# Energy and Power – A brief review on how it works

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**Abstract**

In conjunction with worldwide decreasing of energy sources and increasing of electric power consumption, the environment problematic is getting into spotlight more and more presently. Due to these facts, it is necessary to search for new alternatives and new solutions of energy power generation as there are a lot of problems with this technology nowadays. This work review on how 10 energy – generating systems work and provides clear technology behind their working principles. Each illustration explained the technology behind central components and shows each system in action starting with how power is harnessed from water and wind.

Keywords: Fission and fussion; Fuel; Onshore and offshore; Cells; Reactor.

## 1.0 Introduction

Due to technology advancement we source energy from hydro (water), nuclear (fission and fusion), wind, sun (solar), wave, tide, geothermal and fuels (coal, oil and natural gas) using special techniques or methods to meet the demand of the world (fig. 1). Energy exists in many forms – movement or motion, heat, light, sound, chemical substances in fuels, electrical and magnetic forces, and radioactivity. According to Parker, 2010, we use energy when we cook a meal or travel in a plane. Energy is never created or destroyed – it changes from one form to another. For example, a vehicle's fuel energy changes into heat, sound and movement. In a television, electrical energy becomes tiny dots of coloured light.

This analysis will focus briefly on how the various forms of energy is harnessed and how it is utilized to meet every day energy demand.

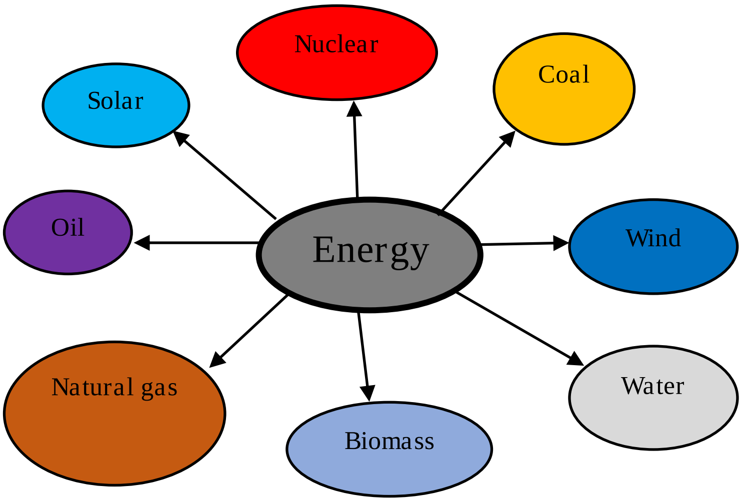



Fig. 1: Sources of energy

## 2.0 Coal Mine

**Coal mining** is simply the process of extracting coal from the ground. Coal is valued for its energy content, and, has been widely used to generate electricity, extract iron from iron ore and for cement production in cement industry. In Nigeria, coal deposits are found in many states such as Enugu (known as the "the coal city" because of its vast coal deposits), Benue, Kogi, Delta, Kwara, Plateau, Abia, Anambra, Bauchi, Edo, Ondo, Adamawa and Imo.

After the civil war, coal production in Nigeria declined drastically and with the economy diversion to crude oil, the mining of coal has been removed from the Nigerian natural resources limelight (Engr Sam Otenaike; Engr Gbenga Onifade, 2017)

## 2.1 How coal was formed

Coal is a combustible black or brownish-black sedimentary rock composed mostly of carbon and hydrocarbons. It is a nonrenewable energy source because it takes millions of years to form (fig. 2). The energy in coal comes from the energy stored by plants that lived hundreds of millions of years ago, when the earth was partly covered with swampy forests. A layer of dead plants at the bottom of the swamps was covered by layers of water and dirt, trapping the energy of the dead plants. The heat and pressure from the top layers helped the plant remains turn into what we today call coal (Coal, Formed, We, & Coal, n.d.).

