy). But fossils fuels have a disadvantage in that they are non-renewable on a human time scale, and because other potentially harmful effects on the environment. In any event, the exploitation of all energy sources (with the possible exception of direct solar energy used for heating), ultimately rely on materials on planet Earth.

Sustainability & The Environment

The definition of "sustainability" is the study of how natural systems function, remain diverse and produce everything it needs for the ecology to remain in balance. It also acknowledges that human civilization takes resources to sustain our modern way of life. The Three Pillars of Sustainability.

Economic Development

This is the issue that proves the most problematic as most people disagree on political ideology what is and is not economically sound, and how it will affect businesses and by extension, jobs and employability. It is also about providing incentives for businesses and other organizations to adhere to sustainability guidelines beyond their normal legislative requirements. Also, to encourage and foster incentives for the average person to do their bit where and when they can; one person can rarely achieve much, but taken as a group, effects in some areas are cumulative. The supply and demand market is consumerist in nature and modern life requires a lot of resources every single day; for the sake of the environment, getting what we consume under control is the paramount issue. Economic development is about giving people what they want without compromising quality of life, especially in the developing world, and reducing the financial burden and "red tape" of doing the right thing.

Social Development

There are many facets to this pillar. Most importantly is awareness of and legislation protection of the health of people from pollution and other harmful activities of business and other organizations. In North America, Europe and the rest of the developed world, there are strong checks and programmers of legislation in place to ensure that people's health and wellness is strongly protected. It is also about maintaining access to basic resources without compromising the quality of life. The biggest hot topic for many people right now is sustainable housing and how we can better build the homes we live in from sustainable material. The final element is education - encouraging people to participate in environmental sustainability and teaching them about the effects of environmental protection as well as warning of the dangers if we cannot achieve our goals.

Environmental Protection

We all know what we need to do to protect the environment, whether that is recycling, reducing our power consumption by switching electronic devices off rather than using standby, by walking short journeys instead of taking the bus. Businesses are regulated to prevent pollution and to keep their own carbon emissions low. There are incentives to installing renewable power sources in our homes and businesses. Environmental protection is the third pillar and to many, the primary concern of the future of humanity. It defines how we should study and protect ecosystems, air quality, integrity and sustainability of our resources and focusing on the elements that place stress on the environment.

Primary Goals of Sustainability

- The end of poverty and hunger
- Better standards of education and healthcare - particularly as it pertains to water quality and better sanitation
- To achieve gender equality
- Sustainable economic growth while promoting jobs and stronger economies
- All of the above and more while tackling the effects of climate change, pollution and other environmental factors that can harm and do harm people's health, livelihoods and lives.
- Sustainability to include health of the land, air and sea

Energy Sources

There are 5 fundamental sources of energy:

1. Nuclear fusion in the Sun (solar energy)
2. Gravity generated by the Earth & Moon.
3. Nuclear fission reactions.
4. Energy in the interior of the Earth.
5. Energy stored in chemical bonds.

Other than this it can be classified in two broad terms:-

1. Renewable resources
   a. Solar energy
   b. Wind energy
   c. Geothermal energy
   d. Hydropower energy
   e. Biomass
   f. Hydrogen and fuel cells
2. Non renewable Resources
   a. Nuclear energy
   b. Fuel energy (Coal/ Petroleum)

1. Renewable resources-: A renewable resource is a resource which can be used repeatedly and replaced naturally. Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally

replenished). In 2008, about 19% of global final energy consumption came from renewable, with 13% coming from traditional biomass, which is mainly used for heating, and 3.2% from hydroelectricity. New renewable (small hydro, modern biomass, wind, solar, geothermal, and bio-fuels) accounted for another 2.7% and are growing very rapidly. The share of renewable in electricity generation is around 18%, with 15% of global electricity coming from hydroelectricity and 3% from new renewable.

Types of Renewable resources

1. Solar. This form of energy relies on the nuclear fusion power from the core of the Sun. This energy can be collected and converted in a few different ways. The range is from solar water heating with solar collectors or attic cooling with solar attic fans for domestic use to the complex technologies of direct conversion of sunlight to electrical energy using mirrors and boilers or photovoltaic cells. Unfortunately these are currently insufficient to fully power our modern society.

2. Wind The movement of the atmosphere is driven by differences of temperature at the Earth's surface due to varying temperatures of the Earth's surface when lit by sunlight. Wind energy can be used to pump water or generate electricity, but requires extensive areal coverage to produce significant amounts of energy.

3. Hydroelectric energy this form uses the gravitational potential of elevated water that was lifted from the oceans by sunlight. It is not strictly speaking renewable since all reservoirs eventually fill up and require very expensive excavation to become useful again. At this time, most of the available locations for hydroelectric dams are already used in the developed world.

4. Biomass is the term for energy from plants. Energy in this form is very commonly used throughout the world. Unfortunately the most popular is the burning of trees for cooking and warmth. This process releases copious amounts of carbon dioxide gases into the atmosphere and is a major contributor to unhealthy air in many areas. Some of the more modern forms of biomass energy are methane generation and production of alcohol for automobile fuel and fueling electric power plants.

5. Hydrogen and fuel cells these are also not strictly renewable energy resources but are very abundant in availability and are very low in pollution when utilized. Hydrogen can be burned as a fuel, typically in a vehicle, with only water as the combustion product. This clean burning fuel can mean a significant reduction of pollution in cities. Or the hydrogen can be used in fuel cells, which are similar to batteries, to power an electric motor. In either case significant production of hydrogen requires abundant power. Due to the need for energy to produce the initial hydrogen gas, the result is the relocation of pollution from the cities to the power plants. There are several promising methods to produce hydrogen, such as solar power, that may alter this picture drastically.

6. Geothermal power Energy left over from the original accretion of the planet and augmented by heat from radioactive decay seeps out slowly everywhere, everyday. In certain areas the geothermal gradient (increase

in temperature with depth) is high enough to exploit to generate electricity. This possibility is limited to a few locations on Earth and many technical problems exist that limit its utility. Another form of geothermal energy is Earth energy, a result of the heat storage in the Earth's surface. Soil everywhere tends to stay at a relatively constant temperature, the yearly average, and can be used with heat pumps toheat a building in winter and cool a building in summer. This form of energy can lessen the need for other power to maintain comfortable temperatures in buildings, but cannot be used to produce electricity.

2. Non renewable Resources
    1. Nuclear Fission Reactions Radioactive Uranium is concentrated and made into fuel rods that generate large amounts of heat as a result of radioactive decay. This heat is used to turn water into steam. Expansion of the steam can then be used to drive a turbine and generate electricity. Once proposed as a cheap, clean, and safe way to generate energy, Nuclear power has come under some disfavor. Costs of making sure nuclear power plants are clean and safe and the problem of disposing of radioactive wastes, which are unsafe, as well as questions about the safety of the plants under human care, has contributed to this disfavor.
    2. Energy in the Interior of the Earth Decay of radioactive elements has produced heat throughout Earth history. It is this heat that causes the temperature to increase with depth in the Earth and is responsible for melting of mantle rocks to form magmas. Magmas can carry the heat upward into the crust. Groundwater circulating in the vicinity of igneous intrusions carries the heat back toward the surface. If this hot water can be tapped, it can be used directly to heat homes, or if trapped at great depth under pressure it can be turned into steam which will expand.
    3. Fossil Fuels The origin of fossil fuels and biomass energy in general, starts with photosynthesis. Photosynthesis is the most important chemical reaction to us as human beings, because without it, we could not exist. Photosynthesis is the reaction that combines water and carbon dioxide from the Earth and its atmosphere with solar energy to form organicmolecules that make up plants and oxygen essential for respiration. Because all life forms depend on plants for nourishment, either directly or indirectly, photosynthesis is the basis for life on Earth.Thus when oxygen is added to organic material, either through decay by reaction with oxygen in the atmosphere, or by adding oxygen directly by burning, energy is produced, and water and carbon dioxide return to the Earth or its atmosphere.
    4. Petroleum To produce a fossil fuel, the organic matter must be rapidly buried in the Earth so that it does not oxidize (react with oxygen in the atmosphere). Then a series of slow chemical reactions occur which turn the organic molecules into hydrocarbons- Oil and Natural Gas, together called Petroleum. Hydrocarbons are complex organic molecules that consist of chains of hydrogen and carbon.

Energy transformation

Energy transformation also termed as energy conversion, is the process of changing energy from one of its forms into another. In physics, energy is a quantity that provides the capacity to perform many actions—think of lifting or warming an object. In addition to being convertible, energy is transferable to a different location or object, but it cannot be created or destroyed. Energy in many of its forms may be used in natural processes, or to provide some service to society such as heating, refrigeration, lightening or performing mechanical work to operate machines. For example, in order to heat your home, your furnace can burn fuel, whose chemical potential energy is thus converted into thermal energy, which is then transferred to your home's air in order to raise its temperature.

Conversion of thermal energy to other types:-

Conversions to thermal energy (thus raising the temperature) from other forms of energy, may occur with essentially 100% efficiency[citation needed] (many types %, such as when potential energy is converted to kinetic energy as an object falls in vacuum, or when an object orbits nearer or farther from another object, in space.

Though, conversion of thermal energy to other forms, thus reducing the temperature of a system, has strict limitations, often keeping its efficiency much less than 100% (even when energy is not allowed to escape from the system). This is because thermal energy has already been partly spread out among many available states of a collection of microscopic particles constituting the system, which can have enormous numbers of possible combinations of momentum and position (these combinations are said to form a phase space). In such circumstances, a measure called entropy, or evening-out of energy distributions, dictates that future states of an isolated system must be of at least equal evenness in energy distribution. In other words, there is no way to concentrate energy without spreading out energy somewhere else.

Transformation of kinetic energy of charged particles to electric energy:-

In order to make the energy transformation more efficient, it is desirable to avoid the thermal conversion. For example, the efficiency of nuclear energy reactors, where kinetic energy of nuclei is first converted to thermal energy and then to electric energy, lies around 35%.By direct conversion of kinetic energy to electric, i.e. by eliminating the thermal energy transformation, the efficiency of energy transformation process can be dramatically improved.

Energy Transformation From The Early Universe

Energy transformations in the universe over time are (generally) characterized by various kinds of energy which has been available since the Big Bang, later being "released" (that is, transformed to more active types of energy such as kinetic or radiant energy), when a triggering mechanism is available to do it.

- Release of energy from gravitational potential
- Release of energy from radioactive potential
- Release of energy from hydrogen fusion potential

Examples of sets of energy conversions in machines

- For instance, a coal-fired power plant involves these energy transformations:
- Chemical energy in the coal converted to thermal energy in the exhaust gases of combustion.

- Thermal energy of the exhaust gases converted into thermal energy of steam through the heat exchanger.
- Thermal energy of steam converted to mechanical energy in the turbine.
- Mechanical energy of the turbine converted to electrical energy by the generator, which is the ultimate output
- In such a system, the first and fourth step are highly efficient, but the second and third steps are less efficient. The most efficient gas-fired electrical power stations can achieve 50% conversion efficiency. Oil- and coal-fired stations achieve less.

In a conventional automobile, these energy transformations are involved:

- Chemical energy in the fuel converted to kinetic energy of expanding gas via combustion
- Kinetic energy of expanding gas converted to linear piston movement
- Linear piston movement converted to rotary crankshaft movement
- Rotary crankshaft movement passed into transmission assembly
- Rotary movement passed out of transmission assembly
- Rotary movement passed through differential
- Rotary movement passed out of differential to drive wheels
- Rotary movement of drive wheels converted to linear motion of the vehicle.

Energy storage

Energy storage is the capture of energy produced at one time for use at a later time. A device that stores energy is sometimes called an accumulator or battery. Energy comes in multiple forms including radiation, chemical, gravitational potential, electrical potential, electricity, elevated temperature, latent heat and kinetic. Energy storage involves converting energy from forms that are difficult to store to more conveniently or economically storable forms. Bulk energy storage is currently dominated by hydroelectric dams, both conventional as well as pumped.

Some technologies provide short-term energy storage, while others can endure for much longer.

A wind-up clock stores potential energy (in this case mechanical, in the spring tension), a rechargeable battery stores readily convertible chemical energy to operate a mobile phone, and a hydroelectric dam stores energy in a reservoir as gravitational potential energy. Fossil fuels such as coal and gasoline store ancient energy derived from sunlight by organisms that later died, became buried and over time were then converted into these fuels. Food (which is made by the same process as fossil fuels) is a form of energy stored in chemical form.

Ice storage tanks store ice frozen by cheaper energy at night to meet peak daytime demand for cooling. The energy isn't stored directly, but the work-product of consuming energy (pumping away heat) is stored, having the equivalent effect on daytime consumption.

Fossile fuel:-

a fossil fuel is a fuel formed by natural processes, such as anaerobic decomposition of buried dead organisms, containing energy originating in ancient photosynthesis. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 650 million years. Fossil fuels contain high percentages of carbon and include petroleum, coal, and natural gas. Other commonly used derivatives include kerosene and propane. Fossil fuels range from volatile materials with low carbon to hydrogen ratios like methane, to liquids like petroleum, to non-volatile materials composed of almost pure carbon, like anthracite coal. Methane can be found in hydrocarbon fields either alone, associated with oil, or in the form of methane catharses.

Advantages of Fossil Fuels

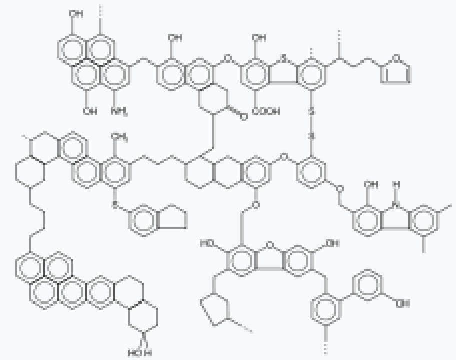
- A major advantage of fossil fuels is their capacity to generate huge amounts of electricity in just a single location.
- Fossil fuels are very easy to find.
- When coal is used in power plants, they are very cost effective. Coal is also in abundant supply.
- Transporting oil and gas to the power stations can be made through the use of pipes making it an easy task.
- Power plants that utilize gas are very efficient.
- Power stations that make use of fossil fuel can be constructed in almost any location. This is possible as long as large quantities of fuel can be easily brought to the power plants.

Disadvantages of Fossil Fuels

- Pollution is a major disadvantage of fossil fuels. This is because they give off carbon dioxide when burned thereby causing a greenhouse effect. This is also the main contributory factor to the global warming experienced by the earth today.
- Coal also produces carbon dioxide when burned compared to burning oil or gas. Additionally, it gives off sulphur dioxide, a kind of gas that creates acid rain.
- Environmentally, the mining of coal results in the destruction of wide areas of land. Mining this fossil fuel is also difficult and may endanger the lives of miners. Coal mining is considered one of the most dangerous jobs in the world.
- Power stations that utilize coal need large amounts of fuel. In other words, they not only need truckloads but trainloads of coal on a regular basis to continue operating and generating electricity. This only means that coal-fired power plants should have reserves of coal in a large area near the plants location.
- Use of natural gas can cause unpleasant odors and some problems especially with transportation.
- Use of crude oil causes pollution and poses environmental hazards such as oil spills when oil tankers, for instance, experience leaks or drown deep under the sea. Crude oil contains toxic chemicals which cause air pollutants when combusted.

Coal is a combustible black or brownish-black sedimentary rock usually occurring in rock strata in layers or veins called coal beds or coal seams. The harder forms, such as anthracite coal, can be regarded as metamorphic rock because of later exposure to elevated temperature and pressure. Coal is composed primarily of carbon, along with variable quantities of other elements, chiefly hydrogen, sulfur, oxygen, and nitrogen.[1] Coal is a fossil fuel that forms when dead plant matter is converted into peat, which in turn is converted into lignite, then sub-bituminous coal, after that bituminous coal, and lastly anthracite. This involves biological and geological processes. The geological processes take place over millions of years.

Formation

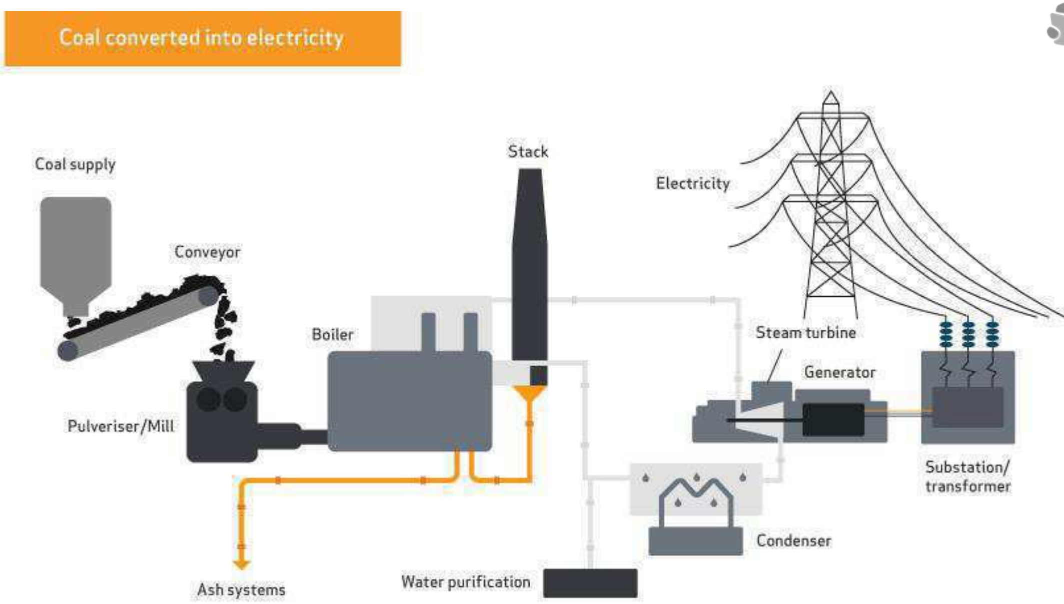


Example chemical structure of coal

At various times in the geologic past, the Earth had dense forests[8] in low-lying wetland areas. Due to natural processes such as flooding, these forests were buried underneath soil. As more and more soil deposited over them, they were compressed. The temperature also rose as they sank deeper and deeper. As the process continued the plant matter was protected from biodegradation and oxidation, usually by mud or acidic water. This trapped the carbon in immense peat bogs that were eventually covered and deeply buried by sediments. Under high pressure and high temperature, dead vegetation was slowly converted to coal. As coal contains mainly carbon, the conversion of dead vegetation into coal is called carbonization

Production of electricity from coal

Steam coal, also known as thermal coal, is used in power stations to generate electricity. Coal is first milled to a fine powder, which increases the surface area and allows it to burn more quickly. In these pulverised coal combustion (PCC) systems, the powdered coal is blown into the combustion chamber of a boiler where it is burnt at high temperature (see diagram). The hot gases and heat energy produced converts water – in tubes lining the boiler – into steam.
The high pressure steam is passed into a turbine containing thousands of propeller-like blades. The steam pushes these blades causing the turbine shaft to rotate at high speed. A generator is mounted at one end of the turbine shaft and consists of carefully wound wire coils. Electricity is generated when these are rapidly rotated in a strong magnetic field. After passing through the turbine, the steam is condensed and returned to the boiler to be heated once again.
The electricity generated is transformed into the higher voltages (up to 400,000 volts) used for economic, efficient transmission via power line grids. When it nears the point of consumption, such as our homes, the electricity is transformed down to the safer 100-250 voltage systems used in the domestic market.



Efficiency improvements

Improvements continue to be made in conventional PCC power station design and new combustion technologies are being developed. These allow more electricity to be produced from less coal - known as improving the thermal efficiency of the power station. Efficiency gains in electricity generation from coal-fired power stations will play a crucial part in reducing CO2 emissions at a global level. A one percentage point improvement in the efficiency of a conventional pulverised coal combustion plant results in a 2-3% reduction in CO2 emissions.

Shale oil

Shale oil is unconventional oil produced from oil shale rock fragments by pyrolysis, hydrogenation, or thermal dissolution. These processes convert the organic matter within the rock (kerogen) into synthetic oil and gas. The resulting oil can be used immediately as a fuel or upgraded to meet refinery feedstock specifications by adding hydrogen and removing impurities such as sulfur and nitrogen. The refined products can be used for the same purposes as those derived from crude oil.

The term "shale oil" is also used for crude oil produced from shale's of other very low permeability formations. However, to reduce the risk of confusion of shale oil produced from oil shale with crude oil in oil-bearing shale's, the term "tight oil" is preferred for the latter.

Shale oil extraction

Shale oil is extracted by pyrolysis, hydrogenation, or thermal dissolution of oil shale. The pyrolysis of the rock is performed in a retort, situated either above ground or within the rock formation itself. As of 2008, most oil shale industries perform the shale oil extraction process after the rock is mined, crushed and transported to a retorting facility, although several experimental technologies perform the process in place (in-situ). The temperature at which the kerogen decomposes into usable hydrocarbons varies with the time-scale of the process; in the above-ground retorting process decomposition begins at 300 °C (570 °F), but proceeds

more rapidly and completely at higher temperatures. Decomposition takes place most quickly at a temperature between 480 and 520 °C (900 and 970 °F).

Hydrogenation and thermal dissolution (reactive fluid processes) extract the oil using hydrogen donors, solvents, or a combination of these. Thermal dissolution involves the application of solvents at elevated temperatures and pressures, increasing oil output by cracking the dissolved organic matter. Different methods produce shale oil with different properties.

