Energy Resources

Conventional Energy Resources: Energy resources that are traditionally in use for all these years (particularly prior to the oil crisis of 1973) are known as conventional forms, e.g. coal, petroleum, natural gas, fire-wood, hydropower and even nuclear fission fuels.

Non-conventional Energy Resources: These include the alternate resources of energy that are being considered and commercialised for large scale use after the oil crisis. These resources are going to have increased share of energy use in future. These alternate resources are generally renewable forms including solar, wind, geothermal, ocean wave, tidal, biomass, biogas, nuclear fusion energy etc.

A more appropriate categorisation of an energy resource is based on its durability and regenerating capacity, which classifies it as renewable or non-renewable.

Renewable Resources are those which can be generated continuously in nature and are inexhaustible e.g. wood, solar energy, wind energy, tidal energy, hydropower, biomass energy, bio-fuels, geo-thermal energy and hydrogen. They are also known as non-conventional sources of energy and they can be used again and again in an endless manner.

Non-renewable Resources which have accumulated in nature over a long span of time and cannot be quickly replenished when exhausted e.g. coal, petroleum, natural gas and nuclear fuels like uranium and thorium.

Wood is a renewable resource as we can get new wood by growing a sapling into a tree within 15–20 years but it has taken millions of years for the formation of coal from trees and cannot be regenerated in our life time, hence coal is not renewable.

Coal: Coal was formed 255-350 million years ago in the hot, damp regions of the earth during the carboniferous age. The ancient plants along the banks of rivers and swamps were buried after death into the soil and due to the heat and pressure gradually got converted into peat and coal over millions of years. There are mainly three types of coal, namely anthracite (hard coal), bituminous (soft coal) and lignite (brown coal). Anthracite coal has maximum carbon (90%) and calorific value (8700 kcal/kg.). Bituminous, lignite and peat contain 80, 70 and 60% carbon, respectively. Coal is the most abundant fossil fuel in the world. At the present rate of usage, the coal reserves are likely to last for about 200 years and if its use increases by 2% per year, then it will last for another 65 years. India has about 5% of world's coal and Indian coal is not very good in terms of heat capacity.

Major coal fields in India are Raniganj, Jharia, Bokaro, Singrauli and Godavari valley. The coal states of India are Jharkhand, Orissa, West Bengal, Madhya Pradesh, Andhra Pradesh and Maharashtra. Anthracite coal occurs only in J & K.

When coal is burnt it produces carbon dioxide, which is a greenhouse gas responsible for causing enhanced global warming. Coal also contains impurities like sulphur and as it burns the smoke contains toxic gases like oxides of sulphur and nitrogen. Coal conversion technologies involve conversion of coal from solid form to liquid or gaseous form by coal liquefaction and gasification, respectively. Direct burning of coal releases emissions like smoke, particulate matter, SO_X, NO_X, CO and CO_2, whereas gaseous or liquid fuel forms cause less pollution. Energy from petroleum is harnessed by refining and fractional distillation.

Petrol:
It is the lifeline of global economy. There are 13 countries in the world having 67% of the petroleum reserves which together form the OPEC (Organization of Petroleum Exporting Countries). About 1/4th of the oil reserves are in Saudi Arabia.
At the present rate of usage, the world's crude oil reserves are estimated to get exhausted in just 40 years. Some optimists, however, believe that there are some yet undiscovered reserves. Even then the crude oil reserves will last for another 40 years or so. Crude petroleum is a complex mixture of alkane hydrocarbons. Hence, it has to be purified and refined by the process of fractional distillation, during which process different constituents separate out at different temperatures. We get a large variety of products from this, namely, petroleum gas, kerosene, petrol, diesel, fuel oil, lubricating oil, paraffin wax, asphalt, plastic etc. Basic steps in harnessing energy from petroleum include exploration of oil resources, drilling of wells, production, storage and transport of crude oil, refining of crude oil, storage and transportation of products. Exploration is usually done in areas having sedimentary rocks,

where petroleum deposits generally occur, which may be on-shore (land) or off-shore (sea) at shallow, medium or large depths.
Drilling is done from specifically formed drilling platforms. For enhanced extraction, the following techniques are used:

- By injecting fluid (air, gas, steam, water) into the well.
- By using chemical explosives to loosen tight formations.
- By adding chemicals to reduce viscosity of the crude oil.
- By allowing microbial growth inside to increase bulk, reduce viscosity and enhance recovery, known as Microbially Enhanced Oil Recovery (MEOR).
- By controlled underground burning to push up oil.