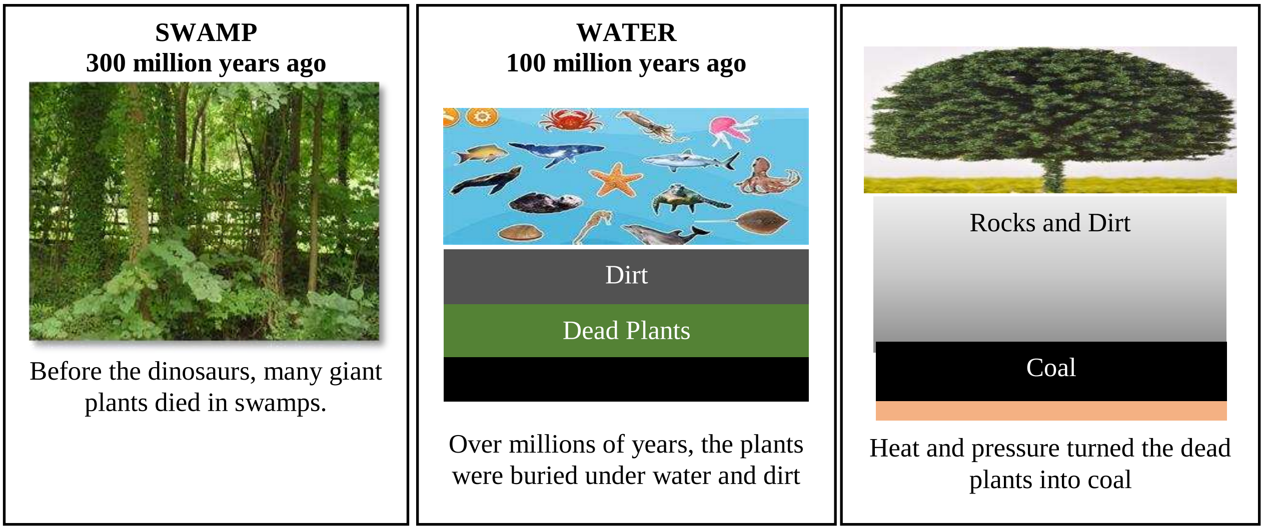



Fig. 2: How coal was formed

### 2.2 Methods of extraction

Surface mining and deep underground mining are the two basic methods of mining.

- Coal at depths less than approximately 180 ft (55 m), are usually surface mined.
- Coal that occurs at depths of 180 to 300 ft (55 to 90 m) are usually deep mined, but in some cases where the thickness of the seam is 60-90 feet (20-25 m) surface mining techniques can be used.
- Coals occurring below 300 ft (90 m) are usually deep mined.
- Other types of coal mining are strip mining, contour mining, mountaintop removal mining and underground mining.

### 2.3 What coal did today – Uses of coal

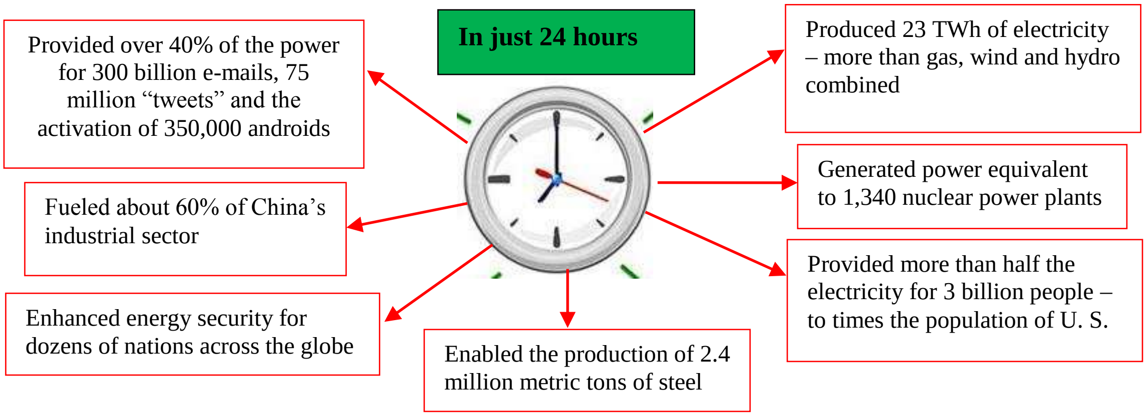



Fig. 3: Uses of coal (Wikipedia, The Free Encyclopedia, 2018)

Coal has many important uses worldwide. The most significant uses are in electricity generation, steel production, cement manufacturing and other industrial processes, and as a liquid fuel(Anonymous, 2002).

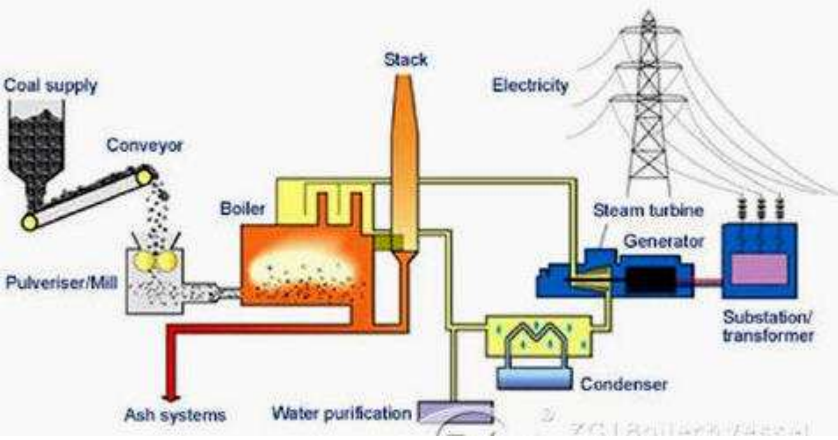



Fig. 4: Coal fired power plant diagram (Pilania, 2014)

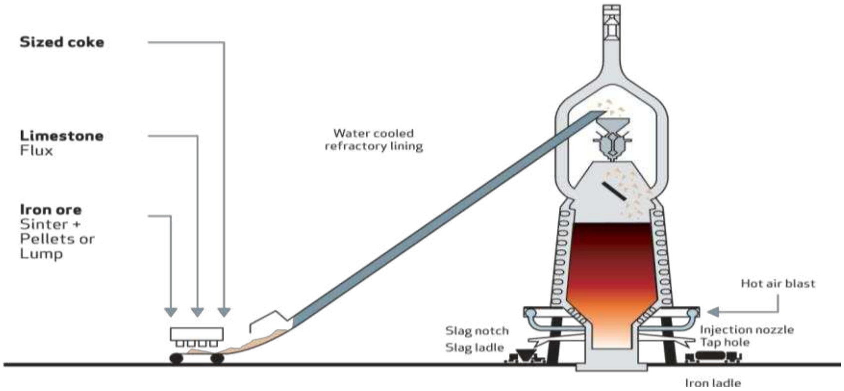



Fig. 5: Coal use in steel production

## 3.0 Oil and Gas Platform

Oil and gas platform are used anywhere there is petroleum oil or gas – these two energy-packed fossil fuels often occur together beneath the earth surface. The onshore and offshore drilling are the two common methods used in drilling oil and gas.