Properties of Shale

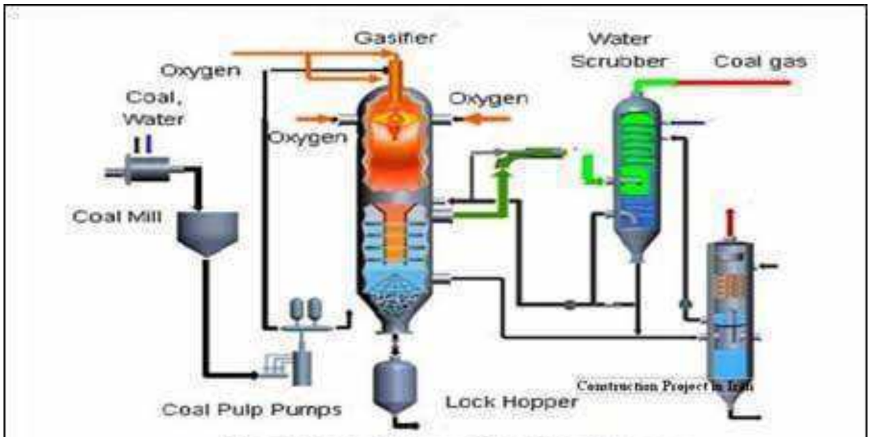
Properties of raw shale oil vary depending on the composition of the parent oil shale and the extraction technology used. Like conventional oil, shale oil is a complex mixture of hydrocarbons, and it is characterized using bulk properties of the oil. Shale oil usually contains large quantities of olefinic and aromatic hydrocarbons. Shale oil can also contain significant quantities of heteroatoms. A typical shale oil composition includes 0.5–1% of oxygen, 1.5–2% of nitrogen and 0.15–1% of sulfur, and some deposits contain more heteroatoms. Mineral particles and metals are often present as well. Generally, the oil is less fluid than crude oil, becoming pourable at temperatures between 24 and 27 °C (75 and 81 °F), while conventional crude oil is pourable at temperatures between −60 to 30 °C (−76 to 86 °F); this property affects shale oil's ability to be transported in existing pipelines

Coal Gasification

Coal gasification is the process of producing syngas–a mixture consisting primarily of carbon monoxide (CO), hydrogen (H_2), carbon dioxide (CO_2), methane (CH_4), and water vapour (H_2O)–from coal and water, air and/or oxygen.

coal was gasified using early technology to produce coal gas (also known as "town gas"), which is a combustible gas traditionally used for municipal lighting and heating before the advent of industrial-scale production of natural gas.

In current practice, large-scale instances of coal gasification are primarily for electricity generation, such as in integrated gasification combined cycle power plants, for production of chemical feedstocks, or for production of synthetic natural gas. The hydrogen obtained from coal gasification can be used for various purposes such as making ammonia, powering a hydrogen economy, or upgrading fossil fuels.



Coal Water Slurry Gasifier Process

During gasification, the coal is blown through with oxygen and steam (water vapor) while also being heated (and in some cases pressurized). If the coal is heated by external heat sources the process is called "allothermal", while "autothermal" process assumes heating of the coal via exothermal chemical reactions occurring inside the gasifier itself. It is essential that the oxidizer supplied is insufficient for complete oxidizing (combustion) of the fuel. During the reactions mentioned, oxygen and water molecules oxidize the coal and produce a gaseous mixture of carbon dioxide (CO_2), carbon monoxide (CO), water vapour (H_2O), and molecular hydrogen (H_2). (Some by-products like tar, phenols, etc. are also possible end products, depending on the specific gasification technology utilized.) This process has been conducted in-situ within natural coal seams (referred to as underground coal gasification) and in coal refineries. The desired end product is usually syngas (i.e., a combination of H_2 + CO), but the produced coal gas may also be further refined to produce additional quantities of H_2:

$$3C \text{ (i.e., coal)} + O_2 + H_2O \rightarrow H_2 + 3CO$$

If the refiner wants to produce alkanes (i.e., hydrocarbons present in natural gas, gasoline, and diesel fuel), the coal gas is collected at this state and routed to a Fischer-Tropsch reactor. If, however, hydrogen is the desired end-product, the coal gas (primarily the CO product) undergoes the water gas shift reaction where more hydrogen is produced by additional reaction with water vapor:

$$CO + H_2O \rightarrow CO_2 + H_2$$

Although other technologies for coal gasification currently exist, all employ, in general, the same chemical processes. For low-grade coals (i.e., "brown coals") which contain significant amounts of water, there are technologies in which no steam is required during the reaction, with coal (carbon) and oxygen being the only reactants. As well, some coal gasification technologies do not require high pressures. Some utilize pulverized coal as fuel while others work with relatively large fractions of coal. Gasification technologies also vary in the way the blowing is supplied.

"Direct blowing" assumes the coal and the oxidizer being supplied towards each other from the opposite sides of the reactor channel. In this case the oxidizer passes through coke and (more likely) ashes to the reaction zone where it interacts with coal. The hot gas produced then passes fresh fuel and heats it while absorbing some products of thermal destruction of the fuel, such as tars and phenols. Thus, the gas requires significant refining before being used in the Fischer-Tropsch reaction. Products of the refinement are highly toxic and require special facilities for their utilization. As a result, the plant utilizing the described technologies has to be very large to be economically efficient. One of such plants called SASOL is situated in the Republic of South Africa (RSA). It was built due to embargo applied to the country preventing it from importing oil and natural gas. RSA is rich in Bituminous coal and Anthracite and was able to arrange the use of the well known high pressure "Lurgi" gasification process developed in Germany in the first half of 20th century.

"Reversed blowing" (as compared to the previous type described which was invented first) assumes the coal and the oxidizer being supplied from the same side of the reactor. In this case there is no chemical interaction between coal and oxidizer before the reaction zone. The gas produced in the reaction zone passes solid products of gasification (coke and ashes), and CO_2 and H_2O contained in the gas are additionally chemically restored to CO and H_2. As compared to the "direct blowing" technology, no toxic by-products are present in the gas: those are disabled in the reaction zone.

Underground coal gasification

Underground coal gasification is an industrial gasification process, which is carried out in non-mined coal seams using injection of a gaseous oxidizing agent, usually oxygen or air, and bringing the resulting product gas to surface through production wells drilled from the surface. The product gas could to be used as a chemical feedstock or as fuel for power generation. The technique can be applied to resources that are otherwise not economical to extract and also offers an alternative to conventional coal mining methods for some resources. Compared to traditional coal mining and gasification, UCG has less environmental and social impact, though some concerns including potential for aquifer contamination are known

Carbon capture technology

Carbon capture, utilization, and sequestration (or storage) is increasingly being utilized in modern coal gasification projects to address the greenhouse gas emissions concern associated with the use of coal and carbonaceous fuels. In this respect, gasification has a significant advantage over conventional coal combustion, in which CO_2 resulting from combustion is considerably diluted by nitrogen and residual oxygen in the near-ambient pressure combustion exhaust, making it relatively difficult, energy-intensive, and expensive to capture the CO_2 (this is known as “post-combustion” CO_2 capture).

CO_2 capture technology options

All coal gasification-based conversion processes require removal of hydrogen sulfide (H_2S; an acid gas) from the syngas as part of the overall plant configuration. Typical acid gas removal (AGR) processes employed for gasification design are either a chemical solvent system (e.g., amine gas treating systems based on MDEA, for example) or a physical solvent system (e.g., Rectisol or Selexol). Process selection is mostly dependent on the syngas cleanup requirement and costs. Conventional chemical/physical AGR processes using MDEA, Rectisol or Selexol are commercially proven technologies and can be designed for selective removal of CO_2 in addition to H_2S from a syngas stream. For significant capture of CO_2 from a gasification plant (e.g., > 80%) the CO in the syngas must first be converted to CO_2 and hydrogen (H_2) via a water-gas-shift (WGS) step upstream of the AGR plant.

For gasification applications, or IGCC, the plant modifications required to add the ability to capture CO_2 are minimal. The syngas produced by the gasifiers needs to be treated through various processes for the removal of impurities already in the gas stream, so all that is required to remove CO_2 is to add the necessary equipment, an absorber and regenerator, to this process train. In combustion applications, smodifications must be done to the exhaust stack and because of the lower concentrations of CO_2 present in the exhaust, much larger volumes of total gas require processing, necessitating larger and more expensive equipment.

By-products

he by-products of coal gas manufacture included coke, coal tar, sulfur and ammonia; all useful products. Dyes, medicines, including sulfa drugs, saccharin and many organic compounds are therefore derived from coal gas.

Coke is used as a smokeless fuel and for the manufacture of water gas and producer gas. Coal tar is subjected to fractional distillation to recover various products, including

- tar, for roads
- benzole, a motor fuel
- creosote, a wood preservative

- phenol, used in the manufacture of plastics
- cresols, disinfectants

Sulfur is used in the manufacture of sulfuric acid and ammonia is used in the manufacture of fertilisers.

Indian Scenario

India is one of the countries where the present level of energy consumption, by world standards, is very low. The estimate of annual energy consumption in India is about 330 Million Tones Oil Equivalent (MTOE) for the year 2004. Accordingly, the per capita consumption of energy is about 305 Kilogram Oil Equivalent (KGOE). As compared to this, the energy consumption in some of the other countries is of the order of over 4050 for Japan, over 4275 for South Korea, about 1200 for China, about 7850 for USA, about 4670 for OECD countries and the world average is about 1690.

In so far as electricity consumption is concerned, India has reached a level of about 600-kilowatt hour (kwh) per head per year. The comparable figures for Japan are about 7,800, for South Korea about 7,000, for China about 1380, for USA about 13,000, for OECD countries about 8050 and world average are about 2430. Thus, both in terms of per capita energy consumption and in terms of per capita electricity consumption, India is far behind many countries, and as a matter of fact, behind even the world average. Therefore, to improve the standards of living of Indian people and to let them enjoy the benefit of economic development, it is imperative that both energy consumption and electricity consumption level is enhanced. India is targeting a growth rate of 9 – 10%, having already reached a level of almost 8%. To sustain the double-digit growth rate for next 10-15 years, it would be essential that the level of energy availability and consumption, and electricity consumption in particular, is enhanced substantially.In the profile of energy sources in India, coal has a dominant position. Coal constitutes about 51% of India's primary energy resources followed by Oil (36%), Natural Gas (9%), Nuclear (2%) and Hydro (2%). To address the issue concerning energy consumption, and more particularly, the need for enhancing the energy supply, India has accorded appropriate priority to both - supply side management and demand side management.

Non-Conventional Energy Sources

	Potential (MW)	Existing capacity (MW)
Wind	45,000	4,400
Small Hydro (upto 25 MW)	15,000	1,700
Solar (PV)	20 MW/Sq.Km	Very little
Biogas plants	12 million	3.8 million
Urban/Industrial waste based plant	2,700	Very little

Indian Government has accorded very high priority to develop and expand installed capacity base through non-conventional sources of electricity generation. There is a separate Ministry in the Government of India to exclusively focus on this important area of power generation. National Electricity Policy notified in 2005 in pursuance of the Electricity Act, 2003, prescribes that State Electricity Regulatory Commissions should prescribe a proportion of power which should be produced and supplied to the grid through the non-conventional sources. Some of the Regulatory Commissions have come out with specific policy guidelines with a different approach on tariff for these plants in order to encourage these technologies and plants. National Electricity Tariff Policy mandates that State Commissions should fix such minimum percentage latest by April, 2006. India has very high potential for these capacities:

It may be seen from the above that India has achieved substantial success on wind turbine based power generation. Ministry of Non-conventional Energy Sources (MNES) has set a target of achieving at least 10,000 MW capacity through various non-conventional sources, by the year 2012.

Conventional Sources of Electricity Generation

Fossil fuel based thermal power, hydro-electric, and nuclear constitute the conventional sources of power. Non-conventional sources are less than 5% of total installed capacity in India. The present installed capacity (as in March 2006) is about 1,25,000 MW, consisting of coal based plants (56%), gas based plants (10%), hydro-electric (26%), nuclear (3%) non-conventional (5%).

Indian Power Sector was opened up for private power generation in 1991. In terms of ownership structure, the profile consists of Central Government owned companies (32%), State Government owned companies/Electricity Boards (57%) and Private Sector (11%). 100% FDI is permitted in all segments of electricity industry – viz. Generation, Transmission, Distribution, Trading.

In the last three years far-reaching structural changes have been introduced in the Indian Electricity Sector. Electricity Act 2003 is an historic legislative initiative with powerful potential to transform the power sector industry and market structure.

Most important features of the Electricity Act 2003 are as follows:

1. The Act creates a liberal and transparent framework for power development
2. It facilitates investment by creating competitive environment and reforming distribution segment of power industry.
3. Entry Barriers have been removed/reduced in following areas:
   a) Delicensed generation.
   b) Freedom to captive generation including group captive
   c) Recognizing trading as an independent activity
   d) Open access in transmission facilitating multi buyer and seller model.
   4. Open access to consumers above 1 MW within five years commencing from 27th January, 2004 (date of enforcement of amendment to Electricity Act) Regulators have been mandated to ensure this.
   5. Multiple licenses in distribution in the same area of supply so that competition could yield better services to consumers.
   6. Regulatory Commissions – to develop market and to fix tariff.

Biomass Energy

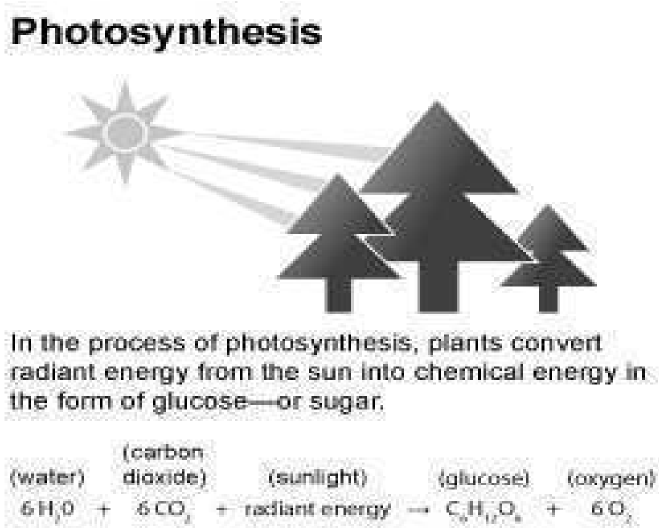
Renewable energy from plants and animals/ biomass is a renewable energy source from living or recently living plant and animal materials which can be used as fuel. An example of biomass is plant material that produces electricity with steam. An example of biomass is animal fossil fuel.

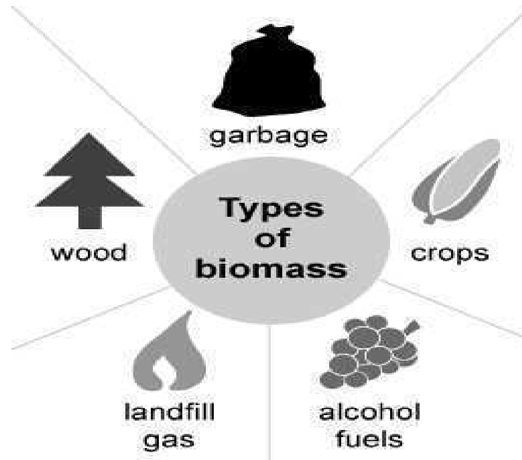
Biomass is organic material that comes from plants and animals, and it is a renewable source of energy.

Biomass contains stored energy from the sun. Plants absorb the sun's energy in a process called photosynthesis. When biomass is burned, the chemical energy in biomass is released as heat. Biomass can be burned directly or converted to liquid biofuels or biogas that can be burned as fuels.

Or

Biomass energy is the energy which is contained inside plants and animals. This can include organic matter of all kinds: plants, animals, or waste products from organic sources. These sorts of energy sources are known as biofuels and typically include wood chips, rotted trees, manure, sewage, mulch, and tree components. Chlorophyll present in plants absorbs carbon dioxide from the atmosphere and water from the ground through the process of photosynthesis. The same energy is passed to animals when they eat them. It is considered to be as renewable source of energy because carbon dioxide and water contained inside plants and animals are released back in to the atmosphere when they are burned and we can grow more plants and crops to create biomass energy.





<u>Types of Biomass</u>

We use four types of biomass today: 1) wood and agricultural products; 2) solid waste; 3) landfill gas; and 4) alcohol fuels.

1. Wood and Agricultural Biomass:- Most biomass used today is home grown energy. Wood-logs, chips, bark, and sawdust-accounts for about 79 percent of biomass energy. But any organic matter can produce biomass energy. Other biomass sources include agricultural waste products like fruit pits and corn cobs.

2. Solid Waste:- There is nothing new about people burning trash. What's new is burning trash to generate electricity. This turns waste into a usable form of energy. A ton (2,000 pounds) of garbage contains about as much heat energy, as pounds of coal. Power plants that burn garbage for energy are called waste-to-energy plants. These plants generate electricity much as coal-fired plants do except that garbage-not coal-is the fuel used to fire an industrial boiler. Making electricity from garbage costs more than making it from coal and other energy sources. The main advantage of burning solid waste is it reduces the amount of garbage dumped in landfills by 60 to 90 percent, and reduces the cost of landfill disposal.

3. Landfill Gas:- Bacteria and fungi are not picky eaters. They eat dead plants and animals, causing them to rot or decay. Even though this natural process is slowed in the artificial environment of a landfill, a substance called methane gas is still produced as the waste decays. New regulations require landfills to collect methane gas for safety and environmental reasons. Methane gas is colorless and odorless, but it is not harmless. The gas can cause fires or explosions if it seeps into nearby homes and is ignited. Landfills can collect the methane gas, purify it, and then use it as an energy source. Methane, which is the same thing as natural gas, is a good energy source. Most gas furnaces and

gas stoves use methane supplied by natural gas utility companies. The city landfill in Florence, Alabama recovers 32 million cubic feet of methane gas a day. The city purifies the gas and then pumps it into natural gas pipelines.

4. Alcohol Fuels:- Wheat, corn, and other crops can be converted into a variety of liquid fuels including ethanol and methanol. Using ethanol as a motor fuel is nothing new. Its use is almost as old as the automobile. Gasohol does have some advantages over gasoline. It has a higher octane rating than gasoline (provides your car with more power), and it is cleaner-burning than unleaded gasoline, with one-third less carbon monoxide emissions. Gasohol may also help reduce America's dependence on foreign oil.

Sources of Biomass

Here are various biomass sources, which are a great source of energy that can be used for various applications:

1) Wood and waste wood: Wood is the most commonly used type of biomass. Since the earliest days the fuel being used for cooking and heating is the wood. Even at present wood as the biomass material is major source of energy in a number of developing countries.

Wood as a biomass can be used in various forms like large wooden blocks obtained from the trees, wooden chips, and saw dust. The wasted wood and wooden scrap are also the source of biomass.

2) Leaves of the plants: In the densely planted places lots of leaves fall from the trees. These can be dried, powdered and converted into small pieces, which can be used as the biomass fuel to generate heat used usually for cooking food.

3) Broken branches and twigs of the trees: No part of the plant goes wasted when it leaves the main body of the tree. Large and small branches and even all the small twigs are the source of biomass energy.

4) Agricultural waste: Lots of waste materials obtained from the farms are a great source of biomass materials. Livestock waste can also be used to generate methane gas.

5) Waste paper: Tons of waste paper is produced every day. These can be burnt to produce lots of heat. The paper is manufactured from the plants, so it is considered to be biomass material.

6) Garbage: The garbage, also called as municipal solid waste is another source of biomass. The garbage can be in the form of food scrap, lawn clippings, waste paper, fallen leaves etc all mixed together or collected individually.

7) Human waste: The human wastes are also considered to the source of biomass. These can used to generate methane gas which is the major component of natural gas.

Biomass Gasification

Biomass gasification, or producing gas from biomass, involves burning biomass under restricted air supply for the generation of producer gas. Producer gas is a mixture of gases:

18%–22% carbon monoxide (CO), 8%–12% hydrogen (H2), 8%–12% carbon dioxide (CO2), 2%–4% methane (CH4) and 45%–50% nitrogen (N2) making up the rest.

Gasification reactions

Producing gas from biomass consists of the following main reactions, which occur inside a biomass gasifier.

1. Drying: Biomass fuels usually contain 10%–35% moisture. When biomass is heated to about 100 °C, the moisture is converted into steam.
2. Pyrolysis: After drying, as heating continues, the biomass undergoes pyrolysis. Pyrolysis involves burning biomass completely without supplying any oxygen. As a result, the biomass is decomposed or separated into solids, liquids, and gases. Charcoal is the solid part, tar is the liquid part, and flue gases make up the gaseous part.
3. Oxidation: Air is introduced into the gasifier after the decomposition process. During oxidation, which takes place at about 700–1,400 °C, charcoal, or the solid carbonized fuel, reacts with the oxygen in the air to produce carbon dioxide and heat.

$$C + O_2 \rightarrow CO_2 + \text{heat}$$

4. Reduction: At higher temperatures and under reducing conditions, that is when not enough oxygen is available, the following reactions take place forming carbon dioxide, hydrogen, and methane.

$$C + CO_2 \rightarrow 2\,CO$$
$$C + H_2O \rightarrow CO + H_2$$
$$CO + H_2O \rightarrow CO_2 + H_2$$
$$C + 2H_2 \rightarrow CH_4$$

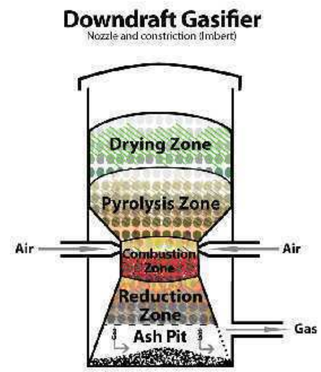
Types of gasifiers

Gasifiers can be classified based on the density factor, which is a ratio of the solid matter (the dense phase) a gasifier can burn to the total volume available. Gasifiers can be
(a) dense phase reactors, or (b) lean phase reactors.