After extraction, crude oil is separated from natural gas and water, stored and transported through pipelines or tankers. Crude oil is refined by the following processes:

- Separation of some components by distillation.
- Chemical purification or removal of impurities by adsorption (on charcoal).
- Formation of hydrocarbons by cracking or hydrogenation.

During refining of crude oil, several products are obtained that are used in domestic, transport, industrial and electric power sectors.
Petroleum is a cleaner fuel as compared to coal as it burns completely and leaves no residue. It is also easier to transport and use. That is the reason why petroleum is preferred amongst all the fossil fuels.

Natural Gas:
It is mainly composed of methane (95%) with small amounts of propane and ethane. It is a fossil fuel. Natural gas deposits mostly accompany oil deposits because it has been formed by decomposing remains of dead animals and plants buried under the earth. Natural gas is the cleanest fossil fuel. It can be easily transported through pipelines. It has a high calorific value of about 50 kJ/g and burns without any smoke. Currently, the amount of natural gas deposits in the world are of the order of 80,450g m^{-3}. Russia has maximum reserves (40%), followed by Iran (14%) and USA (7%). Natural gas reserves are found in association with all the oil fields in India. Some new gas fields have been found in Tripura, Jaisalmer, off-shore area of Mumbai and the Krishna-Godavari Delta. Natural gas is used as a domestic and industrial fuel. It is used as a fuel in thermal power plants for generating electricity. It is used as a source of hydrogen gas in fertilizer industry and as a source of carbon in tyre industry.
Compressed Natural Gas (CNG): It is being used as an alternative to petrol and diesel for transport of vehicles. Delhi has totally switched over to CNG where buses and auto-rickshaws run on this new fuel. CNG use has greatly reduced vehicular pollution in the city.
Synthetic Natural Gas (SNG): It is a mixture of carbon monoxide and hydrogen. It is a connecting link between a fossil fuel and substituted natural gas. Low grade coal is initially transformed into synthetic gas by gasification followed by catalytic conversion to methane.

Nuclear Energy:
Nuclear energy is known for its high destructive power as evidenced from nuclear weapons. The nuclear energy can also be harnessed for providing commercial energy. Nuclear energy can be generated by two types of reactions:
Nuclear fission: It is the nuclear change in which nucleus of certain isotopes with large mass numbers are split into lighter nuclei on bombardment by neutrons and a large amount of energy is released through a chain reaction as shown in Fig.

$$_{92}U^{235} + {_0}n^1 \longrightarrow {_{36}}Kr^{92} + {_{56}}Ba^{141} + 3\ {_0}n^1 + \text{Energy}$$

Nuclear reactors make use of nuclear chain reaction. In order to control the rate of fission, only 1 neutron released is allowed to strike for splitting another nucleus. Uranium-235 nuclei are most commonly used in nuclear reactors.
Calculation of Energy Released in Nuclear Fission: The energy released in fission process can be calculated from the binding energies of the nuclei as well as from the mass defect.
Calculation of Energy Released from Mass Defect: Binding energy of $_{92}U^{235}$ = 7.6 MeV per nucleon

Binding energy of products of fission (Ba^{141} and $Kr^{92)}$ = 8.5 MeV per nucleon
Formation of U nucleus from its nucleons releases energy = 235 X 7.6 MeV
Formation of U nuclei of products of fission can releases energy = 235 X 8.5 MeV
Hence the energy released during fission of U^{235} = 235(8.5-7.6)
= 211.5 MeV

Fission of one mole of U^{235} will release energy = 211.5 X 6.022 X 10^{23} MeV

Fission of one mole of U^{235} will release energy in kJ = 211.5 X 6.022 X 10^{23} X 1.602 X 10^{-16} kJ