## 3.1 Onshore drilling and offshore drilling

Onshore drilling refers to drilling deep holes under the earth's surface whereas offshore drilling relates to drilling underneath the seabed. These drilling methods are used in order to extract natural resources – usually oil and gas – from the earth. Offshore drilling was much more difficult than the traditional onshore drilling method, but due to innovative methods that have surfaced such as making either floating or fixed platforms on the bed of the ocean to support drilling offshore drilling has become easier.

Offshore drilling rigs are classified differently, mainly based on their movability and how deep the sea bed is. There are two types of offshore drilling rigs.

1. **Bottom-supported units** are rigs that have contact with the seafloor. There are submersible bottom-supported units and also jack up units that are supported by structured columns.

2. **Floating units** do not come in direct contact with the ocean floor and instead float on the water. Some are partially submerged and anchored to the sea bed while others are drilling ships which can drill at different water depths.

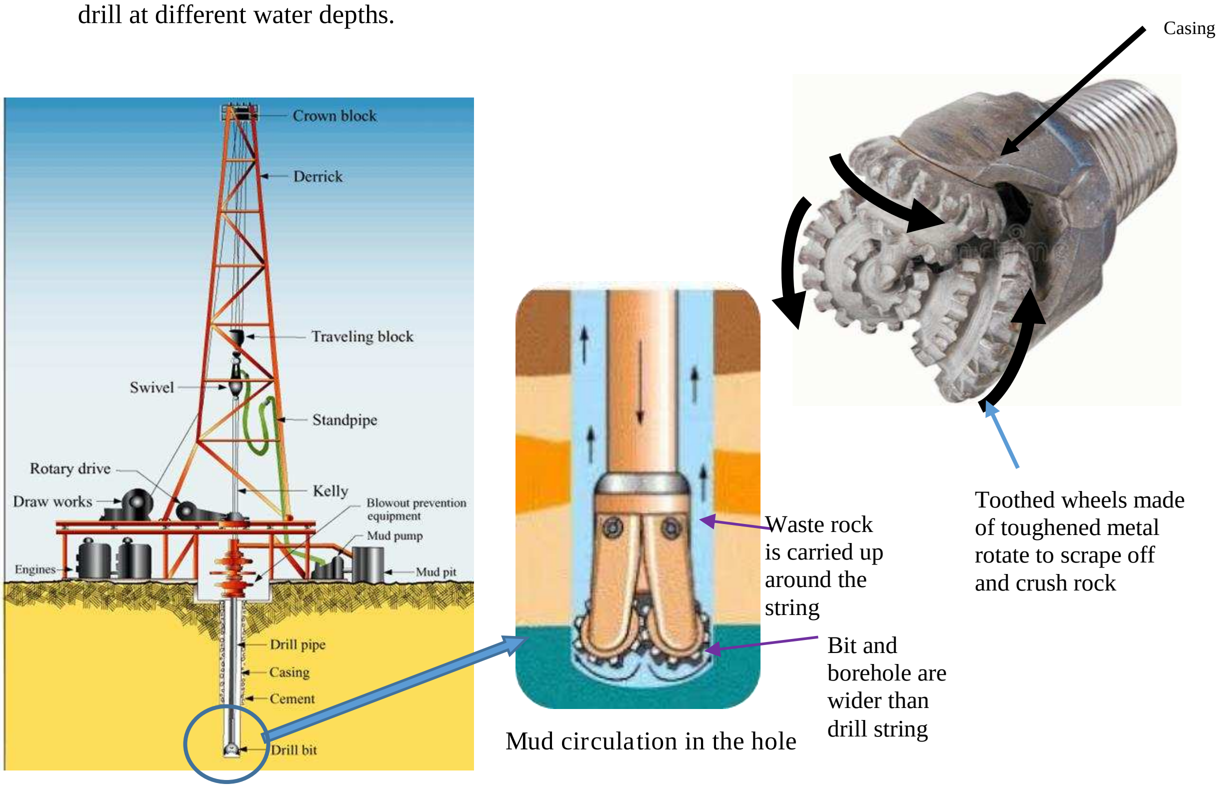



Fig. 4: Petroleum onshore drilling rig – picture from internet adapted with additional illustrations