Dense phase reactors

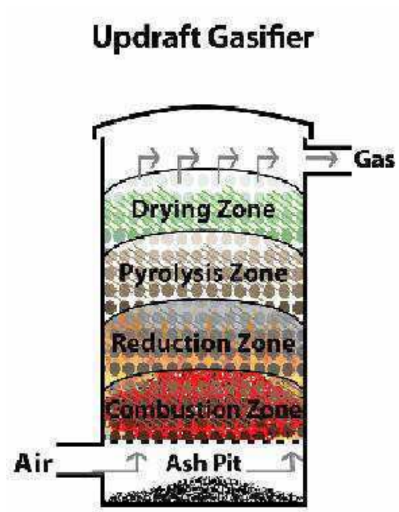
In dense phase reactors, the feedstock fills most of the space in the reactor. They are common, available in different designs depending upon the operating conditions, and are of three types: downdraft, updraft, and cross-draft.

1. Downdraft or co-current gasifiers:- The downdraft (also known as co-current) gasifier is the most common type of gasifier. In downdraft gasifiers, the pyrolysis zone is above the combustion zone and the reduction zone is below the combustion zone. Fuel is fed from the top. The flow of air and gas is downwards (hence the name) through the combustion and reduction zones. The term co-current is used because air moves in the same direction as that of fuel, downwards. A downdraft gasifier is so designed that tar, which is produced in the pyrolysis zone, travels through the combustion zone, where it is broken down or burnt. As a result, the mixture of gases in the exit stream is relatively clean. The position of the combustion zone is thus a critical element in the downdraft gasifier, its main advantage being that it produces gas with low tar content, which is suitable for gas engines.



<u>**Updraft or counter-current gasifier**</u>

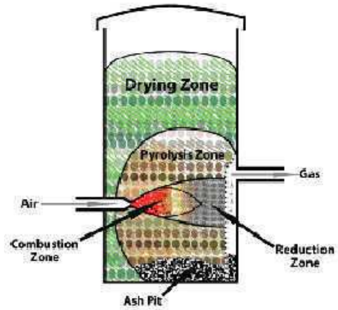
In updraft gasifiers (also known as counter-current), air enters from below the grate and flows upwards, whereas the fuel flows downwards. An updraft gasifier has distinctly defined zones for partial combustion, reduction, pyrolysis, and drying. The gas produced in the reduction zone leaves the gasifier reactor together with the products of pyrolysis from the pyrolysis zone and steam from the drying zone. The resulting combustible producer gas is rich in hydrocarbons (tars) and, therefore, has a higher calorific value, which makes updraft gasifiers more suitable where heat is needed, for example in industrial furnaces. The producer gas needs to be thoroughly cleaned if it is to be used for generating electricity.



<u>**Cross-draft gasifier**</u>

In a cross-draft gasifier, air enters from one side of the gasifier reactor and leaves from the other. Cross-draft gasifiers have a few distinct advantages such as compact construction and low cleaning requirements. Also, cross-draft gasifiers do not need a grate; the ash falls to the bottom and does not come in the way of normal operation.

Crossdraft Gasifier

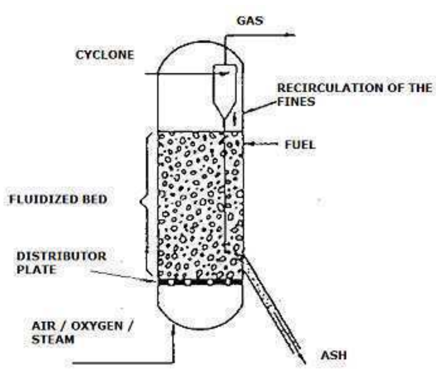


Lean phase reactors

Lean phase gasifiers lack separate zones for different reactions. All reactions – drying, combustion, pyrolysis, and reduction – occur in one large reactor chamber. Lean phase reactors are mostly of two types, fluidized bed gasifiers and entrained-flow gasifiers.

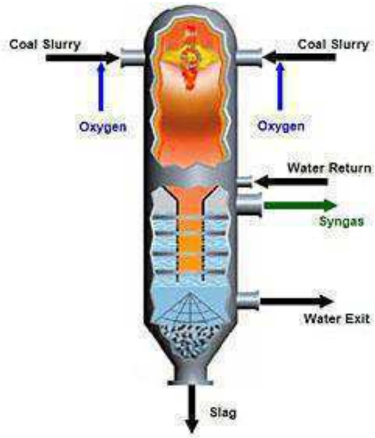
Fluidized bed gasifiers

In fluidized bed gasifiers, the biomass is brought into an inert bed of fluidized material (e.g. sand, char, etc.). The fuel is fed into the fluidized system either above-bed or directly into the bed, depending upon the size and density of the fuel and how it is affected by the bed velocities. During normal operation, the bed media is maintained at a temperature between 550 °C and 1000 °C. When the fuel is introduced under such temperature conditions, its drying and pyrolyzing reactions proceed rapidly, driving off all gaseous portions of the fuel at relatively low temperatures. The remaining char is oxidized within the bed to provide the heat source for the drying and devolatilizing reactions to continue. Fluidized bed gasifiers are better than dense phase reactors in that they produce more heat in short time due to the abrasion phenomenon between inert bed material and biomass, giving a uniformly high (800–1000 ºC) bed temperature. A fluidized bed gasifier works as a hot bed of sand particles agitated constantly by air. Air is distributed through nozzles located at the bottom of the bed.



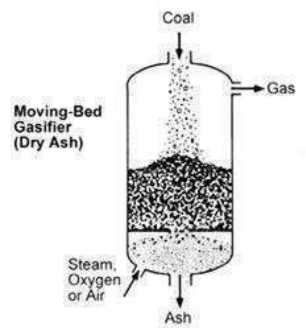
Entrained-flow gasifiers

In entrained-flow gasifiers, fuel and air are introduced from the top of the reactor, and fuel is carried by the air in the reactor. The operating temperatures are 1200–1600 °C and the pressure is 20–80 bar. Entrained-flow gasifiers can be used for any type of fuel so long as it is dry (low moisture) and has low ash content. Due to the short residence time (0.5–4.0 seconds), high temperatures are required for such gasifiers. The advantage of entrained-flow gasifiers is that the gas contains very little tar.

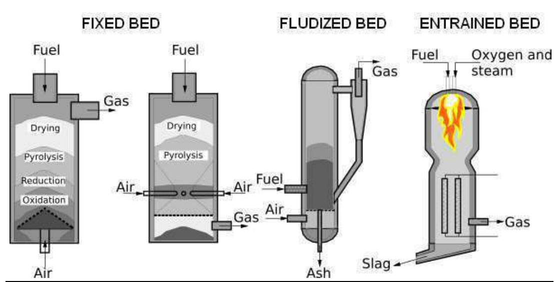


<u>The fixed bed</u>

The fixed bed gasification system consists of a reactor/gasifier with a gas cooling and cleaning system. The fixed bed gasifier has a bed of solid fuel particles through which the gasifying media and gas move either up or down. It is the simplest type of gasifier consisting of usually a cylindrical space for fuel feeding unit, an ash removal unit and a gas exit. In the fixed bed gasifier, the fuel bed moves slowly down the reactor as the gasification occurs. The fixed bed gasifiers are of simple construction and generally operate with high carbon conversion, long solid residence time, low gas velocity and low ash carry over. In fixed bed gasifiers, tar removal used to be a major problem, however recent progress in thermal and catalytic conversion of tar has given credible options.



<u>Comperitive diagram of gasifiers</u>



<u>Types Of Conversion Technologies</u>

There are four types of conversion technologies currently available, each appropriate for specific biomass? types and resulting in specific energy products:

1. **<u>Thermal conversion</u> is the use of heat, with or without the presence of oxygen, to convert biomass materials or feedstocks into other forms of energy. Thermal conversion technolgies include direct combustion, pyrolysis, and torrefaction.**

As the term implies, thermal conversion involves the use of heat as the primary mechanism for converting biomass into another form. Combustion, pyrolysis, torrefaction, and gasification are the basic thermal conversion technologies either in use today or being developed for the future.

1. Combustion

Direct combustion is the burning of biomass in the presence of oxygen. Furnaces and boilers are used typically to produce steam for use in district heating/cooling systems or to drive turbines to produce electricity. In a furnace, biomass burns in a combustion chamber converting the biomass into heat. The heat is distributed in the form of hot air or water. In a boiler, the heat of combustion is converted into steam. Steam can be used to produce electricity, mechanical energy, or heating and cooling. A boiler's steam contains 60-85% of the energy in biomass fuel.

Co-firing – This is a sub-set of combustion based power production. Some of the modern coal fired power plants use biomass for co-firing along with coal. It is quite efficient, cost-effective and requires moderate additional investment. In general, combustion efficiency of biomass can be 10 percentage points lower than for coal at the same installation, but co-firing efficiency in large-scale coal plants (35%-45%) is higher than the efficiency of biomass-dedicated plants. In the case of co-combustion of up to 5%-10% of biomass (in energy terms) only minor changes in the handling equipment are needed and the boiler is not noticeably de-rated.

2. Pyrolysis

These processes do not necessarily produce useful energy directly, but under controlled temperature and oxygen conditions are used to convert biomass feedstocks into gas, oil or forms of charcoal. These energy products are more energy dense than the original biomass, and therefore reduce transport costs, or have more predictable and convenient combustion characteristics allowing them to be used in internal combustion engines and gas turbines. Pyrolysis is a processes of subjecting a biomass feedstock to high temperatures (greater than 430 °C) under pressurized environments and at low oxygen levels. In the process, biomass undergoes partial combustion. Processes of pyrolysis result in liquid fuels and a solid residue called char, or biochar. Biochar is like charcoal and rich in carbon. Liquid phase products result from temperatures which are too low to destroy all of the carbon molecules in the biomass so the result is production of tars, oils, methanol, acetone, etc.

- The two main methods of pyrolysis are "fast" pyrolysis and "slow" pyrolysis. Fast pyrolysis yields 60% bio-oil, 20% biochar, and 20% syngas, and can be done in seconds, whereas slow pyrolysis can be optimized to produce substantially more char (~50%) along with organic gases, but takes on the order of hours to complete. In either case, the gas or oil can be used as a fuel for firing the boiler for steam production and subsequent power production.
- Typically pyrolysis plants work well beyond 2 MW scale, while gasification plants work well until 2 MW scale, at the current technological progress. Thus, it can be said that pyrolysis takes off where gasification ends.
- Slow Pyrolysis
- In the case of slow pyrolysis when you get an organic gas and charcoal. The gas can be cooled and fed to a gas engine for power production. Cooling this gas however results in a significant amount of hydrocarbons being removed. Thus most of the energy is wasted away. A more efficient idea that is being explored is to use this heterogeneous gas straight for combustion of boilers and running a steam cycle. Charcoal is a valuable product, which fetches anywhere between Rs 10-Rs 25 per Kg. It

has a much better calorific value than coal and people in many places use charcoal because coal might not be available in those places.

- Fast Pyrolysis
- Fast pyrolysis is a process in which organic materials are rapidly heated to 450 - 600°C in absence of air. Under these conditions, organic vapors, permanent gases and charcoal are produced. The vapors are condensed to pyrolysis oil. Typically, 50 - 75 wt % of the feedstock is converted into pyrolysis oil. The pyrolysis oil can be used as a replacement for furnace oil.

3. Torrefaction:- Like pyrolysis, is the conversion of biomass with the application of heat in the absence of oxygen, but at lower temperatures than those typically used in pyrolysis. In torrefaction temperatures typically range between 200-320 °C. In the torrefaction process water is removed and cellulose?, hemicellulose and lignins are partially decomposed. The final product is an energy dense solid fuel frequently referred to as “bio-coal”.

2. Thermochemical conversion is the application of heat and chemical processes in the production of energy products from biomass. A key thermochemical conversion process if gasification.

Gasification

Gasification is the use of high temperatures and a controlled environment that leads to nearly all of the biomass being converted into gas. This takes place in two stages: partial combustion to form producer gas and charcoal, followed by chemical reduction. These stages are spatially separated in the gasifier, with gasifier design very much dependant on the feedstock characteristics. Gasification requires temperatures of about 800°C. Gasification technology has existed since the turn of the century when coal was extensively gasified in the UK and elsewhere for use in power generation and in houses for cooking and lighting. A major future role is envisaged for electricity production from biomass plantations and agricultural residues using large scale gasifiers with direct coupling to gas turbines.

3. Biochemical conversion involves use of enzymes, bacteria or other microorganisms to break down biomass into liquid fuels, and includes anaerobic digestion, and fermentation.

Anaerobic digestion

Anaerobic digestion is the use of microorganisms in oxygen-free environments to break down organic material. Anaerobic digestion is widely used for the production of methane- and carbon-rich biogas from crop residues, food scraps, and manure (human and animal). Anaerobic digestion is frequently used in the treatment of wastewater and to reduce emissions from landfills. Anaerobic digestion involves a multi-stage process. First, bacteria are used in hydrolysis to break down carbohydrates, for example, into forms digestible by other bacteria. The second set of bacteria convert the resulting sugars and amino acids into carbon dioxide, hydrogen, ammonia and organic acids. Finally, still other bacterias convert these products into methane and carbon dioxide. Mixed bacterial cultures are characterized by optimal temperature ranges for growth. These mixed cultures allow digesters to be operated over a wide temperature range, for example, above 0° C and up to 60° C. When functioning well, the bacteria convert about 90% of the biomass feedstock into biogas (containing about 55% methane), which is a readily useable energy source. Solid remnants of the original biomass input are left over after the digestion process. This by-product, or digestate, has many potential uses. Potential uses include fertilizer (although it should be chemically assessed for toxicity and growth-inhibiting factors first), animal bedding and low-grade building products like fiberboard.

Fermentation

At its most basic, fermentation is the use of yeasts to convert carbohydrates into alcohol – most notably ethanol, also called bioethanol. The total process involves several stages. In the first stage crop materials are pulverized or ground and combined with water to form a slurry. Heat and enzymes are then applied to break down the ground materials into a finer slurry. Other enzymes are added to convert starches into glucose sugar. The sugary slurry is then pumped into a fermentation chamber to which yeasts are added. After about 48-50 hours, the fermented liquid is distilled to divide the alcohol from the solid materials left over.

3. Chemical conversion involves use of chemical agents to convert biomass into liquid fuels.

ADVANTAGES

1) Biomass used as a fuel reduces need for fossil fuels for the production of heat, steam, and electricity for residential, industrial and agricultural use.
2)Biomass is always available and can be produced as a renewable resource.
3)Biomass fuel from agriculture wastes maybe a secondary product that adds value to agricultural crop.
4)Growing Biomass crops produce oxygen and use up carbon dioxide.
5)The use of waste materials reduce landfill disposal and makes more space for everything else.
6)Carbon Dioxide which is released when Biomass fuel is burned, is taken in by plants.
7)Less money spent on foreign oil.

DISADVANTAGES

1)Agricultural wastes will not be available if the basic crop is no longer grown.
2)Additional work is needed in areas such as harvesting methods.
3)Land used for energy crops maybe in demand for other purposes, such as faming, conservation, housing, resort or agricultural use.
4)Some Biomass conversion projects are from animal wastes and are relatively small and therefore are limited.
5)Research is needed to reduce the costs of production of Biomass based fuels.
6)Is in some cases is a major cause of pollution.

Or

Advantages of Biomass Energy

In many ways, biomass is a new source of power. While wood has always served as a fuel source for fires and ovens and conventional heating methods, biomass energy advancements are a few steps beyond that. Now these biomass fuel products are harvested and mass-produced and used in everything from engines to power plants.

1. No Harmful Emissions: Biomass energy, for the most part, creates no harmful carbon dioxide emissions. Many energy sources used today struggle to control their carbon dioxide emissions, as these can cause harm to the ozone layer and increase the effects of greenhouse gases, potentially warming the planet. It is completely natural, has no such carbon dioxide side effects in its use.

2. Clean Energy: Because of its relatively clean use, biomass energy, when used in commercial businesses such as airlines, receives tax credit from the US government. This is good for the environment and good for business. It does release carbon dioxide but captures carbon dioxide for its own growth. Carbon dioxide released by fossil fuel are released into the atmosphere and are harmful to the environment.

3. Abundant and Renewable: Biomass products are abundant and renewable. Since they come from living sources, and life is cyclical, these products potentially never run out, so long as there is something living on earth and there is someone there to turn that living things components and waste products into energy. In the United Kingdom, biomass fuels are made from recycled chicken droppings. In the United States and Russia, there are plentiful forests for lumber to be used in the production of biomass energy.

4. Reduce Dependency on Fossil Fuels: It has developed as an alternate source of fuel for many homeowners and have helped them to reduce their dependency on fossil fuels.

5. Reduce Landfills: Another benefit of this energy is that it can take waste that is harmful to the environment and turn it into something useful. For instance, garbage as landfill can, at least partially, be burned to create useable biomass energy.

6. Can be used to Create Different Products: Biomass energy is also versatile, as different forms of organic matter can be used to create different products. Ethanol and similar fuels can be made from corn and other crops. With so many living things on the planet, there is no limit to how many ways it can be found and used.

Biomass energy power plant

Disadvantages of Biomass Energy

Besides above advantages, there are also some downsides to it. Let’s see below some of its disadvantages.

1. Expensive: Firstly, its expensive. Living things are expensive to care for, feed, and house, and all of that has to be considered when trying to use waste products from animals for fuel.

2. Inefficient as Compared to Fossil Fuels: Secondly, and connected to the first, is the relative inefficiency of biomass energy. Ethanol, as a biodiesel is terribly inefficient when compared to gasoline, and it often has to be mixed with some gasoline to make it work properly anyway. On top of that, ethanol is harmful to combustion engines over long term use.

3. Harmful to Environment: Thirdly, using animal and human waste to power engines may save on carbon dioxide emissions, but it increases methane gases, which are also harmful to the Earth’s— ozone layer. So really, we are no better off environmentally for using one or the other. And speaking of using waste products, there is the smell to consider. While it is not physically harmful, it is definitely unpleasant, and it can attract unwanted pests (rats, flies) and spread bacteria and infection.

4. Consume More Fuel: Finally, using trees and tree products to power machines is inefficient as well. Not only does it take a lot more fuel to do the same job as using conventional fuels, but it also creates environmental problems of its own. To amass enough lumber to power a nation full of vehicles or even a power plant, companies would have to clear considerable

forest area. This results in major topological changes and destroys the homes of countless animals and plants.

5. Require More Land: Combustion of biomass products require some land where they can easily be burnt. Since, it produces gases like methane in atmosphere; therefore it can be produced in those areas which are quite far from residential homes.

Wind – Energy

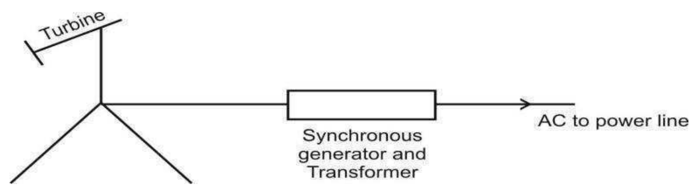


Fig. 1.3 (A): Wind Power Direct Feed to Main Power line

Wind result from air in motion due to pressure gradient. Wind is basically caused by the solar energy irradiating the earth. This is why wind utilization is considered a part of solar technology.

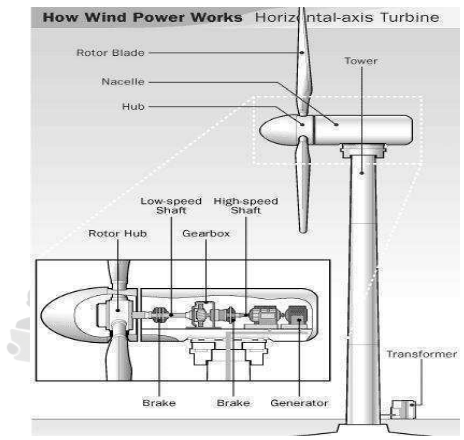


Fig. 1.3 (B): Wind Power Direct Feed to Main Power line

Energy of wind can be economically used for the generation of electrical energy.

Winds are caused from two main factors:

1) Heating and cooling of the atmosphere which generates convection currents.
   Heating is caused by the absorption of solar energy on the earth's surface and in the atmosphere.
2) The rotation of the earth with respect to atmosphere and its motion around the sun. Wind mill consists of wind turbine head, transmission and another supporting structure. Wind energy conversion devices like wind turbines are used for converting wind energy into mechanical energy.
   Wind turbine consists basically of a few sails, vans and blades radiating from a central axis when wind blows against the blades or vans they rotate about the axis. The rotational motion is utilized to perform some useful work. By connecting the wind turbine to an electric generator wind energy can be converted into electric energy. Wind densities upto 10 KW/m^3/day are available. More than 20,000 MW electricity can be generated in India from wind.

Three factors which determine the output from a wind energy converter:

1. The wind speed.
2. The Cross-section of wind swept by rotor.
3. Conversion efficiency of the rotor transmission system and generator or pump.

   A. Horizontal axis

B. Vertical axis

Wind power is the use of air flow through wind turbines to mechanically power generators for electric power. Wind power, as an alternative to burning fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation, consumes no water, and uses little land.[2] The net effects on the environment are far less problematic than those of nonrenewable power sources.

Wind farms consist of many individual wind turbines which are connected to the electric power transmission network. Onshore wind is an inexpensive source of electric power, competitive with or in many places cheaper than coal or gas plants.[3][4][5]Offshore wind is steadier and stronger than on land, and offshore farms have less visual impact, but construction and maintenance costs are considerably higher. Small onshore wind farms can feed some energy into the grid or provide electric power to isolated off-grid locations.

Wind power gives variable power which is very consistent from year to year but which has significant variation over shorter time scales. It is therefore used in conjunction with other electric power sources to give a reliable supply. As the proportion of wind power in a region increases, a need to upgrade the grid, and a lowered ability to supplant conventional production can occur. Power management techniques such as having excess capacity, geographically distributed turbines, dispatchable backing sources, sufficient hydroelectric power, exporting and importing power to neighboring areas, or reducing demand when wind production is low, can in many cases overcome these problems. In addition, weather forecasting permits the electric power network to be readied for the predictable variations in production that occur.