= 20.41 X 10^{9} kJ

Fission of one gram of U^{235} would release energy = 8.68 X 10^{7} kJ

Calculation of Energy Release from Mass Defect:

$${}_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{36}Kr^{92} + {}_{56}Ba^{141} + 3\ {}_{0}n^{1} + \text{Energy}$$

Stable stable

Atomic mass of Kr in a.m.u. = 91.905

Atomic mass of Ba in a.m.u. = 140.908

Mass of neutron in a.m.u. = 1.009

Total mass of reactants = 235.044 + 1.009 = 236.053 a.m.u.

Total mass of products = 91.905 + 140.908 + 3.207 = 235.840 a.m.u.

Mass defect (ΔM) = 236.053 a.m.u. + 235.840 a.m.u.

Mass defect (ΔM) = 0.213 a.m.u.

The fission reaction is thus accompanied by a loss of mass of 0.213 a.m.u., which is converted into energy.

Energy released = 0.213 a.m.u. X 938.5 MeV/a.m.u. = 191.41 MeV

This value is fairly close to 211.5 MeV calculated from the binding energy curve assuming that the products of fission are Ba and Kr.

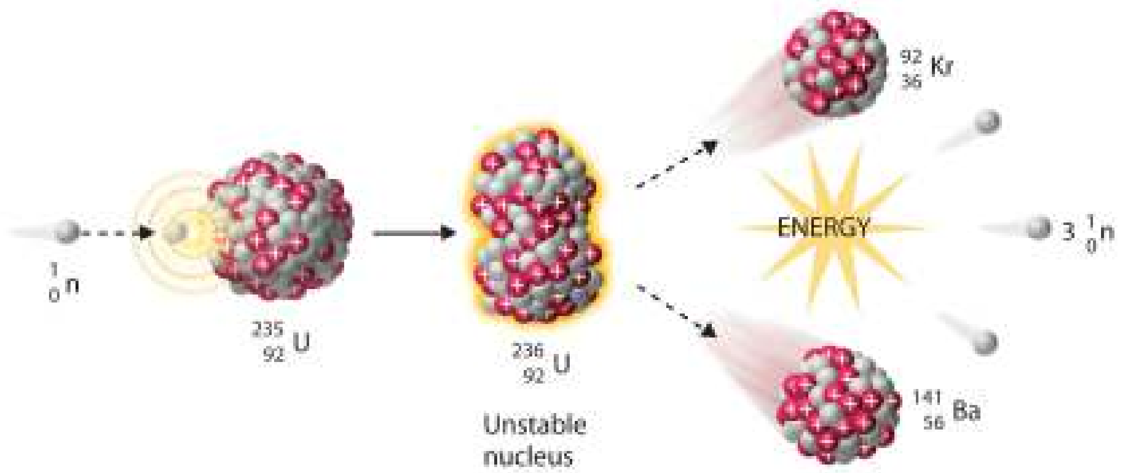


Figure: Nuclear fission chain reaction. Adopted from https://socratic.org/questions/does-nuclear-fission-have-a-high-or-low-activation-point.

Nuclear fusion: Here two isotopes of a light element are forced together at extremely high temperatures (1 billion ºC) until they fuse to form a heavier nucleus releasing enormous energy in the process. It is difficult to initiate the process but it releases more energy than nuclear fission

$${}_{1}H^{2} + {}_{1}H^{2} \longrightarrow {}_{2}He^{4} + {}_{0}n^{1} + \text{Energy}$$

Two hydrogen-2 (Deuterium) atoms may fuse to form the nucleus of Helium at 1 billion ºC and release a huge amount of energy. Nuclear fusion reaction can also take place between one Hydrogen-2 (Deuterium) and one Hydrogen-3 (Tritium) nucleus at 100 million ºC forming Helium-4 nucleus, one neutron and a huge amount of energy.