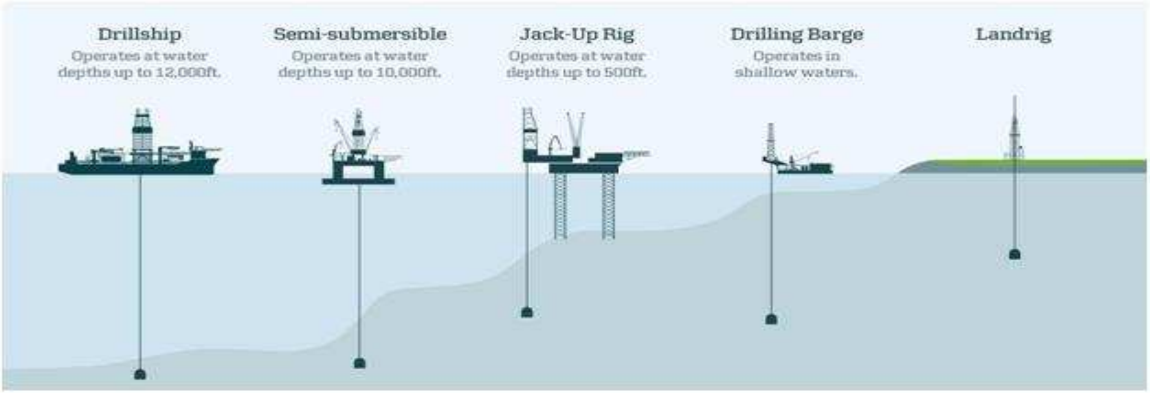



Fig.5: Diagram of different types of offshore drilling rigs.

### 3.2 How does the drill bit work?

Few machines have such a hard-wearing time as the oil drill bit. The drill bit three toothed wheels interlock or mesh so that they rasp and bite through solid rock as its string spins (fig.4). A specially made fluid ‘mud’ is pumped down the hollow inside of the drill string. It cools and lubricate the bit wheels, and flows back up around the drill string, carrying pieces or cutting of rocks. At the surface the expensive ‘mud’ is filtered and pumped down again.

The energy in oil and gas is measured in a unit called BOE (Barrel of Oil Equivalent. One BOE is about 1.7MWh. That is enough energy to supply a typical house with electricity for four months (Parker, 2010).

## 4.0 Wind Turbines

Like hydroelectricity and solar power, wind energy comes from the Sun (fig. 7). Its heat warms different parts of the land, sea and air by varying amounts. As hotter air rises, cooler air moves along to take its place – and this moving air is the wind blowing. (Parker, 2010)

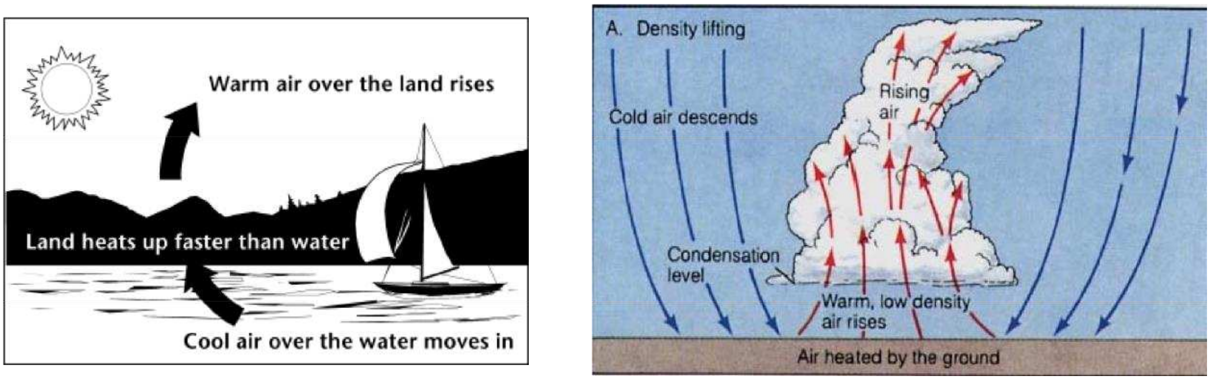



Fig. 7: How wind is formed

A wind turbine converts the kinetic energy in wind into mechanical energy. If the mechanical energy is then converted to electricity, the machine is called a wind generator. Wind turbines are mounted on a tower to capture the most energy (Nagpurwala, n.d.).

## 4.1 Working of Wind Turbine

The working principle of wind turbine is simple – change mechanical energy in air to electrical energy. We have different types of wind turbines and their principle of operations are the same.

Letcher (2017) reported that when the blades cut through the air with angle of attack to the wind it will cause a pressure differential (fig. 8). The resulting pressure differentials cause a force called lift, which propels the blade forward. This lift is created because of the airfoil shape of the turbines blades and in order to propel the turbine, the net torque caused by lift forces must be greater than the net torque caused by drag forces. The blades turn a generator that converts blade rotation into electricity. The tail keeps the blades facing the wind. In high winds, the blades turn sideways to limit speed.