Wind turbines mainly are of two types: vertical axis(VAWT) and horizontal axis(HAWT). HAWT are the most common type of wind turbines built across the world. VAWT is a type of wind turbine which have two or three blades and in which the main rotor shaft runs vertically. They are however used less frequently as they are not as effective as HAWT.
The Vertical Axis Wind Turbine (VAWT) is the most popular of the turbines that people are adding to make their home a source of renewable energy. While it is not as commonly used as the Horizontal Axis Wind Turbine, they are great for placement at residential locations and more. Here we will take a look at the VAWT, and fill you in on the pros and the cons as well as other important information that will alleviate stress and headache when you simply want to do your part to keep the environment protected.

Vertical turbines spin on the vertical axis and comes in various shapes sizes and colors. It's movement is similar to a coin spinning on the edge. The main difference between the VAWT and HAWT is the position of blades. In HAWT, blades are on the top, spinning in the air while in VAWT, generator is mounted at the base of the tower and blades are wrapped around the shaft. Vertical Axis Wind Turbines are designed to be economical and practical, as well as quiet and efficient. They are great for use in residential areas whereas the HAWT is best for use at a business location. There are two different styles of vertical wind turbines out there. One is the Savonius rotor, and the second is the Darrieus model. The first model looks like a 55 gallon drum that is been cut in half with the halves placed onto a rotating shaft. The second model is smaller and looks much like an egg beater. Most of the wind turbines being used today are the Savonius models. We will take a look more in- depth at both of these types of turbines available.
A wind turbine secures air into a hub, which them turns into a generator. The air that passes through the blades of the wind turbine is spun into the generator through rotational momentum. The VAWT, as the turbines are oftener shortened, feature the following qualities:

- **Two to three blades with a vertically operating main rotor shaft – the more blades that you have on the unit, the more wind energy it will receive and the more efficiency it will offer**
- **Used less frequently than a horizontal wind turbine**
- **The position of the blades is different in the VAWT. On this model, the base of the tower holds the generator, and the blades then wrap themselves around the shaft. People use the VAWT because they can be placed closer to the ground, which makes them acceptable and effective for use at a residential location.**
- **With the vertical axis wind turbine, the rotor shaft is arranged in a vertical pattern**
- **The VAWT are easier and more affordable to maintain than horizontal units**
- **One complain that some users have with the VAWT is that is creates less wind energy, which may cause a number of different noises to be heart. Turbulent air flow is also a possibility that can shorten the life of the system.**
- **Installation of the VAWT onto the roof will cause the wind speed to double for maximum wind turbulence and wind energy usage.**

Types of Vertical Axis Wind Turbines

there are two different types of VAWTs that you can choose from. While we looked at these types briefly above, now we will take a look at more information about each type and discuss the important factors that you should know. First, let's take a look at the Darrieus wind turbine mode.

Darrieus Wind Turbine

Darrieus Wind Turbine is commonly known as an "Eggbeater" turbine. It was invented by Georges Darrieus in 1931. A Darrieus is a high speed, low torque machine suitable for generating alternating current (AC) electricity. Darrieus generally require manual push therefore some external power source to start turning as the starting torque is very low. Darrieus has two vertically oriented blades revolving around a vertical shaft.

The Darrieus wind turbine offers the following features:

- **These eggbeater shaped turbines are great at efficiency, however, they are not as reliable.**
- **In order to use the Darrieus wind turbine you must have an outside source of power in order to start them**
- **It is in your best interest to choose a wind turbine that has at least three blades.**
- **To support such a wind turbine it is necessary that you have a superstructure which will connect it near the top bearing.**

Savonius Wind Turbine: A Savonius vertical-axis wind turbine is a slow rotating, high torque machine with two or more scoops and are used in high-reliability low-efficiency power turbines. Most wind turbines use lift generated by airfoil-shaped blades to drive a rotor, the Savonius uses drag and therefore cannot rotate faster than the approaching wind speed. Now let's take a look at the second type, which is also the most popular of the two. The Savonius wind turbine is the most popular of the two types. Let's go ahead and look at some of the features these VAWT offer to the homeowner.

- **As a drag type of turbine, these units are less efficient.**
- **When you live in an area that has strong and gusting winds or when you need a unit that self-starts, this is the best type available to you.**
- **This unit is larger than the Darrieus model.**

Savonius vertical axis wind turbine needs to be manually started. The slow speed of Savonius increases cost and produces less efficiency.

Advantages of Vertical Axis Wind Turbines

You might be wondering why you would consider using a VAWT instead of a HAWT. There are actually a number of reasons that this decision is made. Let's take a look at some of the advantages that you can enjoy with this type of wind turbine in use at your home.

- You can build your wind turbine close to the ground so if you do not have a suitable rooftop for placement, or if you live where there are hills, ridges, etc. that prohibit the flow of air, they work wonderfully for your needs.
- Since VAWT are mounted closer to the ground they make maintenance easier, reduce the construction costs, are more bird friendly and does not destroy the wildlife.
- You do not need any mechanisms in order to operate the wind turbine
- Lower wind startup speed
- The main advantage of VAWT is it does not need to be pointed towards the wind to be effective. In other words, they can be used on the sites with high variable wind direction.
- You can use the wind turbine where tall structures are not allowed.
- VAWT's are quiet, efficient, economical and perfect for residential energy production, especially in urban environments.
- They are cost effective when compare to the HAWTs. It is still best to shop around and check prices before making a purchase, however.
- Many of the turbines are resistant to many of the different weather elements that you may experience. It is imperative to choose a unit that offers this valuable protection and extra durability when you need it the most.

Disadvantages of Vertical Axis Wind Turbines

There are also disadvantages that come with the use of this type of wind turbine. While the many advantages are certainly great, it is imperative that you are aware of the disadvantages. Before deciding which type of wind turbine is best for you it is good idea to take a look at both the pros and the cons. What is right for one person may not be right for you, although it is safe to say that a VAWT is great for almost any residential setting.

Let's take a look at some of the disadvantages of using a VAWT:

- Decreased level of efficiency when compared to the HAWT. The reason for the reduced amount of efficiency is usually due to the drag that occurs within the blades as they rotate.
- You are unable to take advantage of the wind speeds that occur at higher levels.
- VAWT's are very difficult to erect on towers, which means they are installed on base, such as ground or building.

Solar energy

Solar panels converts the sun's light in to usable solar energy using N-type and P-type semiconductor material. When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is

called the photovoltaic (PV) effect. Currently solar panels convert most of the visible light spectrum and about half of the ultraviolet and infrared light spectrum to usable solar energy. Solar energy technologies use the sun's energy and light to provide heat, light, hot water, electricity, and even cooling, for homes, businesses, and industry.
There are a variety of technologies that have been developed to take advantage of solar energy.

Solar Energy Technologies:

a) Solar Water heating.
b) Solar Heating of Building.
c) Solar – Distillation
d) Solar Furnaces
e) Solar Cooking
f) Solar Electric Power Generation (Photovoltaic System)
g) Solar Thermal Power Production.
h) Production of Power through Solar Ponds.

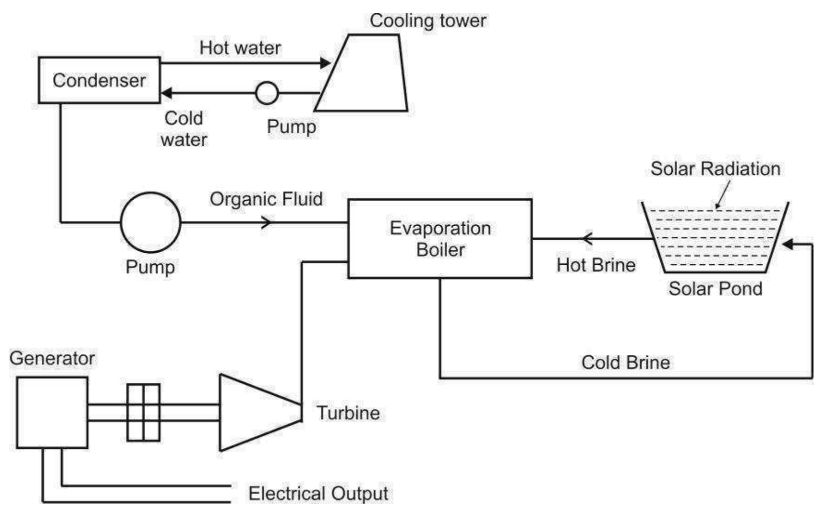


Fig. 1.2 : Solar Pond Electric Power Plant

- India receives 5000 Trillion KW/hr of sun shine in an year. India receives abundant sunshine with about 1648-2108 KWhr/m^2/yr with nearly 250-300 days of useful sunshine in a year. The daily solar energy incidence is between 4 to 7 KWhr/m^2.
- Energy radiated by the sun as electromagnetic waves (Wavelength 0.2 to 0.4 um).
- Due to absorption and scattering in the atmosphere the maximum flux density is 1 KW/sq.m. 45% energy in the form of visible rays and 44% as infra-red radiation.The enormous solar energy resource may be converted into other forms of energy through thermal photovoltaic conversion routes. The solar thermal route uses radiation in the form of heat in turn may be converted to mechanical.

1. Solar Water heating

Solar water heating (SWH) is the conversion of sunlight into heat for water heating using a solar thermal collector. A variety of configurations are available at varying cost to provide solutions in different climates and latitudes. SWHs are widely used for residential and some industrial applications.

A sun-facing collector heats a working fluid that passes into a storage system for later use. SWH are active (pumped) and passive (convection-driven). They use water only, or both water and a working fluid. They are heated directly or via light-concentrating mirrors. They operate independently or as hybrids with electric or gas heaters. In large-scale installations, mirrors may concentrate sunlight onto a smaller collector.

Active Solar Water Heating Systems

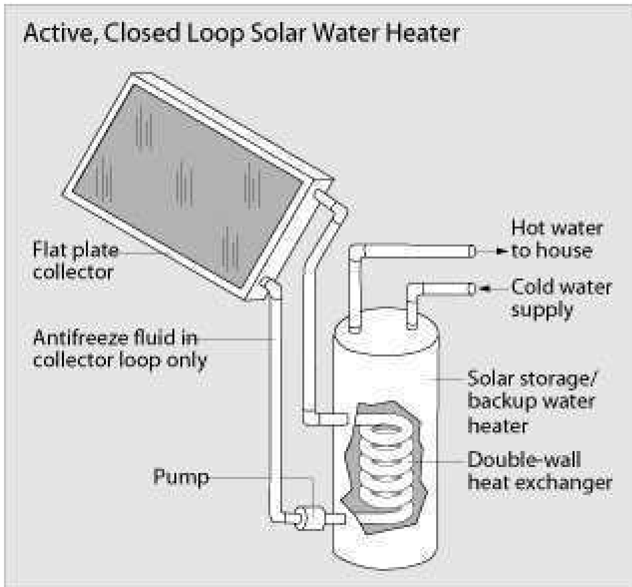
There are two types of active solar water heating systems:

Direct circulation systems

Pumps circulate household water through the collectors and into the home. They work well in climates where it rarely freezes.

Indirect circulation systems

Pumps circulate a non-freezing, heat-transfer fluid through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates prone to freezing temperatures.



Active Solar Heating System

Passive Solar Water Heating Systems

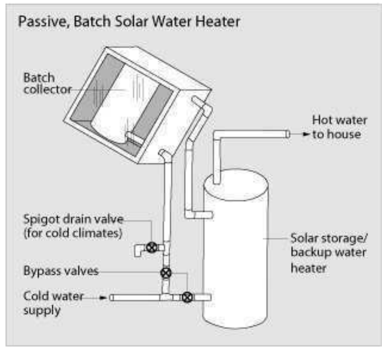
Passive solar water heating systems are typically less expensive than active systems, but they're usually not as efficient. However, passive systems can be more reliable and may last longer. There are two basic types of passive systems:

Integral collector-storage passive systems

These work best in areas where temperatures rarely fall below freezing. They also work well in households with significant daytime and evening hot-water needs.

Thermosyphon systems

Water flows through the system when warm water rises as cooler water sinks. The collector must be installed below the storage tank so that warm water will rise into the tank. These systems are reliable, but contractors must pay careful attention to the roof design because of the heavy storage tank. They are usually more expensive than integral collector-storage passive systems.



Passive Solar Water Heating Systems

Solar space heating systems are an effective and excellent way to reduce costly energy bills during your heating season.

A solar space heater works alongside your current heating system to use the sun's energy to reduce your consumption of oil, propane, or other fossil fuels.

Traditionally used with solar evacuated tube collectors, these systems work to provide free, solar heating for your home throughout your entire heating system. These solar heating systems can also be combined with our solar-ready ultra high efficiency DC-Inverter heat pump chiller.

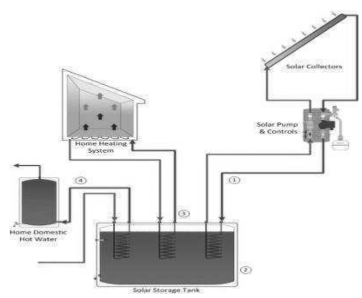
Benefits of Solar Space Heating

The average American family spends over $2,000 a year in heating costs. Heating systems that rely on fossil fuels, such as oil, propane, and natural gas will continue to rise in cost.

By using a solar space heating system, you can take advantage of the sun's free, abundant energy to heat your home for free. Heating your home with a solar heating system can significantly reduce your winter fuel bills. Another excellent benefit is that a solar space heating system also heats domestic hot water.

A solar space heating system will also reduce the amount of air pollution and greenhouse gases that result from your use of fossil fuels such as oil, propane, and other petroleum products.

Solar Heating Tank



Solar space heating and cooling

Many large buildings need ventilated air to maintain indoor air quality. In cold climates, heating this air can use large amounts of energy. A solar ventilation system can preheat the air, saving both energy and money. This type of system typically uses a transpired collector , which consists of a thin, black metal panel mounted on a south-facing wall to absorb the sun's heat. Air passes through the many small holes in the panel. A space behind the perforated wall allows the air streams from the holes to mix together. The heated air is then sucked out from the top of the space into the ventilation system.

Solar process heating systems are designed to provide large quantities of hot water or space heating for nonresidential buildings. A typical system includes solar collectors that work along with a pump, a heat exchanger, and/or one or more large storage tanks. The two main types of solar collectors used - an evacuated-tube collector and a parabolic-trough collector - can operate at high temperatures with high efficiency. An evacuated-tube collector is a shallow box full of many glass, double-walled tubes and reflectors to heat the fluid inside the tubes. A vacuum between the two walls insulates the inner tube, holding in the heat. Parabolic troughs are long, rectangular, curved (U-shaped) mirrors tilted to focus sunlight on a tube, which runs down the center of the trough. This heats the fluid within the tube.

The heat from a solar collector can also be used to cool a building. It may seem impossible to use heat to cool a building, but it makes more sense if you just think of the solar heat as an energy source. Your familiar home air conditioner uses an energy source, electricity, to create cool air. Solar absorption coolers use a similar approach, combined with some very complex chemistry tricks, to create cool air from solar energy. Solar energy can also be used with evaporative coolers (also called "swamp coolers") to extend their usefulness to more humid climates, using another chemistry trick called desiccant cooling.

Wave Energy:

Wave Energy also known as Ocean Wave Energy, is another type of ocean based renewable energy source that uses the power of the waves to generate electricity. Unlike tidal energy which uses the ebb and flow of the tides, wave energy uses the vertical movement of the surface water that produce tidal waves. Wave power converts the periodic up-and-down movement of the oceans waves into electricity by placing equipment on the surface of the oceans that captures the energy produced by the wave movement and converts this mechanical energy into electrical power.

A multipurpose wave regulator system in the form of a long barrier results in the formation of a calm pool between the barrier and shore and this can be used as harbor. Space of aquaculture space for coastal transport with light and faster crafts shore protection against the erosion by sea. It is pollution free.

Waves are generated by wind passing over the surface of the sea. As long as the waves propagate slower than the wind speed just above the waves, there is an energy transfer from the wind to the waves. Both air pressure differences between the upwind and the lee side of a wave crest, as well as friction on the water surface by the wind, making the water to go into the shear stress causes the growth of the waves.[5]

Wave height is determined by wind speed, the duration of time the wind has been blowing, fetch (the distance over which the wind excites the waves) and by the depth and topography of the seafloor (which can focus or disperse the energy of the waves). A given wind speed has a matching practical limit over which time or distance will not produce larger waves. When this limit has been reached the sea is said to be "fully developed".

Wave power devices are generally categorized by the method used to capture the energy of the waves, by location and by the power take-off system. Locations are shoreline, nearshore and offshore. Types of power take-off include: hydraulic ram, elastomeric hose pump, pump-to-shore, hydroelectric turbine, air turbine,[22] and linear electrical generator. When evaluating wave energy as a technology type, it is important to distinguish between the four most common approaches: point absorber buoys, surface attenuators, oscillating water columns, and overtopping devices.

Wave energy is actually a concentrated form of solar power generated by the action of the wind blowing across the surface of the oceans water which can then be used as a renewable source of energy. As the suns rays strike the Earth's atmosphere, they warm it up. Differences in the temperature of the air masses around the globe causes the air to move from the hotter regions to the cooler regions, resulting in winds.

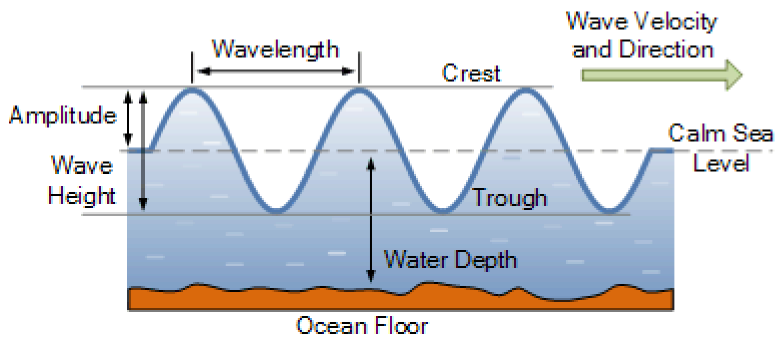
As the wind passes over the surface of the oceans, a portion of the winds kinetic energy is transferred to the water below, generating waves. In fact, the ocean could be viewed as a vast storage collector of energy transferred by the sun to the oceans, with the waves carrying the transferred kinetic energy across the surface of the oceans. Then we can say that waves are actually a form of energy and it is this energy and not water that moves along the ocean's surface.

These waves can travel (or "propagate") long distances across the open oceans with very little loss in energy, but as they approach the shoreline and the depth of the water becomes shallower, their speed slows down but they increase in size. Finally, the wave crashes onto the shoreline, releasing an enormous amount of kinetic energy which can be used for electricity production. A breaking waves energy potential varies from place to place depending upon its geographic location and time of year, but the two main factors which affect the size of the wave energy are the winds strength and the uninterrupted distance over the sea that the wind can blow.

Then we can say that "Wave Energy" is an indirect form of wind energy that causes movement of the water on the surface of the oceans and by capturing this energy the motion of the waves is converted to mechanical energy and used to drive an electricity generator. In many respects, the technology used for capturing this wave energy is similar to tidal energy or hydroelectric power.

The kinetic energy of the wave turns a turbine attached to a generator, which produces electricity. However, the open oceans can be a stormy and violent environment, resulting in the wave energy machines being destroyed by the very energy they were designed to capture.

In its simplest terms, an ocean wave is the up-and-down vertical movement of the sea water which varies sinusoidally with time. This sinusoidal wave has high points called crests and low points called troughs. The difference in height of a wave between the crest and the trough is called the peak-to-peak amplitude, then the waves amplitude or height is the centre of these two points and corresponds to the actual sea level when there is no movement of the water, in other words, a calm sea.



The amplitude of an ocean wave depends on the weather conditions at that time, as the amplitude of a smooth wave, or swell, will be small in calm weather but much larger in stormy weather with strong gales as the sea water moves up and down.

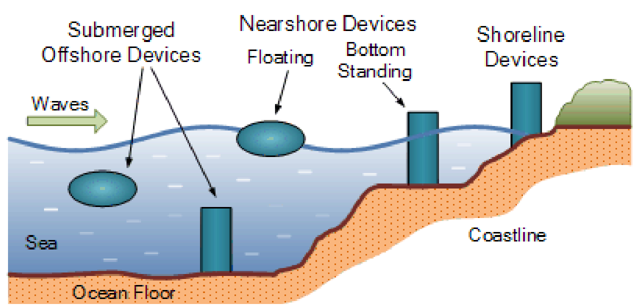
As well as the amplitude of the wave, another important characteristic is the distance between each successive crest, or trough, known as the wave period, (T). This wave period is the time in seconds between each crest of the wave. Then for a gentle swell this time period may be very long, but for a stormy sea this time period may be very short as each wave crashes onto the one in front.

The reciprocal of this time (1/T) gives us the fundamental frequency of the ocean wave relative to some static point. Smaller periodic waves generated or superimposed onto this fundamental wave such as reflected waves are called harmonic waves. Then the frequency and amplitude characteristics of a wind-generated wave depend on the distance the wind blows over the open water (called the fetch), the length of time the wind blows, the speed of the wind and the water depth.

Waves transport energy from where they were created by storms far out in the ocean to a shoreline. But a typical ocean wave does not resemble a perfect sinusoid, they are more irregular and complex than a simple sinusoidal wave. Only the steady up-and-down movement of a heavy swell resembles a sinusoidal wave much more than the chaotic nature of locally generated wind waves, as real sea waves contain a mixture of waves with different frequencies, wave heights and directions.

Wave Power Devices

Ocean wave energy has many advantages over ocean wind energy in that it is more predictable, less variable and offers higher available energy densities. Depending on the distance between the energy conversion device and the shoreline, wave energy systems can be classified as being either Shoreline devices, near shore devices or offshore devices.



Shoreline devices are wave energy devices which are fixed to or embedded in the shoreline, that is they are both in and out of the water. Nearshore devicesare characterised by being used to extract the wave power directly from the breaker zone and the waters immediately beyond the breaker zone, (i.e. at 20m water depth).