Calculation of Energy Released in Nuclear Fusion: Let us consider the formation of He nucleus. The most abundant isotope of He is ${}_{2}^{4}He$, contains 2 protons and 2 neutrons in the nucleus and 2 electrons outside nucleus. In other words, it is formed by the combination of two hydrogen atoms and two neutrons. Its atomic mass (M') should be given by

$$M' = 2m_H + 2m_n = 2 \text{ X } 1.008665 = 4.03298 \text{ a.m.u.}$$

Actual mass of He = 4.00260 a.m.u.

Mass defect (ΔM) = M'-M

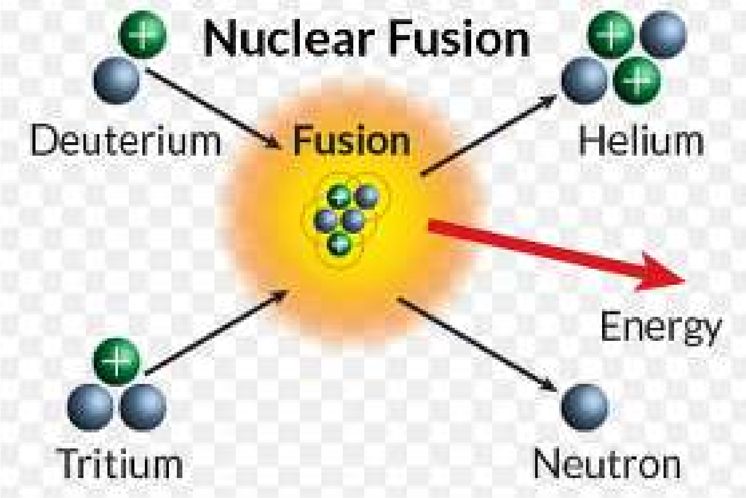
= 4.03298 - 4.00260

Mass defect (ΔM) = 0.03038 a.m.u.

Energy released in the formation of He nucleus = 0.03038 a.m.u. X 931.5 MeV/a.m.u.

Energy released in the formation of one mole of He nuclei = 0.03038 a.m.u. X 931.5 X 6.022 X 10^{23} MeV

= 27.30 X 10^{8} kJ



Adopted from https://nuclear.duke-energy.com/2013/01/30/fission-vs-fusion-whats-the-difference

Nuclear energy has tremendous potential but any leakage from the reactor may cause devastating nuclear pollution e.g. the Chernobyl nuclear disaster (1986). Disposal of the nuclear waste is also a big problem.

Nuclear power in India is still not very well developed. The power plants in India are Pressurised Heavy Water Reactor (PHWR) Power plant type. The nuclear power plants are located at Tarapur (Maharashtra), Rana Pratap Sagar near Kota (Rajasthan), Kalpakkam (Tamil Nadu), Narora (U.P.), Kakrapar (Gujarat), Kaiga (Karnataka), Rawatbhata (Rajasthan) and Kudankulum (Tamil Nadu).

Hydroelectric (Hydropower) Energy: The water flowing in a river is collected by constructing a big dam where the water is stored and allowed to fall from a height. Potential energy stored in water reservoir at high head is converted into kinetic energy in the flowing water. The blades of the turbine located at the bottom of the dam move with the fast moving water which in turn rotate the generator and produce electricity. We can also construct mini or micro hydelpower plants on the rivers in hilly regions for harnessing the hydro energy on a small scale, but the minimum height of the waterfalls should be 10 metres. The hydropower potential of India is estimated to be about 4 × 10^{11} kW hours. Till now we have utilised only a little more than 11% of this potential.

Hydropower does not cause any pollution. It is renewable and normally the hydropower projects are multi-purpose projects that help in controlling floods, used for irrigation, navigation etc. However, big dams are often associated with a number of environmental impacts.