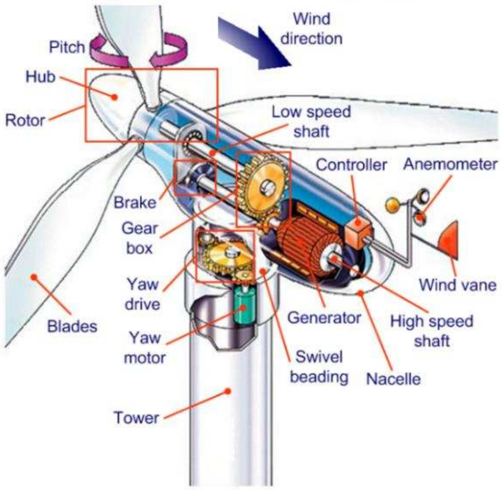



Fig. 8: Parts of wind turbine

## 5.0 Solar Panels

The sun provides us with many forms of energy we rely on every day. They include its light to see by, its warmth and the wind turbines and hydroelectric dams that generates electricity. Another way to produce electricity is to harness sunlight directly by the electronic devices known as photovoltaic or PV cells. These are grouped together on sheets and usually known as ‘solar panels’.

The first solar cell was made in 1883 by Charles Fritts. It converted only about one-hundredth of the light energy falling on it into electrical energy (Parker, 2010).

Fig. 9: Solar PV modules

### 5.1 The solar panels

Solar panels are used in producing or generating energy by collecting sunlight. When rays of sunlight hit solar cells, it will push the electrons in the cell through the wires to create electricity. This electricity is in one direction, so it is called Direct Current (DC). An inverter is needed in most installations to convert the Direct current (DC) to Alternating Current (AC) in order to make it usable with your home's appliances.

On one side of the solar cell, there are more electrons than the other side (fig.10). Manufacturers create this static imbalance of charges on the cell by doping each side of the silicon solar cell with different chemicals (e.g. phosphorous on one side and boron on the other)(Husain & Hasan, 2018). Wires or soldered leads are effectively connected to each side of the cell. The positive and negative wires go to whatever you want to charge or power.

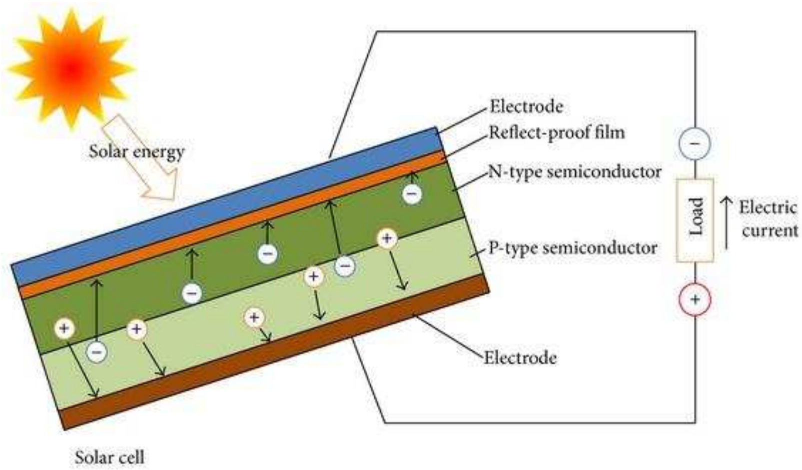


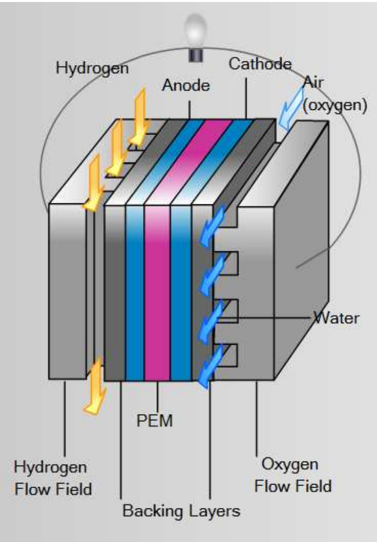

Fig. 10: Si Solar cell

It takes sunlight hitting the silicon in the solar cells to loosen up electrons. And as soon as they are freed up, they immediately start flowing through the wires to power your electrical loads. The more sunlight shines on the cells, the more electrons loosen up, the more electrical current flows and the more power it produces(Benda, n.d.).

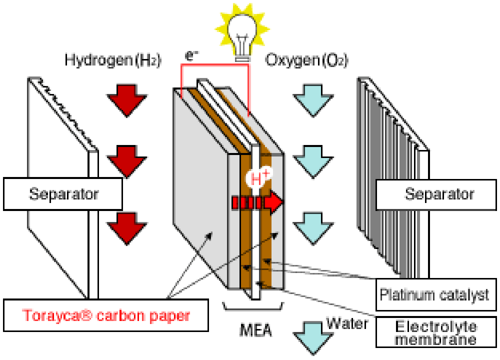
A photovoltaic cell is a device that converts sunlight into electricity using semiconductor materials; it has the same working principle as a semiconducting diode. The semiconductor material, such as silicon, has the property to eject electrons when sunlight is absorbed; the PV's cell then directs the electrons in one direction, which forms a current, as illustrated in Fig. 10 (Husain & Hasan, 2018).