Offshore devices or deep water devices are the farthest out to sea and extend beyond the breaker lines utilising the high-energy densities and higher power wave profiles available in the deep water waves and surges.

One of the advantages of offshore devices is that there is no need for significant coastal earthworks, as there is with onshore devices.

As most of the energy within a wave is contained near the surface and falls off sharply with depth. There is a surprising range of designs available that maximise the energy available for capture. These wave energy devices are either fixed bottom standing designs used in shallow water and which pierce the waters surface, or fully floating devices that are used to capture the kinetic energy content of a waves movement and convert each movement into electricity using a generator.

There are currently four basic “capture” methods:

- Point Absorbers – These are small vertical devices either fixed directly to the ocean floor or tethered via a chain that absorb the waves energy from all directions. These devices generate electricity from the bobbing or pitching action of a floating device. Typical wave energy devices include, floating buoys, floating bags, ducks, and articulated rafts, etc. These devices convert the up-and-down pitching motion of the waves into rotary movements, or oscillatory movements in a variety of devices to generate electricity. One of the advantages of floating devices over fixed devices it that they can be deployed in deeper water, where the wave energy is greater.

- Wave Attenuators – also known as “linear absorbers”, are long horizontal semi-submerged snake-like devices that are oriented parallel to the direction of the waves. A wave attenuator is composed of a series of cylindrical sections linked together by flexible hinged joints that allow these individual sections to rotate and yaw relative to each other. The wave-induced motion of the device is used to pressurise a hydraulic piston, called a ram, which forces high pressure oil through smoothing accumulators to turn a hydraulic turbine generator producing electricity. Then wave attenuators convert the oscillating movement of a wave into hydraulic pressure.
- Oscillating Water Column – is a partly submerged chamber fixed directly at the shoreline which converts wave energy into air pressure. The structure could be a natural cave with a blow hole or a man made chamber or duct with an wind turbine generator located at the top well above the waters surface. The structure is built perpendicular to the waves so that the ebbing and flowing motion of the waves force the trapped water inside the chamber to oscillate in the vertical direction.
  - As the waves enter and exit the chamber, the water column moves up and down and acts like a piston on the air above the surface of the water, pushing it back and forth. This air is compressed and decompressed by this movement and is channelled through a wind turbine generator to produce electricity. The speed of air in the duct can be enhanced by making the cross-sectional area of the duct much less than that of the column.
  - Overtopping Devices – also known as “spill-over” devices, are either fixed or floating structures that use ramps and tapered sides positioned perpendicular to the waves. The sea waves are driven up the ramp and over the sides filling-up a small tidal reservoir which is located 2 to 3 metres above sea level. The potential energy of the water trapped inside the reservoir is then extracted by returning the water back to the sea through a low head Kaplan turbine generator to produce electricity.

  Then overtopping devices convert the potential energy available in the head of water into mechanical energy. The disadvantage of onshore overtopping schemes is that they have a relatively low power output and are only suitable for sites where there is a deep water shoreline and a low tidal range of less than about a metre.

The idea of harnessing the tremendous power of the oceans waves is not new. Like other forms of hydro power, wave energy does not require the burning of fossil fuels, which can pollute the air, contributing to acid rain and global warming. The energy is entirely clean and endlessly renewable. Wave power has many advantages compared to other forms of renewable energy with its main advantage being that it is predictable.

However, like many other forms of renewable energy, ocean wave energy also has its disadvantages such as its inflexible generation times dependant upon the tides, the visual impact of wave devices on the seas surface, as well as the threat of collision to shipping and navigation.

<u>Wave Energy Advantages</u>

- Wave energy is an abundant and renewable energy resource as the waves are generated by the wind.

- Pollution free as wave energy generates little or no pollution to the environment compared to other green energies.
- Reduces dependency on fossil fuels as wave energy consumes no fossil fuels during operation.
- Wave energy is relatively consistent and predictable as waves can be accurately forecast several days in advance.
- Wave energy devices are modular and easily sited with additional wave energy devices added as needed.
- Dissipates the waves energy protecting the shoreline from coastal erosion.
- Presents no barriers or difficulty to migrating fish and aquatic animals.

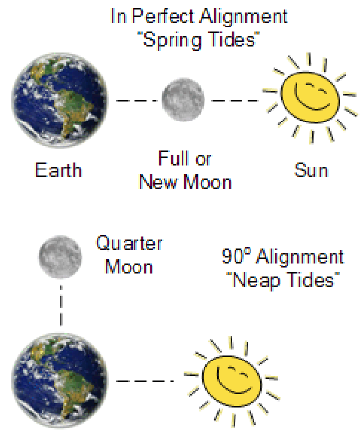
Wave Energy Disadvantages

- Visual impact of wave energy conversion devices on the shoreline and offshore floating buoys or platforms.
- Wave energy conversion devices are location dependent requiring suitable sites were the waves are consistently strong.
- Intermittent power generation as the waves come in intervals and does not generate power during calm periods.
- Offshore wave energy devices can be a threat to navigation that cannot see or detect them by radar.
- High power distribution costs to send the generated power from offshore devices to the land using long underwater cables.
- They must be able to withstand forces of nature resulting in high capital, construction and maintenance costs.

Tidal energy

Tidal Energy or Tidal Power as it is also called, is another form of hydro power that utilises large amounts of energy within the oceans tides to generate electricity. Tidal Energy is an “alternative energy” that can also be classed as a “renewable energy source”, as the Earth uses the gravitational forces of both the moon and the sun everyday to move vast quantities of water around the oceans and seas producing tides.

As the Earth, its Moon and the Sun rotate around each other in space, the gravitational movement of the moon and the sun with respect to the earth, causes millions of gallons of water to flow around the Earth’s oceans creating periodic shifts in these moving bodies of water. These vertical shifts of water are called “tides”.



When the earth and the moons gravity lines up with each other, the influences of these two gravitational forces becomes very strong and causes millions of gallons of water to move or flow towards the shore creating a "high tide" condition. Likewise when the earth and the moons gravity are at 90o to each other, the influences of these two gravitational forces is weaker and the water flows away from the shore as the mass of water moves to another location on the earth, creating a "low tide" condition. This ebbing and flowing of the tides happens twice during each period of rotation of the earth with stronger weekly and annual lunar cycles superimposed onto these tides.

When the moon is in perfect alignment with the earth and the sun, the gravitational pull of the moon and sun together becomes much stronger than normal with the high tides becoming very high and the low tides becoming very low during each tidal cycle. Such tides are known as spring tides (maximum). These spring tides occur during the full or new moon phase.

The other tidal situation arises during neap tides (minimum) when the gravitational pull of the moon and the sun are against each other, thus cancelling their effects. The net result is a smaller pulling action on the sea water creating much smaller differences between the high and low tides thereby producing very weak tides. Neap tides occur during the quarter moon phase. Then spring tides and neap tides produce different amounts of potential energy in the movement of the sea water as their effects differ from the regular high and low sea levels and we can use these tidal changes to produce renewable energy. So we can say that the tides are turning for alternative energy.

So we now know that the constant rotational movement of the earth and the moon with regards to each other causes huge amounts of water to move around the earth as the tides go in and out. These tides are predictable and regular resulting in two high tides and two low tides each day with the level of the oceans constantly moving between a high tide and a low tide, and then back to a high tide again. The time taken for a tidal cycle to happen is about 12 hours and 24 minutes (called the "diurnal cycle") between two consecutive high tides allowing Oceanographers and Meteorologist to accurately predict the ebb and flow of the tides around the oceans many years in advance.

The main big advantage of this is that the tides are therefore perfectly predictable and regular unlike wind energy or solar energy, allowing miles of coastline to be used for tidal energy exploitation and the larger the tidal influence, the greater the movement of the tidal water and therefore the more potential energy that can be harvested for power generation. Therefore Tidal Energy can be considered as a renewable energy source as the oceans

energy is replenished by the sun as well as through tidal influences of the moon and suns gravitational forces.

Tidal Energy Generation

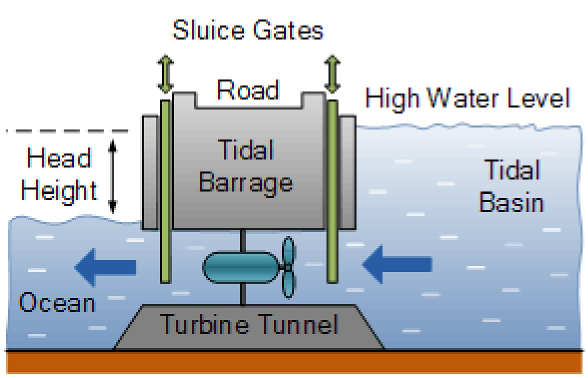
Since the position of the earth and the moon with respect to the sun changes throughout the year, we can utilise the potential energy of the water contained in the daily movement of the rising and falling sea levels to generate electricity. The generation of electricity from tides is similar in many ways to hydro-electric generation we looked at in the hydro energy tutorials. The difference this time is that the water flows in and out of the turbines in both directions instead of in just one forward direction.

Tidal energy, just like hydro energy transforms water in motion into a clean energy. The motion of the tidal water, driven by the pull of gravity, contains large amounts of kinetic energy in the form of strong tidal currents called tidal streams. The daily ebbing and flowing, back and forth of the oceans tides along a coastline and into and out of small inlets, bays or coastal basins, is little different to the water flowing down a river or stream.

The movement of the sea water is harnessed in a similar way using waterwheels and turbines to that used to generate hydro electricity. But because the sea water can flow in both directions in a tidal energy system, it can generate power when the water is flowing in and also when it is ebbing out. Therefore, tidal generators are designed to produce power when the rotor blades are turning in either direction. However, the cost of reversible electrical generators are more expensive than single direction generators.

<u>Different Types of Tidal Energy Systems</u>

1. Tidal Barrage :- A Tidal Barrage is a type of tidal power generation that involves the construction of a fairly low dam wall, known as a "barrage" and hence its name, across the entrance of a tidal inlet or basin creating a tidal reservoir. This dam has a number of underwater tunnels cut into its width allowing sea water to flow through them in a controllable way using "sluice gates". Fixed within the tunnels are huge water turbine generators that spin as the water rushes past them generating tidal electricity.



Tidal barrages generate electricity using the difference in the vertical height between the incoming high tides and the outgoing low tides. As the tide ebbs and flows, sea water is allowed to flow in or out of the reservoir through a one way underwater tunnel system. This flow of tidal water back and forth causes the water turbine generators located within the tunnels to rotate producing tidal energy with special generators used to produce electricity on both the incoming and the outgoing tides.

The one disadvantage of Tidal Barrage Generation, is that it can only generate electricity when the tide is actually flowing either "in" or "out" as during high and low tide times the tidal water is stationary. However, because tides are totally predictable, other power stations can compensate for this stationary period when there is no tidal energy being produced. Another disadvantage of a tidal barrage system, is the environmental and ecological effects that a long concrete dam may have on the estuaries they span.

Tidal Stream:- A Tidal Stream Generation system reduces some of the environmental effects of tidal barrages by using turbine generators beneath the surface of the water. Major tidal flows and ocean currents, like the Gulf Stream, can be exploited to extract its tidal energy using underwater rotors and turbines.

Tidal stream generation is very similar in principal to wind power generation, except this time water currents flow across a turbines rotor blades which rotates the turbine, much like how wind currents turn the blades for wind power turbines. In fact, tidal stream generation areas on the sea bed can look just like underwater wind farms.

Unlike off-shore wind power which can suffer from storms or heavy sea damage, tidal stream turbines operate just below the sea surface or are fixed to the sea bed. Tidal streams are formed by the horizontal fast flowing volumes of water caused by the ebb and flow of the tide as the profile of the sea bed causes the water to speed up as it approaches the shoreline.

As water is much more denser than air and has a much slower flow rate, tidal stream turbines have much smaller diameters and higher tip speed rates compared to an equivalent wind turbine. Tidal stream turbines generate tidal power on both the ebb and flow of the tide. One of the disadvantages of Tidal Stream Generation is that as the turbines are submerged under the surface of the water they can create hazards to navigation and shipping.

Other forms of tidal energy include tidal fences which use individual vertical-axis turbines that are mounted within a fence structure, known as the caisson, which completely blocks a channel and force water through them. Another alternative way of harnessing tidal power is by using an “oscillating tidal turbine”. This is basically a fixed wing called a Hydroplane positioned on the sea bed. The hydroplane uses the energy of the tidal stream flowing past it to oscillate its giant wing, similar to a whales flipper, up and down with the movement of the tidal currents. This motion is then used to generate electricity. The angle of the hydroplane to the flow of the tide can be varied to increase efficiency.

Tidal energy is another form of low-head hydro power that is completely carbon neutral like wind and hydro energy. Tidal power has many advantages compared to other forms of renewable energy with its main advantage being that it is predictable. However, like many other forms of renewable energy, tidal energy also has its disadvantages such as its inflexible generation times dependant upon the tides and the fact that it operates in the hostile conditions of the oceans and seas. So here are some of the advantages and disadvantages associated with "tidal energy".

Advantages of Tidal Energy

1. Tidal energy is a renewable energy resource because the energy it produces is free and clean as no fuel is needed and no waste bi-products are produced.
2. Tidal energy has the potential to produce a great deal of free and green energy.
3. Tidal energy is not expensive to operate and maintain compared to other forms of renewable energies.
4. Low visual impact as the tidal turbines are mainly if not totally submerged beneath the water.
5. Low noise pollution as any sound generated is transmitted through the water.
6. High predictability as high and low tides can be predicted years in advance, unlike wind.
7. Tidal barrages provide protection against flooding and land damage.
8. Large tidal reservoirs have multiple uses and can create recreational lakes and areas where before there were none.

Disadvantages of Tidal Energy

1. Tidal energy is not always a constant energy source as it depends on the strength and flow of the tides which themselves are effected by the gravitational effects of the moon and the sun.
2. Tidal Energy requires a suitable site, where the tides and tidal streams are consistently strong.
3. Must be able to withstand forces of nature resulting in high capital, construction and maintenance costs.
4. High power distribution costs to send the generated power from the submerged devices to the land using long underwater cables.
5. Intermittent power generation, only generates power ten hours a day during the ebb and flow of the tides Changes to estuary ecosystem and an increase in coastal erosion where the tides are concentrated.
6. Build up of silt, sediments and pollutants within the tidal barrage from rivers and streams flowing into basin as it is unable to flow out into the sea.
7. Danger to fish and other sea-life as they get stuck in the barrage or sucked through the tidal turbine blades.

Nuclear Power Source

Nuclear energy is used to produce electricity. Heat generated from the splitting of uranium atoms in a process known as fission is used to produce steam. This steam in turn powers turbines, which are used to produce the electricity that supplies the surrounding community. Nuclear power stations are set up in a multiple-step process that has been designed to help contain the energy and many of its negative byproducts. This process alone is the base of several advantages and disadvantages for this energy source.

Nuclear Power Plant

Advantages of Nuclear Energy

Despite potential drawbacks and the controversy that surrounds it, nuclear energy does have a few advantages over some other methods of energy production.

Expense

Less uranium is needed to produce the same amount of energy as coal or oil, which lowers the cost of producing the same amount of energy. Uranium is also less expensive to procure and transport, which further lowers the cost.

Reliability

When a nuclear power plant is functioning properly, it can run uninterrupted for up to 540 days. This results in fewer brownouts or other power interruptions. The running of the plant is also not contingent of weather or foreign suppliers, which makes it more stable than other forms of energy.

No Greenhouse Gases

While nuclear energy does have some emissions, the plant itself does not give off greenhouse gasses. Studies have shown that what life-cycle emissions that the plants do give off are on par with renewable energy sources such as wind power. This lack of greenhouse gases can be very attractive to some consumers.

Disadvantages of Nuclear Energy

One of the reasons that nuclear energy falls under fire so frequently is due to the many disadvantages it brings.

Raw Material

Uranium is used in the process of fission because it's a naturally unstable element. This means that special precautions must be taken during the mining, transporting and storing of the uranium, as well as the storing of any waste product to prevent it from giving off harmful levels of radiation.

Water Pollutant

Nuclear fission chambers are cooled by water. This water is then turned into steam, which is used to power the turbines. When the water cools enough to change back into liquid form, it is pumped outside into nearby wetlands. While measures are taken to ensure that no radiation is being pumped into the environment, other heavy metals and pollutants can make their way out of the chamber. The immense heat given off by this water can also be damaging to eco systems located nearby the reactor.

Waste

When the uranium has finished splitting, the resulting radioactive byproducts need to be removed. While recycling efforts of this waste product have been undertaken in recent years, the storage of the by-product could lead to contamination through leaks or containment failures.

Shutdown Reactors

There have been several nuclear reactors that have failed and been shutdown that are still in existence. These abandoned reactors are taking up valuable land space, could be contaminating the areas surrounding them, and yet are often too unstable to be removed.

A non-renewable resource is a resource of economic value that cannot be readily replaced by natural means on a level equal to its consumption. Most fossil fuels, such as oil, natural gas and coal are considered nonrenewable resources in that their use is not sustainable because their formation takes billions of years.

Earth minerals and metal ores are examples of non-renewable resources. The metals themselves are present in vast amounts in Earth's crust, and their extraction by humans only occurs where they are concentrated by natural geological processes (such as heat, pressure, organic activity, weathering and other processes) enough to become economically viable to extract. These processes generally take from tens of thousands to millions of years, through plate tectonics, tectonic subsidence and crustal recycling.

Natural resources such as coal, petroleum (crude oil) and natural gas take thousands of years to form naturally and cannot be replaced as fast as they are being consumed. Eventually it is considered that fossil-based resources will become too costly to harvest and humanity will need to shift its reliance to other sources of energy such as solar or wind power, see renewable energy.

Energy sources that are almost always classified as non-renewable:

a. Fossil fuels
b. Coal
c. Petroleum
d. Natural gas
e. Fossil fuel

Fossil fuels are fuels formed by natural resources such as anaerobic decomposition of buried dead organisms. The age of the organisms and their resulting fossil fuels is typically millions of years and sometimes exceeds 650 million years. The fossil fuels, which contain high percentages of carbon, include coal, petroleum, and natural gas. Fossil fuels range from volatile materials with low carbon: hydrogen ratios like methane, to liquid petroleum to nonvolatile materials composed of almost pure carbon, like anthracite coal. Methane can be found in hydrocarbon fields, alone associated with oil, or in the form of methane catharses. It is generally accepted that they formed from the fossilized remains of dead plants and animals by exposure to heat and pressure in the Earth's crust over millions of years.

Coal: Coal is a combustible black or brownish-black sedimentary rock normally occurring in rock star forms, such as anthracite coal, can be regarded as metamorphic rock because of later exposure to elevated temperature and pressure. Coal is composed primarily of carbon along with variable quantities of other elements, chiefly sulfur, hydrogen, oxygen and nitrogen. Coal begins as layers of plant matter accumulate at the bottom of a body of water. For the process to continue the plant matter must be protected from biodegradation and oxidization, usually by mud or acidic water. The wide shallow seas of the Carboniferous period provided such conditions. This trapped atmospheric carbon in the ground in immense peat bogs that eventually were covered over and deeply buried by sediments under which they metamorphosed into coal. Over time, the chemical and physical properties of the plant remains (believed to mainly have been fern-like species antedating more modern plant and tree species) were changed by geological action to create a solid material.

Petroleum: Petroleum {L. petroleum, from Greek: petra (rock)+ Latin: oleum (oil)} or crude oil is a naturally occurring, flammable liquid consisting of a complex mixtureof hydrocarbons of various molecular weights and other liquid organic compounds, that are found in geologic formations beneath the Earth's surface. Petroleum is recovered mostly through oil drilling. It is refined and separated, most easily by boiling point, into a large number of consumer products, from gasoline and kerosene to asphalt and chemical reagents used to make plastics and pharmaceuticals. The term petroleum was first used in the treatise De Natura Fossilium, published in 1546 by the German mineralogist Georg Bauer, also known as Georgius Agricola. In the 19th Century, the term petroleum was frequently used to refer to mineral oils produced by distillation from mined organic solids such as cannel coal (and later oil shale) and refined oils produced from them; in the United Kingdom storage (and later transport) of these oils were regulated by a series of Petroleum Acts, from the Petroleum Act 1862 c. 66 onward.

Natural gas: Natural gas is a gas consisting primarily of methane, typically with 0-20% higher hydrocarbons (primarily ethane). It is found associated with other fossil fuels, in coal beds, as methane clathrates, and is an important fuel source and a major feedstock for fertilizers. Most natural gas is created by two mechanisms: biogenic and thermo genic. Biogenic gas is created by methanogen organisms in marshes, bogs, landfills, and shallow sediments. Deeper in the earth, at greater temperature and pressure, thermo genic gas is created from buried organic material. Before natural gas can be used as a fuel, it must undergo processing to remove almost all materials other than methane. The by-products of that processing include ethane, propane, butanes, pentanes, and higher molecular weight hydrocarbons, elemental sulfur, carbon dioxide, water vapour and sometimes helium and nitrogen.

Indian Scenario

India is one of the countries where the present level of energy consumption, by world standards, is very low. The estimate of annual energy consumption in India is about 330 Million Tones Oil Equivalent (MTOE) for the year 2004. Accordingly, the per capita consumption of energy is about 305 Kilogram Oil Equivalent (KGOE). As compared to this, the energy consumption in some of the other countries is of the order of over 4050 for Japan, over 4275 for South Korea, about 1200 for China, about 7850 for USA, about 4670 for OECD countries and the world average is about 1690.