Adopted from https://www.google.co.in/search?q=hydroelectric+power&tbm=isch&ved=2ahUKEwil19vd2IHpAhV0lEsFHYsxBAcQ2cCegQIABAA&oq=Hydroe&gs_lcp=CgNpbWcQARgAMgQIABBDMgQIABBDMgQIABBDMgIIADIECAAQQzICCAAyAggAMgIIADICCAAyAggAUOUyWIVgYP9xaABwAHgAgAHkAYgBqgmSAQUwLjUuMZgBAKABAaoBC2d3cy13aXotaW1n&sclient=img&ei=CTCjXuWuBvSortoPi-OQOA&bih=969&biw=1920&safe=active#imgrc=0KVAuy8wBCC6DM

Solar Energy: Sun is the ultimate source of energy, directly or indirectly for all other forms of energy. The nuclear fusion reactions occurring inside the sun release enormous quantities of energy in the form of heat and light. The solar energy received by the near-earth space is approximately 1.4 kilojoules/second/m^2 known as solar constant. Traditionally, we have been using solar energy for drying clothes and food-grains, preservation of eatables and for obtaining salt from sea-water. Now we have several techniques for harnessing solar energy. Some important solar energy harvesting devices are discussed here.

(i) **Solar heat collectors**: These can be passive or active in nature. Passive solar heat collectors are natural materials like stones, bricks etc. or material like glass which absorb heat during the day time and release it slowly at night. Active solar collectors pump a heat absorbing medium (air or water) through a small collector which is normally placed on the top of the building.

(ii) **Photovoltaic cells (Solar cells) for direct conversion of solar radiations into electrical energy**: Solar cell or PV cell is made of thin wafers of semiconductor material like silicon that forms the semi-conducting N-P junction, corresponding to negative and positive electrodes. The N-and P-type materials are obtained by doping silicon with N-type and P-type impurities.

There are two types of dopants used in doping the tetravalent silicon: penta-valents like arsenic (As), antimony (Sb) or phosphorus (P) and tri-valents like Indium (In), Boron (B) or Aluminium (Al).

When we dope Si with a pentavalent element, four of its electrons bond with four silicon neighbours, whereas the fifth excess electron is free to move due to loose bonding. Here, the number of conduction electrons are more than the number of holes. Hence the majority charge carriers are negatively charged electrons and therefore known as N-type semiconductors.

On the other hand, when tetravalent silicon is doped with a trivalent element, the dopant has one outer electron less than Si. Therefore, this atom can form bonds on three sides with Si, but fails to form bond on one side. In order to hold the dopant atom (e.g. boron), tightly within the crystal lattice of Si, some of the electrons bond on outer side in the neighbouring area tend to slide into this vacant bond, leaving a 'hole' at its own site. This hole is available for conduction. Here the holes are the majority carriers while electrons are minority carriers.

As the solar radiations strike the thin transparent N-type layer, some of the radiations penetrate upto the thick P-type layer. Photons present in the light radiations result in liberation of electron-hole pairs in the P-N junction. Electrons (negative charge) are released from N-type semicouductor and holes (positive charge due to lack of electrons) are created in the P-type semiconductor (Fig.). The potential difference causes flow of electrons, when the electric circuit is completed by connecting electrodes to the load. Thus, there is direct conversion of solar energy to electrical energy.

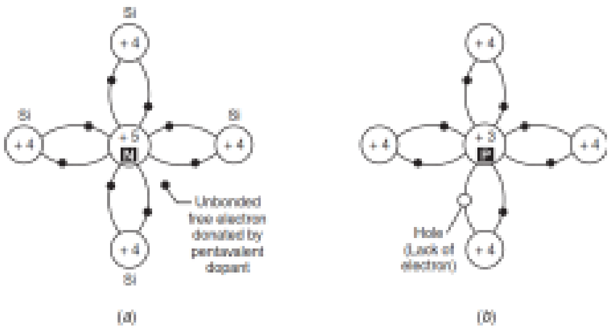


Figure: (a) Pentavalent donar atom doped for N-type semiconductor (b) trivalent acceptor atom doped for p-type semiconductor

Silicon used in PV cells can be obtained from silica or sand, which is abundantly available and inexpensive. The potential difference produced by a single PV cell of 4 cm^2 size is about 0.4–0.5 volts, produces a current of 60–75 milli amperes, and has a rated power of about 0.3 watts. Figure shows the structure of a solar cell.