## 6.0 Fuel Cell

**Hydrogen + Oxygen = Electricity + Water Vapour**




**Ca thode: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$**
**Anode: $2H_2 \rightarrow 4H^+ + 4e^-$**
**Overall: $2H_2 + O_2 \rightarrow 2H_2O$**



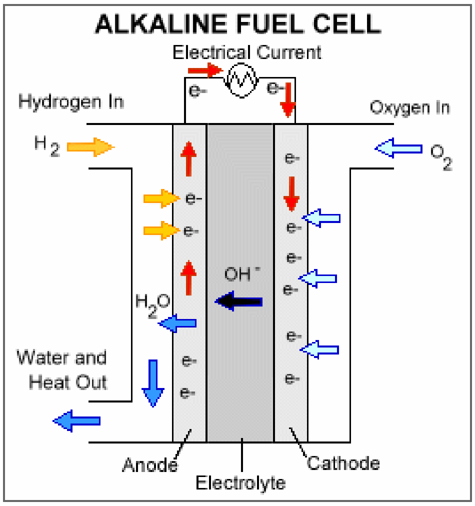




Fig. 11: Fuel cell structure

A fuel cell (fig. 11) is a device that converts energy stored in molecular bonds (chemical energy) into electrical energy. The cell uses hydrogen gas ($H_2$) and oxygen gas ($O_2$) as fuel. The products of the reaction in the cell are water, electricity, and heat. This is a big improvement over internal combustion engines, coal burning power plants, and nuclear power plants, all of which produce harmful by-products.

We only need to supply the fuel cell with $H_2$ which can come from an electrolysis process. The $O_2$ is readily available in the atmosphere.

The basic elements of a PEM (Proton Exchange Membrane) Fuel Cell are the anode, the cathode, electrolyte and catalyst. The heart of the cell is the proton exchange membrane. The fuel cell works based on the principle that it allows protons to pass through it virtually unimpeded, while electrons are blocked. So, when the $H_2$ hits the catalyst and splits into protons and electrons, the protons go directly through to the cathode side, while the electrons are forced to travel through an external circuit. They perform useful work, like lighting a bulb or driving a motor, before combining with the protons and $O_2$ on the other side to produce water (Wilson, 2018).

### 6.1 Advantages of the technology

- By converting chemical potential energy directly into electrical energy, fuel cells avoid the "thermal bottleneck" (a consequence of the $2^{nd}$ law of thermodynamics) and are thus inherently more efficient than combustion engines, which must first convert chemical potential energy into heat, and then mechanical work.

- Direct emissions from a fuel cell vehicle are just water and a little heat. This is a huge improvement over the internal combustion engine's litany of greenhouse gases.

- Fuel cells have no moving parts. They are thus much more reliable than traditional engines.

- Hydrogen can be produced in an environmentally friendly manner, while oil extraction and refining is very damaging (Markowitz, 2018).

### 7.0 Electricity Generator

In electricity generation, a generator is a device that converts motive power (mechanical energy) into electrical power for use in an external circuit. Sources of mechanical energy include steam turbines, gas turbines, water turbines, internal combustion engines and even hand cranks. The first electromagnetic generator, the Faraday disk, was invented in 1831 by British scientist Michael Faraday. Generators provide nearly all of the power for electric power grids.

The reverse conversion of electrical energy into mechanical energy is done by an electric motor, and motors and generators have many similarities. Many motors can be mechanically driven to generate electricity and frequently make acceptable manual generators (Wikipedia, 2018).

Electromagnetic generators fall into one of two broad categories, dynamos and alternators

- Dynamos generate pulsing direct current through the use of a commutator
- Alternators generate alternating current

### 7.1 Working principle of electrical generator

A generator is a device that is used to move electrons through a conductor to give electric power. It does this by using a magnet that forces electrons to move along a wire at a steady rate while putting pressure on them (fig. 13). With the help of a generator, the electrons can transmit electric energy from one point to another. The difference in the number of electrons and the pressure that the generator applies is what creates the different electric currents. The generator spins at a certain number of rotations per minute. The number of electrons that move is measured in amps. The pressure is measured in volts.

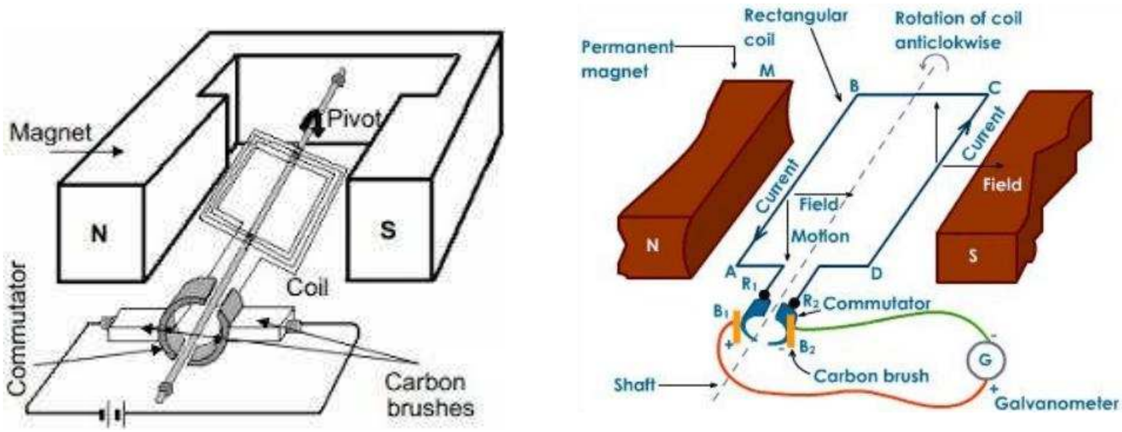



Fig. 13: Working principle of an electric generator

Mechanically a generator consists of a rotating part (rotor) and a stationary part (stator). One of these parts generates a magnetic field, the other has a wire winding in which the changing field induces an electric current.