In so far as electricity consumption is concerned, India has reached a level of about 600-kilowatt hour (kwh) per head per year. The comparable figures for Japan are about 7,800, for South Korea about 7,000, for China about 1380, for USA about 13,000, for OECD countries about 8050 and world average are about 2430. Thus, both in terms of per capita energy consumption and in terms of per capita electricity consumption, India is far behind many countries, and as a matter of fact, behind even the world average. Therefore, to improve the standards of living of Indian people and to let them enjoy the benefit of economic development, it is imperative that both energy consumption and electricity consumption level is enhanced. India is targeting a growth rate of 9 – 10%, having already reached a level of almost 8%. To sustain the double-digit growth rate for next 10-15 years, it would be essential that the level of energy availability and consumption, and electricity consumption in particular, is enhanced substantially.In the profile of energy sources in India, coal has a dominant position. Coal constitutes about 51% of India's primary energy resources followed by Oil (36%), Natural Gas (9%), Nuclear (2%) and Hydro (2%). To address the issue concerning energy consumption, and more particularly, the need for enhancing the energy supply, India has accorded appropriate priority to both - supply side management and demand side management.

Non-Conventional Energy Sources

	Potential (MW)	Existing capacity (MW)
Wind	45,000	4,400

Indian Government has accorded very high priority to develop and expand installed capacity base through non-conventional sources of electricity generation. There is a separate Ministry in the Government of India to exclusively focus on this important area of power generation. National Electricity Policy notified in 2005 in pursuance of the Electricity Act, 2003, prescribes that State Electricity Regulatory Commissions should prescribe a proportion of power which should be produced and supplied to the grid through the non-conventional sources. Some of the Regulatory Commissions have come out with specific policy guidelines with a different approach on tariff for these plants in order to encourage these technologies and plants. National Electricity Tariff Policy mandates that State Commissions should fix such minimum percentage latest by April, 2006. India has very high potential for these capacities:

It may be seen from the above that India has achieved substantial success on wind turbine based power generation. Ministry of Non-conventional Energy Sources (MNES) has set a target of achieving at least 10,000 MW capacity through various non-conventional sources, by the year 2012.

Conventional Sources of Electricity Generation

Fossil fuel based thermal power, hydro-electric, and nuclear constitute the conventional sources of power. Non-conventional sources are less than 5% of total installed capacity in India. The present installed capacity (as in March 2006) is about 1,25,000 MW, consisting of coal based plants (56%), gas based plants (10%), hydro-electric (26%), nuclear (3%) non-conventional (5%).

Indian Power Sector was opened up for private power generation in 1991. In terms of ownership structure, the profile consists of Central Government owned companies (32%), State Government owned companies/Electricity Boards (57%) and Private Sector (11%). 100% FDI is permitted in all segments of electricity industry – viz. Generation, Transmission, Distribution, Trading.

In the last three years far-reaching structural changes have been introduced in the Indian Electricity Sector. Electricity Act 2003 is an historic legislative initiative with powerful potential to transform the power sector industry and market structure.

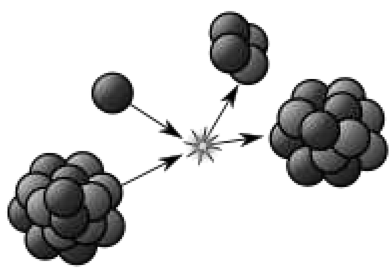
Most important features of the Electricity Act 2003 are as follows:

5. **The Act creates a liberal and transparent framework for power development**
6. **It facilitates investment by creating competitive environment and reforming distribution segment of power industry.**
7. **Entry Barriers have been removed/reduced in following areas:**
   e) **Delicensed generation.**
   f) **Freedom to captive generation including group captive**
   g) **Recognizing trading as an independent activity**
   h) **Open access in transmission facilitating multi buyer and seller model.**
   7. **Open access to consumers above 1 MW within five years commencing from 27th January, 2004 (date of enforcement of amendment to Electricity Act) Regulators have been mandated to ensure this.**
   8. **Multiple licenses in distribution in the same area of supply so that competition could yield better services to consumers.**
   9. **Regulatory Commissions – to develop market and to fix tariff.**

Nuclear energy: Nuclear power is the use of nuclear reactions that release nuclear energy to generate heat, which most frequently is then used in steam turbines to produce electricity in a nuclear power plant. The term includes nuclear fission, nuclear decay and nuclear fusion. Presently, the nuclear fission of elements in the actinide series of the periodic table produce the vast majority of nuclear energy in the direct service of humankind, with nuclear decay processes, primarily in the form of geothermal energy, and radioisotope thermoelectric generators, in niche uses making up the rest.

Nuclear Fusion is a reaction in which two or more atomic nuclei come close enough to form one or more different atomic nuclei and subatomic particles (neutrons or protons). The difference in mass between the products and reactants is manifested as the release of large amounts of energy. This difference in mass arises due to the difference in atomic "binding energy" between the atomic nuclei before and after the reaction. Fusion is the process that powers active or "main sequence" stars, or other high magnitude stars.

The fusion process that produces a nucleus lighter than iron-56 or nickel-62 will generally yield a net energy release. These elements have the smallest mass per nucleon and the largest binding energy per nucleon, respectively. Fusion of light elements toward these releases energy (an exothermic process), while a fusion producing nuclei heavier than these elements, will result in energy retained by the resulting nucleons, and the resulting reaction is endothermic. The opposite is true for the reverse process, nuclear fission. This means that the lighter elements, such as hydrogen and helium, are in general more fusible; while the heavier elements, such as uranium and plutonium, are more fissionable. The extreme astrophysical event of a supernova can produce enough energy to fuse nuclei into elements heavier than iron.

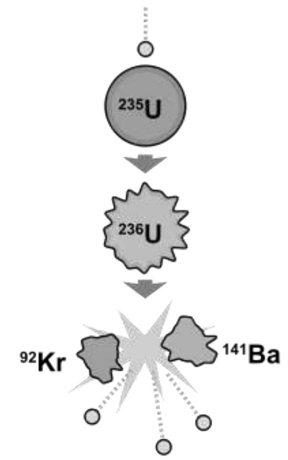


Process of Nuclear Fission

Nuclear Fission is either a nuclear reaction or a radioactive decay process in which the nucleus of an atom splits into smaller parts (lighter nuclei). The fission process often produces free neutrons and gamma photons, and releases a very large amount of energy even by the energetic standards of radioactive decay.

Nuclear fission of heavy elements was discovered on December 17, 1938 by German Otto Hahn and his assistant Fritz Stresemann, and explained theoretically in January 1939 by Lise Meitner and her nephew Otto Robert Frisch. Frisch named the process by analogy with biological fission of living cells. It is an exothermic reaction which can release large amounts of energy both as electromagnetic radiation and as kinetic energy of the fragments (heating the bulk material where fission takes place). In order for fission to produce energy, the total binding energy of the resulting elements must be less negative (higher energy) than that of the starting element.

Fission is a form of nuclear transmutation because the resulting fragments are not the same element as the original atom. The two nuclei produced are most often of comparable but slightly different sizes, typically with a mass ratio of products of about 3 to 2, for common fissile isotopes. Most fissions are binary fissions (producing two charged fragments), but occasionally (2 to 4 times per 1000 events), three positively charged fragments are produced, in a ternary fission. The smallest of these fragments in ternary processes ranges in size from a proton to an argon nucleus.



Process of Nuclear Fusion

REACTORS

All nuclear reactors are devices designed to maintain a chain reaction producing a steady flow of neutrons generated by the fission of heavy nuclei. They are, however, differentiated either by their purpose or by their design features. In terms of purpose, they are either research reactors or power reactors.

TYPES OF REACTORS

Research reactors are operated at universities and research centres in many countries, including some where no nuclear power reactors are operated. These reactors generate neutrons for multiple purposes, including producing radiopharmaceuticals for medical diagnosis and therapy, testing materials and conducting basic research.

Power reactors are usually found in nuclear power plants. Dedicated to generating heat mainly for electricity production, they are operated in more than 30 countries (see Nuclear Power Reactors). Their lesser uses are drinking water or district water production. In the form of smaller units, they also power ships.

Differentiating nuclear reactors according to their design features is especially pertinent when referring to nuclear power reactors (see Types of Nuclear Power Reactors).

Nuclear Power Reactors

There are many different types of power reactors. What is common to them all is that they produce thermal energy that can be used for its own sake or converted into mechanical energy and ultimately, in the vast majority of cases, into electrical energy.

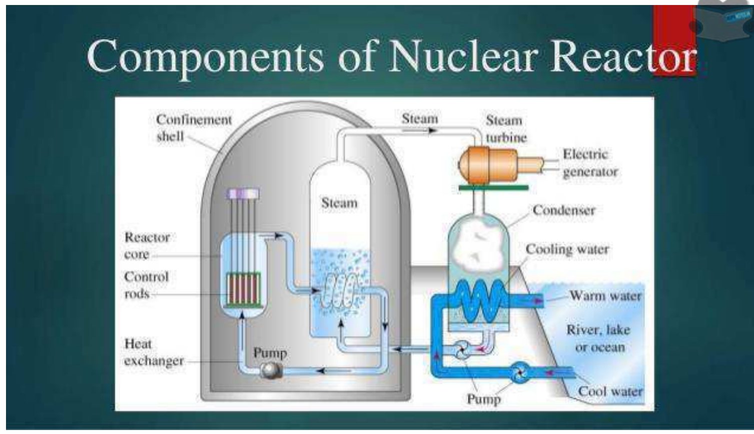
In these reactors, the fission of heavy atomic nuclei, the most common of which is uranium-235, produces heat that is transferred to a fluid which acts as a coolant. During the fission process, bond energy is released and this first becomes noticeable as the kinetic energy of the fission products generated and that of the neutrons being released. Since these particles undergo intense deceleration in the solid nuclear fuel, the kinetic energy turns into heat energy.

In the case of reactors designed to generate electricity, to which the explanations below will now be restricted, the heated fluid can be gas, water or a liquid metal. The heat stored by the fluid is then used either directly (in the case of gas) or indirectly (in the case of water and liquid metals) to generate steam. The heated gas or the steam is then fed into a turbine driving an alternator.

Components of a nuclear reactor

There are several components common to most types of reactors:

1. Fuel. Uranium is the basic fuel. Usually pellets of uranium oxide (UO_2) are arranged in tubes to form fuel rods. The rods are arranged into fuel assemblies in the reactor core.* In a 1000 MWe class PWR there might be 51,000 fuel rods with over 18 million pellets.
2. Moderator. Material in the core which slows down the neutrons released from fission so that they cause more fission. It is usually water, but may be heavy water or graphite.
3. Control rods. These are made with neutron-absorbing material such as cadmium, hafnium or boron, and are inserted or withdrawn from the core to control the rate of reaction, or to halt it. In some PWR reactors, special control rods are used to enable the core to sustain a low level of power efficiently. (Secondary control systems involve other neutron absorbers, usually boron in the coolant – its concentration can be adjusted over time as the fuel burns up.) PWR control rods are inserted from the top, BWR cruciform blades from the bottom of the core.
4. Coolant. A fluid circulating through the core so as to transfer the heat from it. In light water reactors the water moderator functions also as primary coolant. Except in BWRs, there is secondary coolant circuit where the water becomes steam.
5. Pressure vessel or pressure tubes. Usually a robust steel vessel containing the reactor core and moderator/coolant, but it may be a series of tubes holding the fuel and conveying the coolant through the surrounding moderator.
6. Steam generator. Part of the cooling system of pressurised water reactors (PWR & PHWR) where the high-pressure primary coolant bringing heat from the reactor is used to make steam for the turbine, in a secondary circuit. Essentially a heat exchanger like a motor car radiator.* Reactors have up to six 'loops', each with a steam generator.
7. Containment. The structure around the reactor and associated steam generators which is designed to protect it from outside intrusion and to protect those outside from the effects of radiation in case of any serious malfunction inside. It is typically a metre-thick concrete and steel structure.



Types of Nuclear Power Reactors

Nuclear power reactors can be classified according to the type of fuel they use to generate heat.

Uranium–fuelled Reactors

The only natural element currently used for nuclear fission in reactors is uranium. Natural uranium is a highly energetic substance: one kilogram of it can generate as much energy as 10 tonnes of oil. Naturally occurring uranium comprises, almost entirely, two isotopes: U238 (99.283%) and U235 (0.711%). The former is not fissionable while the latter can be fissioned by thermal (i.e. slow) neutrons. As the neutrons emitted in a fission reaction are fast, reactors using U235 as fuel must have a means of slowing down these neutrons before they escape from the fuel. This function is performed by what is called a moderator, which, in the case of certain reactors simultaneously acts as a coolant. It is common practice to classify power reactors according to the nature of the coolant and the moderator plus, as the need may arise, other design characteristics.

Reactor Type	Coolant	Moderator	Fuel	Comment
Pressurised water reactors (PWR, VVER)	Light water	Light water	Enriched uranium	Steam generated in secondary loop
Boiling water reactors (BWR)	Light water	Light water	Enriched uranium	Steam from boiling water fed to turbine
Pressurised heavy water reactor (PHWR)	Heavy water	Heavy water	Natural uranium	
Gas-cooled reactors (Magnox, AGR, UNGG)	CO2	Graphite	Natural or enriched uranium	
Light water graphite reactors (RBMK)	Press-urised boiling water	Graphite	Enriched uranium	Soviet design

PWRs and BWRs are the most commonly operated reactors in Organization for Economic Cooperation and Development (OECD) countries. VVERs, designed in the former Soviet Union, are based on the same principles as PWRs. They use “light water”, i.e. regular water (H2O) as opposed to “heavy water” (deuterium oxide D2O). Moderation provided by light water is not sufficiently effective to permit the use of natural uranium. The fuel must be slightly enriched in U235 to make up for the losses of neutrons occurring during the chain reaction. On the other hand, heavy water is such an effective moderator that the chain reaction can be sustained without having to enrich the uranium. This combination of natural uranium and heavy water is used in PHWRs, which are found in a number of countries, including Canada, Korea, Romania and India.

Graphite-moderated, gas-cooled reactors, formerly operated in France and still operated in Great Britain, are not built any more in spite of some advantages.

RBMK-reactors (pressure-tube boiling-water reactors), which are cooled with light water and moderated with graphite, are now less commonly operated in some former Soviet Union bloc countries. Following the Chernobyl accident (26 April 1986) the construction of this reactor type ceased. The operating period of those units still in operation will be shortened.

Plutonium-fuelled Reactors

Plutonium (Pu) is an artificial element produced in uranium-fuelled reactors as a by-product of the chain reaction. It is one hundred times more energetic than natural uranium; one gram of Pu can generate as much energy as one tonne of oil. As it needs fast neutrons in order to fission, moderating materials must be avoided to sustain the chain reaction in the best conditions. The current Plutonium-fuelled reactors, also called “fast” reactors, use liquid sodium which displays excellent thermal properties without adversely affecting the chain reaction. These types of reactors are in operation in France, Japan and the Commonwealth of Independent States (CIS).

Light Water Reactors

The Light Water Reactors category comprises pressurised water reactors (PWR, VVER) and boiling water reactors (BWR). Both of these use light water and hence enriched uranium. The light water they use combines the functions of moderator and coolant. This water flows through the reactor core, a zone containing a large array of fuel rods where it picks up the heat generated by the fission of the U235 present in the fuel rods. After the coolant has transferred the heat it has collected to a steam turbine, it is sent back to the reactor core, thus flowing in a loop, also called a primary circuit.

In order to transfer high-quality thermal energy to the turbine, it is necessary to reach temperatures of about 300 °C. It is the pressure at which the coolant flows through the reactor core that makes the distinction between PWRs and BWRs.

In PWRs, the pressure imparted to the coolant is sufficiently high to prevent it from boiling. The heat drawn from the fuel is transferred to the water of a secondary circuit through heat exchangers. The water of the secondary circuit is transformed into steam, which is fed into a turbine.

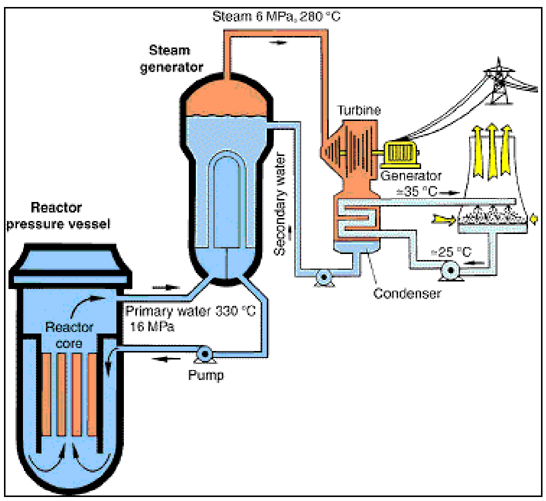
In BWRs, the pressure imparted to the coolant is sufficiently lower than in a PWR to allow it to boil. It is the steam resulting from this process that is fed into the turbine.

This basic difference between pressurised and boiling water dictates many of the design characteristics of the two types of light water reactors, as will be explained below.

Despite their differing designs, it must be noted that the two reactor types provide an equivalent level of safety.

Pressurised Water Reactors

The fission zone (fuel elements) is contained in a reactor pressure vessel under a pressure of 150 to 160 bar (15 to 16 MPa). The primary circuit connects the reactor pressure vessel to heat exchangers. The secondary side of these heat exchangers is at a pressure of about 60 bar (6 MPa) - low enough to allow the secondary water to boil. The heat exchangers are, therefore, actually steam generators. Via the secondary circuit, the steam is routed to a turbine driving an alternator. The steam coming out of the turbine is converted back into water by a condenser after having delivered a large amount of its energy to the turbine. It then returns to the steam generator. As the water driving the turbine (secondary circuit) is physically separated from the water used as reactor coolant (primary circuit), the turbine-alternator set can be housed in a turbine hall outside the reactor building.



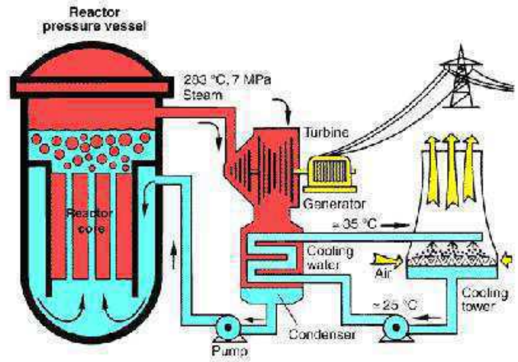
Nuclear power plant with pressurized water reactor

Boiling Water Reactors

The fission zone is contained in a reactor pressure vessel, at a pressure of about 70 bar (7 MPa). At the temperature reached (290 °C approximately), the water starts boiling and the resulting steam is produced directly in the reactor pressure vessel. After the separation of steam and water in the upper part of the reactor pressure vessel, the steam is routed directly to a turbine driving an alternator.

The steam coming out of the turbine is converted back into water by a condenser after having delivered a large amount of its energy to the turbine. It is then fed back into the primary cooling circuit where it absorbs new heat in the fission zone.

Since the steam produced in the fission zone is slightly radioactive, mainly due to short-lived activation products, the turbine is housed in the same reinforced building as the reactor.



Principle of a nuclear power plant with boiling water reactor

Advantages of nuclear power

The generation of electricity through nuclear energy reduces the amount of energy generated from fossil fuels (coal and oil). Less use of fossil fuels means lowering greenhouse gas emissions (CO^2 and others).

Currently, fossil fuels are consumed faster than they are produced, so in the next future these resources may be reduced or the price may increase becoming inaccessible for most of the population.

Another advantage is the required amount of fuel: less fuel offers more energy. It represents a significant save on raw materials but also in transport, handling and extraction of nuclear fuel. The cost of nuclear fuel (overall uranium) is 20% of the cost of energy generated.

The production of electric energy is continuous. A nuclear power plant is generating electricity for almost 90% of annual time. It reduces the price volatility of other fuels such as petrol.

This continuity benefits the electrical planning. Nuclear power does not depends on natural aspects. It's a solutions for the main disadvantage of renewable energy, like solar energy or eolic energy, because the hours of sun or wind does not always coincide with the hours with more energy demand.

It's an alternative to fossil fuels, so the consumption of fuels such as coal or oil is reduced. This reduction of coal and oil consumption benefits the situation of global warming and global climate change. By reducing the consumption of fossil fuels we also improve the quality of the air affecting the disease and quality of life.

Disadvantages of nuclear power

We've previously discussed the advantage of using nuclear energy to reduce fossil fuel consumption. Organizations often use this argument in favor of nuclear energy but it's a partial truth. Much of the consumption of fossil fuels is due to road transport, used in heat engines (cars, trucks, etc.). Savings in fossil fuel for power generation is fairly low.

Despite the high level of sophistication of the safety systems of nuclear power plants the human aspect has always an impact. Facing an unexpected event or managing a nuclear accident we don't have any guarantee that decisions we took are always the best. Two good examples are Chernobyl and Fukushima.

The Chernobyl nuclear accident is, by far, the worst nuclear accident in the history. Different wrong decisions during the management of the nuclear plant caused a big nuclear explosion.

Referring to the Fukushima nuclear accident, the operations done by the staff were highly questionable. Fukushima nuclear accident is the second worst accident in the history.
One of the main disadvantages is the difficulty in the management of nuclear waste. It takes many years to eliminate its radioactivity and risks.
The constructed nuclear reactors have an expiration date. Then, they've to be dismantled, so that main countries producing nuclear energy could maintain a regular number of operating reactors. They've to built about 80 new nuclear reactors during the next ten years.
Nuclear plants have a limited life. The investment for the construction of a nuclear plant is very high and must be recovered as soon as possible, so it raises the cost of electricity generated. In other words, the energy generated is cheap compared to the cost of fuel, but the recovery of its construction is much more expensive.
Nuclear power plants are objectives of terrorist organizations.
Nuclear power plants generate external dependence. Not many countries have uranium mines and not all the countries have nuclear technology, so they have to hire both things overseas.
Current nuclear reactors work by fission nuclear reactions. These chain reactions is generated in case control systems fail, generating continuous reactions causing a radioactive explosion that would be virtually impossible to contain.