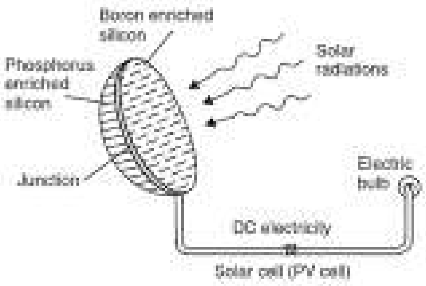
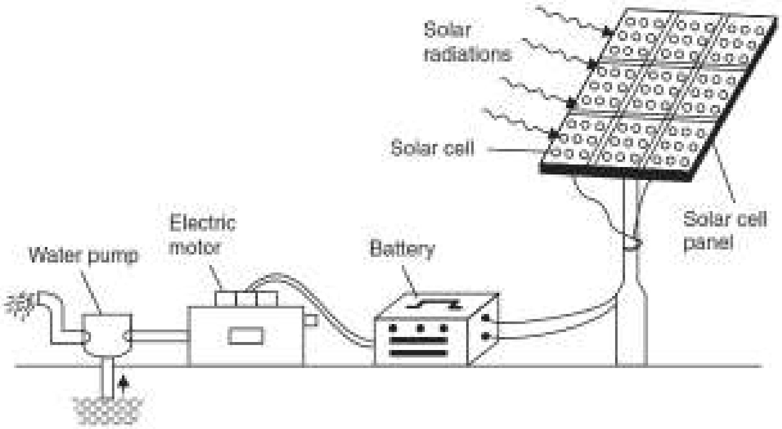


Figure: Solar cell.



A group of solar cells joined together in a definite pattern form a solar panel which can harness a large amount of solar energy and can produce electricity enough to run street-light, irrigation water pump etc. (Fig.). Solar cells are widely used in calculators, electronic watches, radios, street lighting, traffic signals, water pumps etc. They are also used in artificial satellites for electricity generation.

(iii) **Solar cooker**: Solar cookers make use of solar heat by reflecting the solar radiations using a mirror directly on to a glass sheet which covers the black insulated box within which the raw food is kept as shown in Fig. A new design of solar cooker is now available which involves a spherical reflector (concave or parabolic reflector) instead of plane mirror that has more heating effect and hence greater efficiency

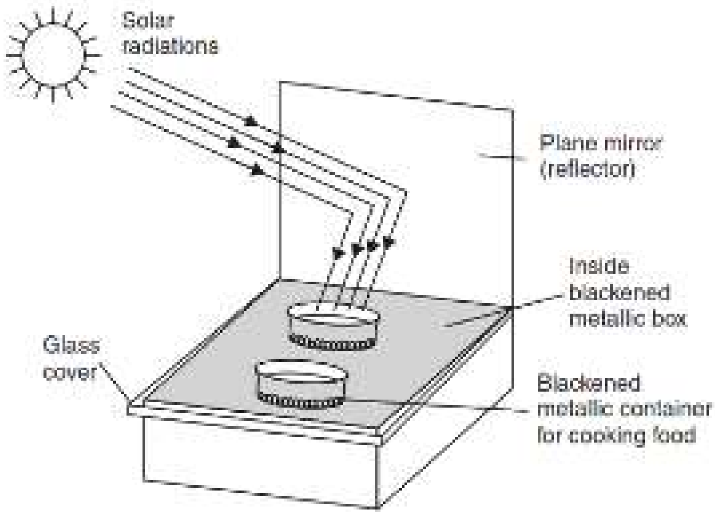


Figure: Solar cooker.

The food cooked in solar cookers is more nutritious due to slow heating. However, it has the limitation that it cannot be used at night or on cloudy days. Moreover, the direction of the cooker has to be adjusted according to the direction of the sun rays.

(iv) **Solar water heater**: It consists of an insulated box painted black from inside and having a glass lid to receive and store solar heat. Inside the box it has black painted copper coil through which cold water is made to flow in, which gets heated and flows out into a storage tank. The hot water from the storage tank fitted on roof top is then supplied through pipes into buildings like hotels and hospitals.