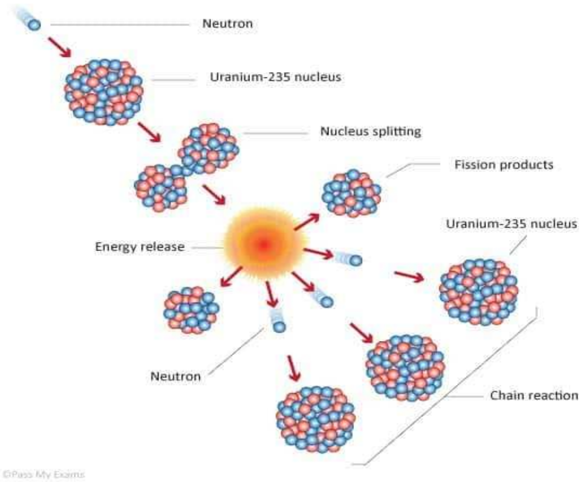
The armature can be on either the rotor or the stator, depending on the design, with the field coil or magnet on the other part.

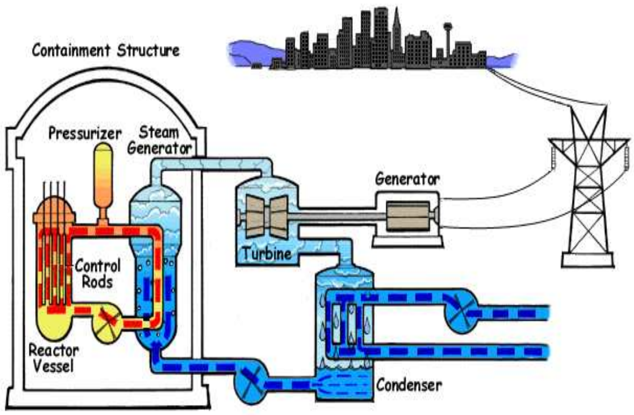
## 8.0 Nuclear Power Station

The nuclear generating plant or nuclear power station is a thermal power station which has steam turbines, electricity generators and transformers like most power stations. It produces the heat energy required to boil the water for the turbines. It has a nuclear reactor where heat is made by splitting apart nuclei – the central parts of atoms. Atoms are the smallest pieces or particles of ordinary substance or matter.

## 8.1 Working principle of nuclear reactor

The conversion to electrical energy takes place indirectly, as in conventional thermal power stations. The fission in a nuclear reactor heats the reactor coolant (fig.17). The coolant may be water or gas or even liquid metal depending on the type of reactor. The reactor coolant then goes to a steam generator and heats water to produce steam. The pressurized steam is then usually fed to a multi-stage steam turbine. After the steam turbine has expanded and partially condensed the steam, the remaining vapour is condensed in a condenser. The condenser is a heat exchanger which is connected to a secondary side such as a river or a cooling tower. The water is then pumped back into the steam generator and the cycle begins again. The water-steam cycle corresponds to the Rankine cycle.




A pressurized water reactor

Fig. 17: Nuclear fission (https://en.wikipedia.org/wiki/Nuclear_power_plant)

## 9.0 Hydroelectric Power Station

According to Parker (2010), the hydroelectric generating plant does not have a direct heat source like the fossil fuel and nuclear power stations. Its energy comes from water flowing along a river. The water runs downhill under the force of gravity, having fallen as rain far upstream. The rain was once water in clouds, and it was originally evaporated from the sea and lakes by the heat of the sun. so a hydroelectric power station is, in effects, Sun – powered (Parker, 2010).

## 9.1 How hydropower plants work

Hydropower plants harness water's energy and use simple mechanics to convert that energy into electricity. **Hydropower plants** are actually based on a rather simple concept – water flowing through a dam turns a turbine, which turns a generator.

Here are the basic components of a conventional hydropower plant:

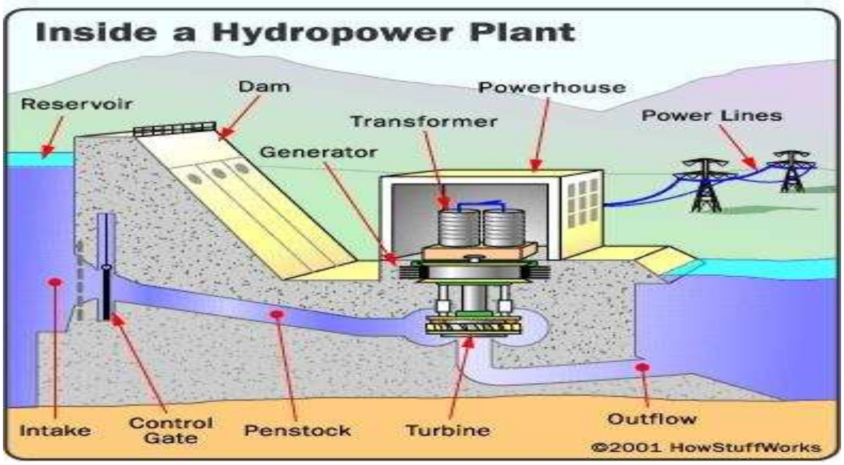



Fig. 18: Components of Hydroelectric Power Plant(Singh, 2015)