Hydrogen energy

Hydrogen can be produced using a number of different processes. Thermochemical processes use heat and chemical reactions to release hydrogen from organic materials such as fossil fuels and biomass. Water (H_2O) can be split into hydrogen (H_2) and oxygen (O_2) using electrolysis or solar energy. Microorganisms such as bacteria and algae can produce hydrogen through biological processes.

THERMOCHEMICAL PROCESSES

Some thermal processes use the energy in various resources, such as natural gas, coal, or biomass, to release hydrogen from their molecular structure. In other processes, heat, in combination with closed-chemical cycles, produces hydrogen from feedstocks such as water. Learn more about the following thermochemical processes:

- Natural gas reforming (also called steam methane reforming or SMR)
- Coal gasification
- Biomass gasification
- Biomass-derived liquid reforming
- Solar thermochemical hydrogen (STCH).

ELECTROLYTIC PROCESSES

Electrolyzers use electricity to split water into hydrogen and oxygen. This technology is well developed and available commercially, and systems that can efficiently use intermittent renewable power are being developed. Learn more about electrolysis.

DIRECT SOLAR WATER SPLITTING PROCESSES

Direct solar water splitting, or photolytic, processes use light energy to split water into hydrogen and oxygen. These processes are currently in the very early stages of research but offer long-term potential for sustainable hydrogen production with low environmental impact. Learn more about the following solar water splitting processes:

- **Photoelectrochemical (PEC)**

In photoelectrochemical (PEC) water splitting, hydrogen is produced from water using sunlight and specialized semiconductors called photoelectrochemical materials, which use light energy to directly dissociate water molecules into hydrogen and oxygen. This is a long-term technology pathway, with the potential for low or no greenhouse gas emissions.

Prodcution

The PEC water splitting process uses semiconductor materials to convert solar energy directly to chemical energy in the form of hydrogen. The semiconductor materials used in the PEC process are similar to those used in photovoltaic solar electricity generation, but for PEC applications the semiconductor is immersed in a water-based electrolyte, where sunlight energizes the water-splitting process.

- **Photobiological**

The photobiological hydrogen production process uses microorganisms and sunlight to turn water, and sometimes organic matter, into hydrogen. This is a longer-term technology pathway in the early stages of research that has a long-term potential for sustainable hydrogen production with low environmental impact.

Prodcution

In photolytic biological systems, microorganisms—such as green microalgae or cyanobacteria—use sunlight to split water into oxygen and hydrogen ions. The hydrogen ions can be combined through direct or indirect routes and released as hydrogen gas. Challenges for this pathway include low rates of hydrogen production and the fact that splitting water also produces oxygen, which quickly inhibits the hydrogen production reaction and can be a safety issue when mixed with hydrogen in certain concentrations. Researchers are working to develop methods to allow the microbes to produce hydrogen for longer periods of time and to increase the rate of hydrogen production.

Some photosynthetic microbes use sunlight as the driver to break down organic matter, releasing hydrogen. This is known as photofermentative hydrogen production. Some of the major challenges of this pathway include a very low hydrogen production rate and low solar-to-hydrogen efficiency, making it a commercially unviable pathway for hydrogen production at this time.

Researchers are looking at ways to make the microbes better at collecting and using energy to make more available for hydrogen production, and to change their normal biological pathways to increase the rate of hydrogen production.

BIOLOGICAL PROCESSES

Microbes such as bacteria and microalgae can produce hydrogen through biological reactions, using sunlight or organic matter. These technology pathways are at an early stage of research, but in the long term have the potential for sustainable, low-carbon hydrogen production. Learn more about the following biological processes:

- **Microbial biomass conversion**

Microbial biomass conversion processes take advantage of the ability of microorganisms to consume and digest biomass and release hydrogen. Depending on the pathway, this research could result in commercial-scale systems in the mid- to long-term timeframe that could be suitable for distributed, semi-central, or central hydrogen production scales, depending on the feedstock used.

Prodcution

In fermentation-based systems, microorganisms, such as bacteria, break down organic matter to produce hydrogen. The organic matter can be refined sugars, raw biomass sources such as corn stover, and even wastewater. Because no light is required, these methods are sometimes called "dark fermentation" methods.

In direct hydrogen fermentation, the microbes produce the hydrogen themselves. These microbes can break down complex molecules through many different pathways, and the byproducts of some of the pathways can be combined by enzymes to produce hydrogen. Researchers are studying how to make fermentation systems produce hydrogen faster (improving the rate) and produce more hydrogen from the same amount of organic matter (increasing the yield).

Microbial electrolysis cells (MECs) are devices that harness the energy and protons produced by microbes breaking down organic matter, combined with an additional small electric current, to produce hydrogen. This technology is very new, and researchers are working on improving many aspects of the system, from finding lower-cost materials to identifying the most effective type of microbes to use.

- **Photobiological.**

The photobiological hydrogen production process uses microorganisms and sunlight to turn water, and sometimes organic matter, into hydrogen. This is a longer-term technology pathway in the early stages of research that has a long-term potential for sustainable hydrogen production with low environmental impact.

<u>Hydrogen energy</u>

Advantages of Hydrogen Energy

1. **It's a renewable energy source and bountiful in supply**

Hydrogen is a rich source of energy for many reasons; the main being that it's bountiful in supply. While it may take a lot of resources to harness it, no other energy source is infinite as hydrogen. That, essentially, means there is no possibility of it running out like other sources of energy.

2. **It practically a clean energy source**

When hydrogen is burnt to produce fuel, the byproducts are totally safe, which means, they have no known side effects. Aeronautical companies actually use hydrogen as a source of drinking water. After hydrogen is utilized, it is normally converted to drinking water for astronauts on ship or space stations.

3. Hydrogen energy is non-toxic

This means that it does not cause any harm or destruction to human health. This aspect makes it preferred compared to other sources of fuel like nuclear energy, natural gas, which are extremely hazardous or daunting to harness safely. It also allows hydrogen to be used in places where other forms of fuel may not be allowed.

4. It's far more efficient than other sources of energy

Hydrogen is solidly efficient energy type since it has the ability to convey a lot of energy for every pound of fuel. This categorically means that an automobile that utilizes hydrogen energy will travel more miles than one with an equal amount of gasoline.

5. Used for powering space ships

Hydrogen energy's efficiency and power makes it an ideal fuel source for spaceships. Its power is so high that it's able to quickly rocket spaceships to exploration missions. It's also the safest form of energy to perform such an energy-intensive task. Hydrogen energy is in fact 3 times more potent than gasoline and other fossil-based sources of fuel. This ideally means that you need less hydrogen to complete an enormous task.

It also offers motive power for airplanes, boats, cars, and both portable and stationary fuel cell applications. The downside to using hydrogen in cars is that it's practically difficult to store in cryogenic or high-pressure tanks.

Disadvantages of Hydrogen Energy

While hydrogen energy has a lot of admirable benefits, it's not really the outright preferable, clean and cheap energy source for most governments and companies. In gaseous state, it's quite volatile. While its volatility gives it an edge over energy sources in terms of accomplishing numerous tasks, it equally renders it risky to use and work around. Some of the disadvantages of hydrogen energy include:

1. Hydrogen energy is expensive

Electrolysis and steam reforming, the two main processes of hydrogen extraction are extremely expensive. This is the real reason it's not heavily used across the world. Today, hydrogen energy is chiefly used to power most hybrid vehicles. A lot of research and innovation is required to discover cheap and sustainable ways to harness this form of energy. Until then, hydrogen energy would remain exclusively for the rich.

2. Storage complications

One of hydrogen properties is that it has a lower density. In fact, it is a lot less denser than gasoline. This means that it has to be compressed to liquid state and stored the same way at lower temperatures to guarantee its effectiveness and efficiency as an energy source. This reason also explains why hydrogen must at all times be stored and transported under high pressure, which is why transportation and common use is far from feasible.

3. It's not the safest source of energy

The power of hydrogen should not be underestimated at all. Although gasoline is a little more dangerous than hydrogen, hydrogen is hugely flammable and frequently makes headlines for its potential dangers. Compared to gas, hydrogen lacks smell, which makes any leak detection almost impossible. To detect leaks, one must install sensors.

4. Tricky to move around

It's a daunting task to transport hydrogen brilliantly due to its lightness. Oil can be transported safely because it's mostly pushed through pipes. Coal can conveniently be transported in dump trucks. Hydrogen also presents challenges when considering moving it in large quantities, which is why it's mostly only transported in small batches.

5. Hydrogen energy cannot sustain the population

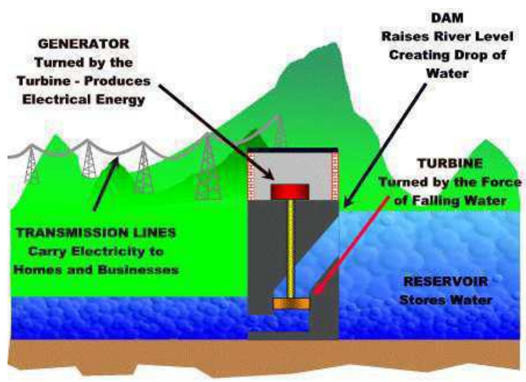
Despite the fact that hydrogen is bountiful in supply, the cost of harnessing it limits extensive utilization. As you realize, it's quite challenging to disrupt the status quo. Energy from fossil fuels still rule the world. There is also no framework put in place to ensure cheap and sustainable hydrogen energy for the normal car owner in the future. Even if hydrogen were to become cheap right now, it would take years to become the most used source of energy since vehicles themselves and service stations would need to be customized to conform to hydrogen requirements. This would require massive capital outlay.

It's a fact that hydrogen energy is a renewable resource because it's abundantly available and its impacts hugely neglected. However, hydrogen companies will, in real sense, need other forms of non-renewable energy such as fossil (coal, natural gas, and oil) to separate it from oxygen. We may be able to minimize over-reliance on fossils fuels when we embrace hydrogen energy, but it will be daunting to get rid of it from the system.

Hydro Power

HYDROPOWER

Hydropower transforms the potential energy of a mass of water flowing in a river or stream with a certain vertical fall (termed the "head") Hydroelectric power is the cheapest source of energy, renewable and environmentally benign during running. The potential annual power generation of a hydropower project is proportional to the head and flow of water.



Elements of hydropower plant

1) Dam

The dam is the most important component of hydroelectric power plant. The dam is built on a large river that has abundant quantity of water throughout the year. It should be built at a location where the height of the river is sufficient to get the maximum possible potential energy from water.

2) Water Reservoir

The water reservoir is the place behind the dam where water is stored. The water in the reservoir is located higher than the rest of the dam structure. The height of water in the reservoir decides how much potential energy the water possesses. The higher the height of water, the more its potential energy. The high position of water in the reservoir also enables it to move downwards effortlessly. The height of water in the reservoir is higher than the natural height of water flowing in the river, so it is considered to have an altered equilibrium.

This also helps to increase the overall potential energy of water, which helps ultimately produce more electricity in the power generation unit.

3) Intake or Control Gates

These are the gates built on the inside of the dam. The water from reservoir is released and controlled through these gates. These are called inlet gates because water enters the power generation unit through these gates. When the control gates are opened the water flows due to gravity through the penstock and towards the turbines. The water flowing through the gates possesses potential as well as kinetic energy.

4) The Penstock

The penstock is the long pipe or the shaft that carries the water flowing from the reservoir towards the power generation unit, comprised of the turbines and generator. The water in the penstock possesses kinetic energy due to its motion and potential energy due to its height. The total amount of power generated in the hydroelectric power plant depends on the height of the water reservoir and the amount of water flowing through the penstock. The amount of water flowing through the penstock is controlled by the control gates.

5) Water Turbines

Water flowing from the penstock is allowed to enter the power generation unit, which houses the turbine and the generator. When water falls on the blades of the turbine the kinetic and potential energy of water is converted into the rotational motion of the blades of the turbine. The rotating blades causes the shaft of the turbine to also rotate. The turbine shaft is enclosed inside the generator. In most hydroelectric power plants there is more than one power generation unit. There is large difference in height between the level of turbine and level of water in the reservoir. This difference in height, also known as the head of water, decides the total amount of power that can be generated in the hydroelectric power plant. There are various types of water turbines such as Kaplan turbine, Francis turbine, Pelton wheels etc. The type of turbine used in the hydroelectric power plant depends on the height of the reservoir, quantity of water and the total power generation capacity.

6) Draft tube:

The draft tube is a part of the reaction turbine. The draft tube is a diverging discharge passage connecting the running with tailrace. It is shaped to decelerate the flow with a minimum loss so that the remaining kinetic energy of the water coming out of the runner is efficiently regained by converting into suction head., thereby increasing the total pressure difference on the runner. This regain of kinetic energy of the water coming out from the reaction turbine is the primary function of the draft tube. The regain of static suction head in case where the runner is located above the tail water level is the secondary purpose of the draft tube.

7) Generators

It is in the generator where the electricity is produced. The shaft of the water turbine rotates in the generator, which produces alternating current in the coils of the generator. It is the rotation of the shaft inside the generator that produces magnetic field which is converted into electricity by electromagnetic field induction. Hence the rotation of the shaft of the turbine is crucial for the production of electricity and this is achieved by the kinetic and potential energy of water. Thus in hydroelectricity power plants potential energy of water is converted into electricity.

Seafty services

9. Spillway:

The function of spillway is to provide safety of the dam. Spillway should have the capacity to discharge major floods without damage to the dam and at the same time keeps the reservoir levels below some predetermined maximum level.Trash Rack:

The water intake from the dam or from the forebay are provided with trash rack. The main function of trash rack is to prevent the entry of any debris which may damage the wicket gates and turbine runners or choke-up the nozzles of impulse turbine. During winter season when water forms ice, to prevent the ice from clinging to the trash racks, they are often heated electrically. Sometimes air bubbling system is provided in the vicinity of the trash racks which brings warmer water to the surface of the trash racks.

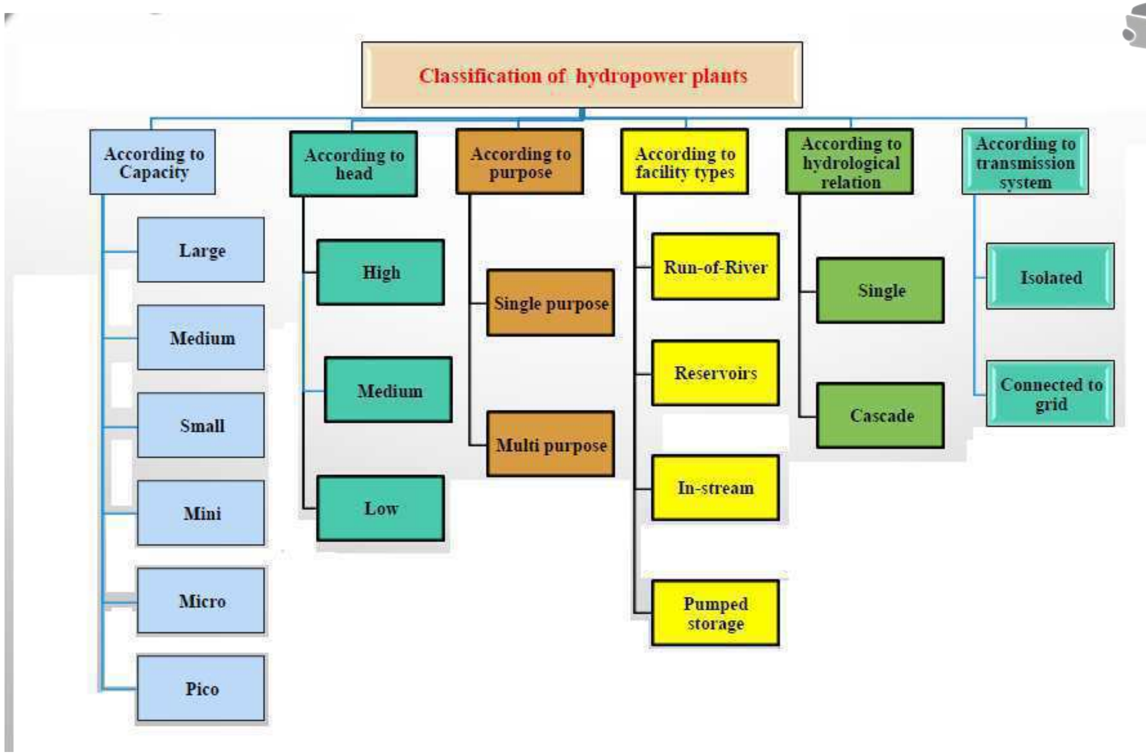
2. Forebay:

The function of forebay is to act as regulating reservoir temporarily storing water when the load on the plant is reduced and to provide water for initial increment of an increasing load while water in the canal is being accelerated. In many cases, the canal itself is large enough to absorb the flow variations. In short, forebay is naturally provided for storage of water to absorb any flow variations if exist. This can be considered as naturally provided surge tank as it does the function of the surge tank. The forebay is always provided with some type of outlet structure to direct water to penstock depending upon the local conditions.

3. Surge Tank:

The main function of surge tank is to reduce the water hammering effect. When there is a sudden increase of pressure in the penstock which can be due sudden decrease in the load demand on the generator. When there is sudden decrease in the load, the turbine gates admitting water to the turbine closes suddenly owing to the action of the governor. This sudden rise in the pressure in the penstock will cause the positive water hammering effect. This may lead to burst of the penstock because of high pressures. When there is sudden increase in the load, governor valves opens and accepts more water to the turbine. This results in creation of vacuum in the penstock resulting into the negative water hammering effect. Therefore the penstock should have to withstand both positive water hammering effect created due to close of governor valve and negative water hammering effect due to opening of governor valve.In order to protect the penstock from these water hammering effects, surge tank is used in hydroelectric power station. A surge tank is introduced in the system between dam and the power house nearest. Surge tank is a tank provided to absorb any water surges caused in the penstok due to sudden loading and unloading of the generator. When the velocity of the water in the penstock decreases due to closing of turbine valves, the water level in the surge tank increases and fluctuating up and down till its motion is damped out by the friction. Similarly when the water accelerates in the penstock, water is provided by the surge tank for acceleration. Surge tank water level falls down and fluctuates up and down absorbing the surges.

Classification Of Hydropower Plants



Classification according to capacity

LARGE: >100 MW

MEDIUM: 25 – 100 MW

SMALL: 1-25 MW

MINI: 100 KW - 1MW

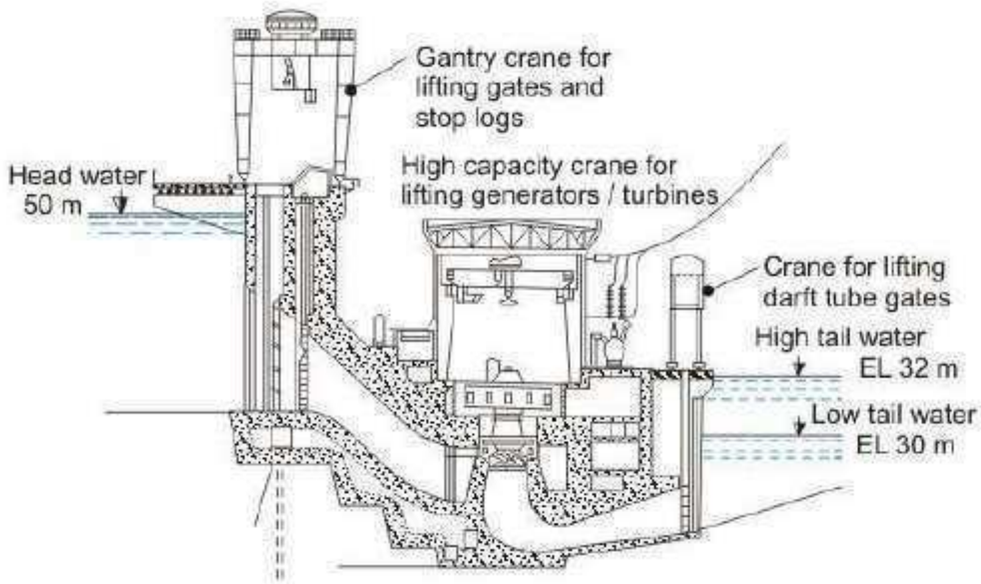
MICRO: 5 – 100 KW

PICO: < 5 KW

Classifcation According To Head

LOW HEAD:

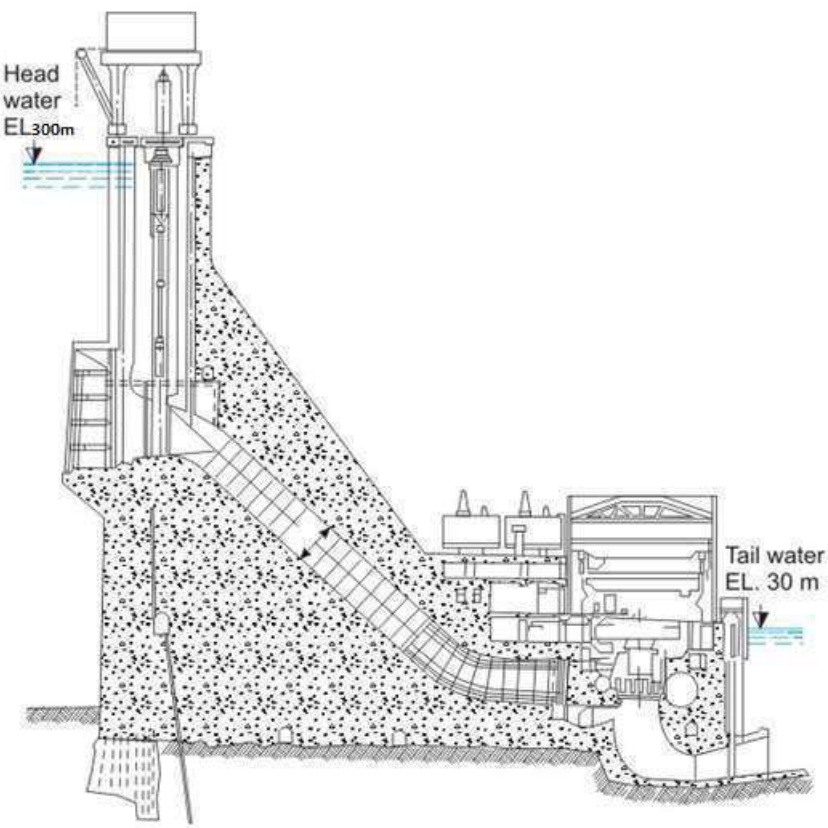
Low head hydro power applications use river current or tidal flows of 30 meters or less to produce energy. These applications do not need to dam or retain water to create hydraulic head, the head is only a few meters. Using the current of a river or the naturally occurring tidal flow to create electricity may provide a renewable energy source that will have a minimal impact on the environment.