(v) **Solar furnace**: Here thousands of small plane mirrors are arranged in concave reflectors, all of which collect the solar heat and produce as high a temperature as 3000°C.

(vi) **Solar power plant**: Solar energy is harnessed on a large scale by using concave reflectors which cause boiling of water to produce steam. The steam turbine drives a generator to produce electricity.

Biofuels: Biofuels can be obtained by fermenting biomass that produces alcohols like ethanol and methanol. Ethanol can be easily produced from carbohydrate rich substances like sugarcane, corn and sorghum (Jowar). It burns clean and is non-polluting. However, as compared to petrol its calorific value is less and therefore, produces much less heat than petrol. It is also considered to be an excellent substitute for kerosene and its combustion is as clean as LPG. Ethanol is obtained from grain-based or sugar-containing plants like maize, cereals or even organic wastes.

Methanol is very useful since it burns at a lower temperature than gasoline or diesel. Thus the bulky radiator may be substituted by sleek designs in our cars. Methanol too is a clean, non-polluting fuel. Methanol can be easily obtained from woody plants.

Gasohol is a common fuel used in Brazil and Zimbabwe for running cars and buses. In India too gasohol is planned to be used on trial basis in some parts of the country, to start with in Kanpur. Gasohol is a mixture of ethanol and gasoline.

Hydrogen as a fuel: As hydrogen burns in air, it combines with oxygen to form water and a large amount of energy (150 kilojoules per gram) is released. Due to its high, rather the highest calorific value, hydrogen can serve as an excellent fuel. Moreover, it is non-polluting and can be easily produced. Production of hydrogen is possible by thermal dissociation, photolysis or electrolysis of water:

(i) By thermal dissociation of water (at 3000 K or above) hydrogen (H_2) is produced.

(ii) Thermochemically, hydrogen is produced by chemical reaction of water with some other chemicals in 2-3 cycles so that we do not need the high temperatures as in direct thermal method and ultimately H_2 is produced.

(iii) Electrolytic method dissociates water into hydrogen (H_2) and oxygen by making a current flow through it.

(iv) Photolysis of water involves breakdown of water in the presence of sunlight to release hydrogen. Green plants and micro-algae also carry out photolysis of water during photosynthesis. Efforts are underway to trap the hydrogen molecule which is produced during photosynthesis. Hydrogen generated by microbial systems is called biohydrogens.

However, hydrogen is highly inflammable and explosive in nature. Hence, safe handling is required for using H_2 as a fuel. Also, it is difficult to store and transport. And being very light, it would have to be stored in bulk.

Presently, H_2 is used in the form of liquid hydrogen as a fuel in spaceships. H_2 can be used in fuel cell to generate electricity. In fuel cell hydrogen is burnt in air or oxygen in the pressure of an electrolyte to produce electricity.

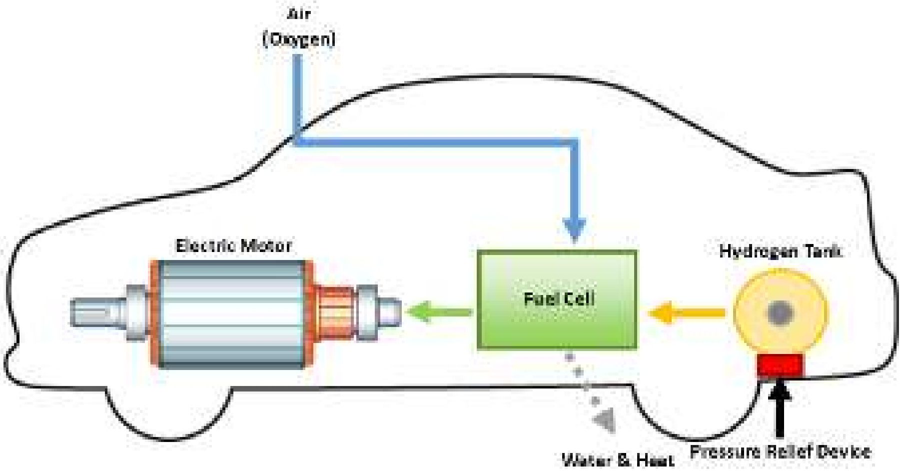


Figure: Adopted from https://www.firehouse.com/rescue/article/12385113/hydrogen-fuel-cell-vehicles-what-first-responders-need-to-know-firehouse