- Dam - Most hydropower plants rely on a dam that holds back water, creating a large reservoir.
- Intake - Gates on the dam open and gravity pulls the water through the penstock, a pipeline that leads to the turbine. Water builds up pressure as it flows through this pipe.
- Turbine - The water strikes and turns the large blades of a turbine, which is attached to a generator above it by way of a shaft.
- Generators - As the turbine blades turn, so do a series of magnets inside the generator. Giant magnets rotate past copper coils, producing alternating current (AC) by moving electrons.
- Transformer - The transformer inside the powerhouse takes the AC and converts it to higher voltage current.
- Power lines - Out of every power plant come four wires: the three phases of power being produced simultaneously plus a neutral or ground common to all three.
- Outflow - Used water is carried through pipelines, called tailraces, and re-enters the river downstream.

The water in the reservoir is considered stored energy. When the gates open, the water flowing through the penstock becomes kinetic energy because it's in motion. The amount of electricity that is generated is determined by several factors. Two of those factors are the volume of water flow and the amount of hydraulic head. The head refers to the distance between the water surface and the turbines. As the head and flow increase, so does the electricity generated. The head is usually dependent upon the amount of water in the reservoir (Bonsor, 2009).

## 10.0 Fusion Power

Nuclear fusion is the energy source of the future. It is what provides the sun and the stars with the energy to shine continuously for billions of years. Fusion has been used here on earth to produce nuclear bombs, but has not yet been controlled so that we can obtain useful energy.

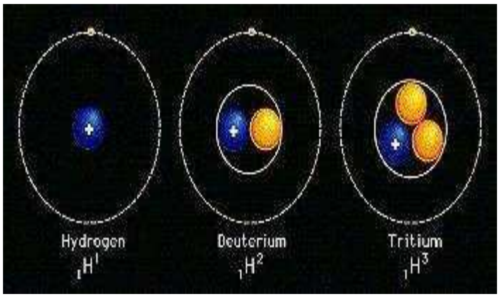
Fusion is formed when two atomic nuclei are forced together by the pressure high enough to overcome the strong repulsive forces of the respective protons in the nuclei. When the nuclei fuse, they form a new element, and release excess energy in the form of a fast-moving neutron. The energy is “extra” because the mass of the newly formed nucleus is less than the sum of the masses of the original two nuclei. The extra mass is converted to energy according to Einstein's equation $E = mc^2$.

### 10.1 How it works

The simple hydrogen atom, which has one proton in its nucleus, has two isotopes. The two isotopes of hydrogen called deuterium and tritium are used by the sun, and in experiments on earth to undergo fusion (Fig. 19).

Deuterium and tritium are used to form a nucleus of helium and a neutron. This fusion releases 17.59 MeV of energy (Fig. 20).

The problem with generating nuclear fusion lies in getting two atoms having the same charge close to each other. Atoms have the same charge generally repel each other, rather than being brought together. However, once brought together, nuclear force begins to take over. This force will attract the nuclei of two or more atoms toward each other and start nuclear fusion, but this happens only if they are of close enough proximity.



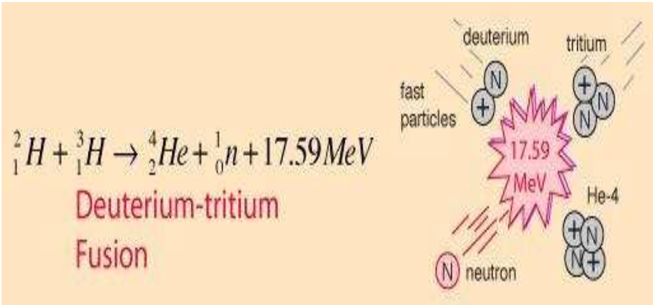




Figure 19 – Hydrogen isotopes

Figure 20 – Nuclear fusion

### 11.0 Conclusion

There are nine major areas of energy resources. They fall into two categories: nonrenewable and renewable. Nonrenewable energy resources, like coal, nuclear, oil, and natural gas, are available in limited supplies. This is usually due to the long time it takes for them to be replenished. Renewable resources are replenished naturally and over relatively short periods of time. The five major renewable energy resources are solar, wind, water (hydro), biomass, and geothermal.

Since the dawn of humanity people have used renewable sources of energy to survive — wood for cooking and heating, wind and water for milling grain, and solar for lighting fires. A little more than 150 years ago people created the technology to extract energy from the ancient fossilized remains of plants and animals. These super-rich but limited sources of energy (coal, oil, and natural gas) quickly replaced wood, wind, solar, and water as the main sources of fuel.

One of the outcomes of a developing energy programme over recent years has been the renewed interest in using municipal, industrial, hospital, and agricultural waste as a source of heat energy. Energy is neither created nor destroyed but can be change from one form to another in order to meet our daily energy demands.

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