Sectional View Of Low Head Hydropower Plant

MEDIUM HEAD:

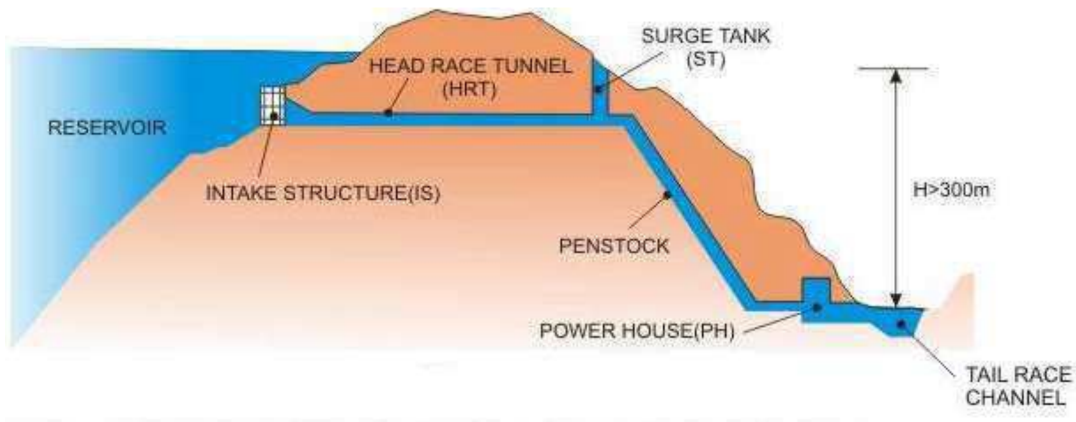
A power station operating under heads from 30m to 300m.



Sectional View Of Medium Head Hydropower Plant

HIGH HEAD:

A power station operating under heads above about 300m. A head of 200m/250m is considered as the limit between medium and high head power stations.

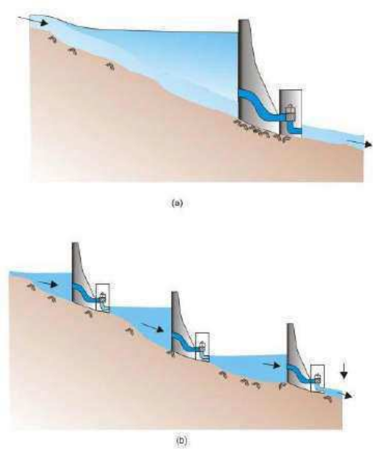


High Head Hydropower Plant

Classification according to hydrological relation

SINGLE STAGE- When the run off from a single hydropower plant is diverted back into river or for any other purpose other than power generation, the setup is known as Single Stage.

CASCADE SYSTEM- When two or more hydropower plants are used in series such that the runoff discharge of one hydro power plant is used as the is a intake discharge of the second hydro power plant such a system is known as CASCADE hydropower plant.



(a) single stage hydropower development scheme

(b) cascade or multistage hydropower system

Classification According To Purpose

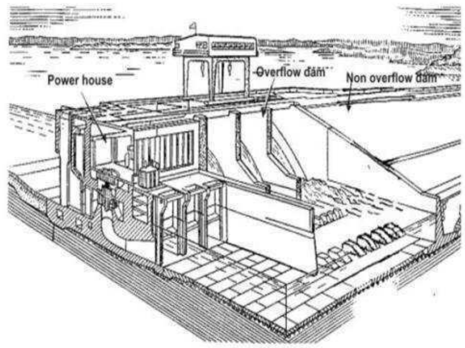
SINGLE PURPOSE: When the whole soul purpose of a project is to produce electricity then such a project is known as a Single Purpose Hydro Power Project.

MULTIPURPOSE : When the water used in hydropower project is to be used for other purposes like irrigation, flood control or fisheries then such a project is known as Multi Purpose Hydro Power Project.

According to facility types

RUN-OF-RIVER TYPE

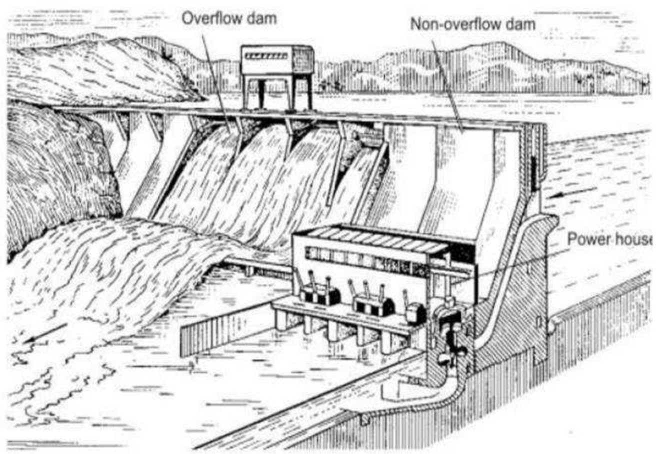
These are hydro power plants that utilize the stream flow as it comes , without any storage being provided.



STORAGE (RESERVOIR) TYPE

Hydropower plants with storage are supplied with water from large storage reservoir that have been developed by constructing dams across rivers.

Assured flow for hydro power generation is more certain for the storage schemes than the run-of-river schemes.

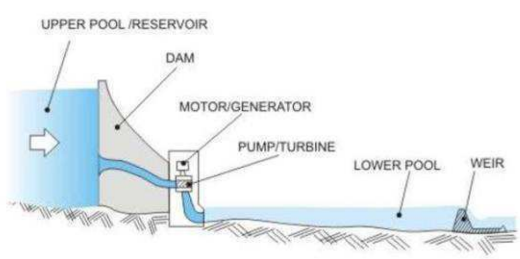


PUMPED STORAGE TYPE

Pumped storage type hydropower plants are those which utilize the flow of water from a reservoir at higher potential to

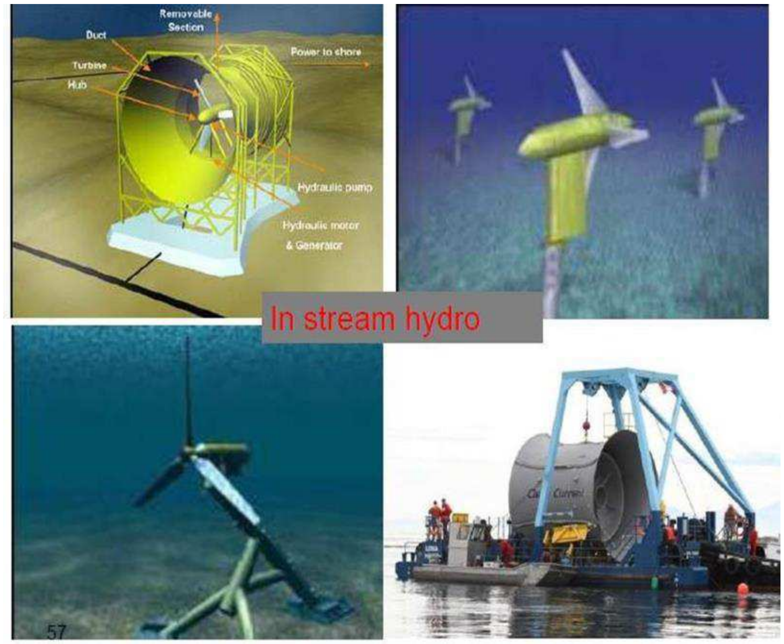
one at lower potential.

During off-peak hours, the reversible units are supplied with the excess electricity available in the power grid which then pumps part of the water of the tail-water pond back into the head-water pond.



IN-STREAM

When the velocity of water i.e kinetic energy flowing in the stream is used for conversion into electrical power, then the system is known as In- stream.



According to trasmission system

ISOLATED: Whenever a hydropower plant is set up in a remote area in order to meet the local demands then such a hydropower plant is known as Isolated System.

CONNECTED TO GRID: Whenever the hydropower plant is set up to meet the demands of areas which are at a fair distance from the plant, then the transmission of power takes through the grid system. Such a setup is referred to as Connected to grid.

Energy storage or regeneration

Pumped-storage hydroelectricity (PSH), or pumped hydroelectric energy storage (PHES), is a type of hydroelectricenergy storage used by electric power systems for load balancing. The method stores energy in the form of gravitational potential energy of water, pumped from a lower elevation reservoir to a higher elevation. Low-cost surplus off-peak electric power is typically used to run the pumps. During periods of high electrical demand, the stored water is released through turbines to produce electric power. Although the losses of the pumping process makes the plant a net consumer of energy overall, the system increases revenue by selling more electricity during periods of peak demand, when electricity prices are highest.

Pumped-storage hydroelectricity allows energy from intermittent sources (such as solar, wind) and other renewables, or excess electricity from continuous base-load sources (such as coal or nuclear) to be saved for periods of higher demand.The reservoirs used with pumped storage are quite small when compared to conventional hydroelectric dams of similar power capacity, and generating periods are often less than half a day.

Pumped storage is the largest-capacity form of grid energy storage available, and, as of 2017, the United States Department of Energy Global Energy Storage Database reports that PSH accounts for over 96% of all active tracked storage installations worldwide, with a total installed nameplate capacity of over 168 GW.[3] The round-trip energy efficiency of PSH varies between 70%–80%, with some sources claiming up to 87%.[8] The main disadvantage of PSH is the specialist nature of the site required, needing both geographical height and water availability. Suitable sites are therefore likely to be in hilly or mountainous regions, and potentially in areas of outstanding natural beauty, and therefore there are also social and ecological issues to overcome. Many recently proposed projects, at least in the U.S., avoid highly sensitive or scenic areas, and some propose to take advantage of "brownfield" locations such as disused mines.

At times of low electrical demand, excess generation capacity is used to pump water into the upper reservoir. When there is higher demand, water is released back into the lower reservoir through a turbine, generating electricity. Reversible turbine/generator assemblies act as a combined pump and turbine generator unit (usually a Francis turbine design).

Types: natural or man-made reservoirs

In open-loop systems, pure pumped-storage plants store water in an upper reservoir with no natural inflows, while pump-back plants utilize a combination of pumped storage and conventional hydroelectric plants with an upper reservoir that is replenished in part by natural inflows from a stream or river. Plants that do not use pumped-storage are referred to as conventional hydroelectric plants; conventional hydroelectric plants that have significant storage capacity may be able to play a similar role in the electrical grid as pumped storage by deferring output until needed.

Economic efficiency

Taking into account evaporation losses from the exposed water surface and conversion losses, energy recovery of 70-80% or more can be regained.[10] This technique is currently the most cost-effective means of storing large amounts of electrical energy, but capital costs and the presence of appropriate geography are critical decision factors in selecting pumped-storage plant sites.

The relatively low energy density of pumped storage systems requires either large flows and/or large differences in height between reservoirs. The only way to store a significant amount of energy is by having a large body of water located relatively near, but as high above as possible, a second body of water. In some places this occurs naturally, in others one or both bodies of water were man-made. Projects in which both reservoirs are artificial and in which no natural inflows are involved with either reservoir are referred to as "closed loop" systems.

These systems may be economical because they flatten out load variations on the power grid, permitting thermal power stations such as coal-fired plants and nuclear power plantsthat provide base-load electricity to continue operating at peak efficiency, while reducing the need for "peaking" power plants that use the same fuels as many base-load thermal plants, gas and oil, but have been designed for flexibility rather than maximal efficiency. Hence pumped storage systems are crucial when coordinating large groups of heterogeneous generators. Capital costs for pumped-storage plants are relatively high, although this is somewhat mitigated by their long service life of up to 75 years or more, which is three to five times longer than utility-scale batteries.

Station	Country	Location	Capacity (MW)	Refs
Bath County Pumped Storage Station	United States	38°12′32″N 79°48′00″W	3,003	[25]
Guangdong Pumped Storage Power Station	China	23°45′52″N 113°57′12″E	2,400	[26][27]
Huizhou Pumped Storage Power Station	China	23°16′07″N 114°18′50″E	2,400	[28][29][30][31]
Okutataragi Pumped Storage Power Station	Japan	35°14′13″N 134°49′55″E	1,932	[32]
Ludington Pumped Storage Power Plant	United States	43°53′37″N 86°26′43″W	1,872	[33][34]

Potential technologies

Seawater

Pumped storage plants can operate with seawater, although there are additional challenges compared to using fresh water. In 1999, the 30 MW Yanbaru project in Okinawa was the first demonstration of seawater pumped storage. It has since been decommissioned. A 300 MW seawater-based Lanai Pumped Storage Project was considered for Lanai, Hawaii, and seawater-based projects have been proposed in Ireland. A pair of proposed projects in the Atacama Desert in northern Chile would use 600 MW of photovoltaic solar (Skies of Tarapacá) together with 300 MW of pumped storage (Mirror of Tarapacá) raising seawater 600 metres (2,000 ft) up a coastal cliff.

Underground reservoirs

The use of underground reservoirs has been investigated. Recent examples include the proposed Summit project in Norton, Ohio, the proposed Maysville project in Kentucky(underground limestone mine), and the Mount Hope project in New Jersey, which was to have used a former iron mine as the lower reservoir. The proposed energy storage at the Callio site in Pyhäjärvi (Finland) would utilize the deepest base metal mine in Europe, with 1,450 metres (4,760 ft) elevation difference. Several new underground pumped storage projects have been proposed. Cost-per-kilowatt estimates for these projects can be lower than for surface projects if they use existing underground mine space. There are limited opportunities involving suitable underground space, but the number of underground pumped storage opportunities may increase if abandoned coal mines prove suitable.

Decentralised systems

Small pumped-storage hydropower plants can be built on streams and within infrastructures, such as drinking water networks and artificial snow making infrastructures. Such plants provide distributed energy storage and distributed flexible electricity production and can contribute to the decentralized integration of intermittent renewable energy technologies, such as wind power and solar power. Reservoirs that can be used for small pumped-storage hydropower plants could include natural or artificial lakes, reservoirs within other structures such as irrigation, or unused portions of mines or underground military installations. In Switzerland one study suggested that the total installed capacity of small pumped-storage hydropower plants in 2011 could be increased by 3 to 9 times by providing adequate policy instruments.

Underwater reservoirs

In March 2017 the research project St. EnSea (Storing Energy at Sea) announced their successful completion of a four-week test of a pumped storage underwater reservoir. In this configuration a hollow sphere submerged and anchored at great depth acts as the lower reservoir, while the upper reservoir is the enclosing body of water. Electricity is created when water is let in via a reversible turbine integrated into the sphere. During off-peak hours the turbine changes direction and pumps the water out again, using "surplus" electricity from the grid. The quantity of power created when water is let in grows proportionally to the height of the column of water above the sphere, in other words: the deeper the sphere is located the more potential energy it can store, which can be transformed into electric power. On the other hand, pumping the water back out at greater depths also uses up more power, since the turbine-turned-pump must act on the same entire column of water.

As such the energy storage capacity of the submerged reservoir is not governed by the gravitational energy in the traditional sense, but rather by the vertical pressure variation.

While St EnSea's test took place at a depth of 100 m in the fresh water Lake Constance, the technology is foreseen to be used in salt water at greater depths. Since the submerged reservoir needs only a connecting electrical cable, the depth at which it can be employed is limited only by the depth at which the turbine can function, currently limited to 700 m. The challenge of designing salt water pumped storage in this underwater configuration brings a range of advantages:

- No land area is required,
- No mechanical structure other than the electrical cable needs to span the distance of the potential energy difference,
- In the presence of sufficient seabed area multiple reservoirs can scale the storage capacity without limits,
- Should a reservoir collapse, the consequences would be limited apart from the loss of the reservoir itself,
- Evaporation from the upper reservoir has no effect on the energy conversion efficiency,
- Transmission of electricity between the reservoir and the grid can be established from a nearby offshore wind farm limiting transmission loss and obviating the need for onshore cabling permits.

Superconducting Magnetic Energy Storage (SMES)

SMES systems store energy in the magnetic field created by the flow of direct current in a superconducting coil which has been cryogenically cooled to a temperature below its superconducting critical temperature.

A typical SMES system includes three parts: superconducting coil, power conditioning system and cryogenically cooled refrigerator. Once the superconducting coil is charged, the current will not decay and the magnetic energy can be stored indefinitely.

The stored energy can be released back to the network by discharging the coil. The power conditioning system uses an inverter/rectifier to transform alternating current (AC) power to direct current or convert DC back to AC power. The inverter/rectifier accounts for about 2–3% energy loss in each direction. SMES loses the least amount of electricity in the energy storage process compared to other methods of storing energy. SMES systems are highly efficient; the round-trip efficiency is greater than 95%.Due to the energy requirements of refrigeration and the high cost of superconducting wire, SMES is currently used for short duration energy storage. Therefore, SMES is most commonly devoted to improving power quality.

Current use

There are several small SMES units available for commercial use and several larger test bed projects. Several 1 MW·h units are used for power quality control in installations around the world, especially to provide power quality at manufacturing plants requiring ultra-clean power, such as microchip fabrication facilities.

These facilities have also been used to provide grid stability in distribution systems. SMES is also used in utility applications. In northern Wisconsin, a string of distributed SMES units were deployed to enhance stability of a transmission loop. The transmission line is subject to large, sudden load changes due to the operation of a paper mill, with the potential for uncontrolled fluctuations and voltage collapse.

The Engineering Test Model is a large SMES with a capacity of approximately 20 MW·h, capable of providing 40 MW of power for 30 minutes or 10 MW of power for 2 hours.

Calculation of stored energy

The magnetic energy stored by a coil carrying a current is given by one half of the inductance of the coil times the square of the current.

Where

E = energy measured in joules

L = inductance measured in henries

I = current measured in amperes

Now let's consider a cylindrical coil with conductors of a rectangular cross section. The mean radius of coil is R. a and b are width and depth of the conductor. f is called form function which is different for different shapes of coil. ξ (xi) and δ (delta) are two parameters to characterize the dimensions of the coil. We can therefore write the magnetic energy stored in such a cylindrical coil as shown below. This energy is a function of coil dimensions,number of turns and carrying current.

Where

E = energy measured in joules

I = current measured in amperes

f(ξ,δ) = form function, joules per ampere-meter

N = number of turns of coil

Solenoid vs Toroid

Besides the properties of the wire, the configuration of the coil itself is an important issue from a mechanical engineering aspect. There are three factors which affect the design and the shape of the coil - they are: Inferior strain tolerance, thermal contraction upon cooling and Lorentz forces in a charged coil. Among them, the strain tolerance is crucial not because of any electrical effect, but because it determines how much structural material is needed to keep the SMES from breaking. For small SMES systems, the optimistic value of 0.3% strain tolerance is selected. Toroidal geometry can help to lessen the external magnetic forces and therefore reduces the size of mechanical support needed. Also, due to the low external magnetic field, toroidal SMES can be located near a utility or customer load.

For small SMES, solenoids are usually used because they are easy to coil and no pre-compression is needed. In toroidal SMES, the coil is always under compression by the outer hoops and two disks, one of which is on the top and the other is on the bottom to avoid breakage. Currently, there is little need for toroidal geometry for small SMES, but as the size increases, mechanical forces become more important and the toroidal coil is needed.

The older large SMES concepts usually featured a low aspect ratio solenoid approximately 100 m in diameter buried in earth. At the low extreme of size is the concept of micro-SMES solenoids, for energy storage range near 1 MJ.

Low-temperature versus high-temperature superconductors

Under steady state conditions and in the superconducting state, the coil resistance is negligible. However, the refrigerator necessary to keep the superconductor cool requires electric power and this refrigeration energy must be considered when evaluating the efficiency of SMES as an energy storage device.

Although the high-temperature superconductor (HTSC) has higher critical temperature, flux lattice melting takes place in moderate magnetic fields around a temperature lower than this critical temperature. The heat loads that must be removed by the cooling system include conduction through the support system, radiation from warmer to colder surfaces, AC losses in the conductor (during charge and discharge), and losses from the cold–to-warm power leads that connect the cold coil to the power conditioning system. Conduction and radiation losses are minimized by proper design of thermal surfaces. Lead losses can be minimized by good design of the leads. AC losses depend on the design of the conductor, the duty cycle of the device and the power rating.

The refrigeration requirements for HTSC and low-temperature superconductor (LTSC) toroidal coils for the baseline temperatures of 77 K, 20 K, and 4.2 K, increases in that order. The refrigeration requirements here is defined as electrical power to operate the refrigeration system. As the stored energy increases by a factor of 100, refrigeration cost only goes up by a factor of 20. Also, the savings in refrigeration for an HTSC system is larger (by 60% to 70%) than for an LTSC systems.

Cost

Whether HTSC or LTSC systems are more economical depends because there are other major components determining the cost of SMES: Conductor consisting of superconductor and copper stabilizer and cold support are major costs in themselves. They must be judged with the overall efficiency and cost of the device. Other components, such as vacuum vessel insulation, has been shown to be a small part compared to the large coil cost. The combined costs of conductors, structure and refrigerator for toroidal coils are dominated by the cost of the superconductor. The same trend is true for solenoid coils. HTSC coils cost more than LTSC coils by a factor of 2 to 4. We expect to see a cheaper cost for HTSC due to lower refrigeration requirements but this is not the case.