Geothermal Energy: Geothermal energy is the energy obtained from the earth (geo) from the hot rocks present inside the earth. It is produced due to the fission of radioactive materials in the earth's core and some places inside the earth become very hot. These are called hot spots. They cause water deep inside the earth to form steam. As more steam is formed, it gets compressed at high pressure and comes out in the form of hot springs which produces geothermal power. To harness this geothermal energy, two holes are dug deep into the earth and cold water is pumped through the first one and steam comes out through the second long pipe which helps in generating electricity. The holes dug for harnessing geothermal energy result in lesser emission of greenhouse gases than due to burning of fossil fuels. Thus if used at a larger scale and more efficiently, it gives a hope to reduce global warming. Geo-thermal energy is one of the rare forms of energy which is not directly or indirectly from solar energy. In areas where hot springs are found, hot springs baths are very common and enjoyable form of recreation. However, they need to be in a controlled environment since they cannot be accessed without proper supervision. We have earlier seen how it is harnessed, the process involved is a long and expensive one and not feasible in some areas. Construction of geothermal energy plants can affect the seismic stability to a large extent. Even though there are lesser emissions, digging deep holes causes seismic disturbances which have led to earthquakes.

https://moderndiplomacy.eu/2018/05/04/geothermal-energy-is-on-a-hot-path/

Advantages of Geothermal Energy:

- It is a renewable source of energy.
- By far, it is non-polluting and environment friendly.
- There is no wastage or generation of by-products.
- Geothermal energy can be used directly. In ancient times, people used this source of energy for heating homes, cooking, etc.
- Maintenance cost of geothermal power plants is very less.
- Geothermal power plants do not occupy too much space and thus help in protecting natural environment.
- Unlike solar energy, it is not dependent on the weather conditions.

Disadvantages of Geothermal Energy:

- Only few sites have the potential of Geothermal Energy.
- Most of the sites, where geothermal energy is produced, are far from markets or cities, where it needs to be consumed.
- Total generation potential of this source is too small.
- There is always a danger of eruption of volcano.
- Installation cost of steam power plant is very high.
- There is no guarantee that the amount of energy which is produced will justify the capital expenditure and operations costs.
- It may release some harmful, poisonous gases that can escape through the holes drilled during construction.

Adopted from
http://www.idconline.com/technical_references/pdfs/civil_engineering/Geothermal_Energy_Advantages_and_Disadvantages.pdf

Tidal Energy: Tidal power or **tidal energy** is the form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity.

Although not yet widely used, tidal energy has the potential for future electricity generation. Tides are more predictable than the wind and the sun. Among sources of renewable energy, tidal energy has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability. However, many recent technological developments and improvements, both in design (e.g. dynamic tidal power, tidal lagoons) and turbine technology (e.g. new axial turbines, cross flow turbines), indicate that the total availability of tidal power may be much higher than previously assumed and that economic and environmental costs may be brought down to competitive levels.

Historically, tide mills have been used both in Europe and on the Atlantic coast of North America. The incoming water was contained in large storage ponds, and as the tide went out, it turned waterwheels that used the mechanical power it produced to mill grain. The earliest occurrences date from the Middle Ages, or even from Roman times.[2][3] The process of using falling water and spinning turbines to create electricity was introduced in the U.S. and Europe in the 19th century.

The world's first large-scale tidal power plant was the Rance Tidal Power Station in France, which became operational in 1966. It was the largest tidal power station in terms of output until Sihwa Lake Tidal Power Station opened in South Korea in August 2011. The Sihwa station uses sea wall defense barriers complete with 10 turbines generating 254 MW.

Figure: Sihwa Lake Tidal Power Station, located in Gyeonggi Province, South Korea, is the world's largest tidal power installation, with a total power output capacity of 254 MW.

Adopted from https://en.wikipedia.org/wiki/Tidal_power