Name of Faculty: TARUN VARMA

Designation: A.P.

Department: ECE

Subject: Energy &Environmental Engineering (ES-401)

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# MODULE 1

# INTRODUCTION TO ENERGY SCIENCE

## 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

Conventional sources of energy coal, petroleum, natural gas are the common sources. These account for about 89.4% of the world's production of commercial energy, hydroelectric and nuclear power accounting for only 10.6%, oil - 39.5%, Natural gas - 19.6%, Coal - 30.3%, Hydro-electric - 6.7%, Nuclear - 3.9%.

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.

## Energy Sources

There are 5 fundamental sources of energy:

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

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

1. Renewable resources

- Solar energy
- Wind energy
- Geothermal energy
- Hydropower energy
- Biomass

- Hydrogen and fuel cells

2. Non Renewable Resources

- Fossil fuels
- Coal
- Petroleum
- Natural gas
- Fossil fuel

**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.

**Application of solar energy**

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.

i) Solar Green Houses.

**Gravity Generated by the Earth & Moon**

Gravitational pull of the Moon on the Earth causes tides. Tidal flow can be harnessed to drive turbines. This is also a nearly unlimited source of energy and is largely non-polluting. Combining both solar energy and gravity provides other useful sources of energy. Solar radiation heats air and evaporates water. Gravity causes cooler air to sink and condense water vapor. Gravity then pulls condensed water back to Earth, where it flows downhill. The circulation of the atmosphere by the process is what we call the wind. Energy can be extracted from the wind using windmills. Water flowing downhill has a result of gravity can also be harnessed for energy to drive turbines and generate electricity. This is called hydroelectric energy. These sources of energy are mostly renewable, but only locally, and are generally non-polluting.

**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.

**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.

**Energy Stored in Chemical Bonds**

Energy stored in chemical bonds drives chemical reactions. When the reactions take place this energy is either released or absorbed. If it is absorbed, it is stored in the chemical bond for later use. If it is released, it can produce useful heat energy.

Hydrogen Fuel Cells are one example: A chemical reaction occurs wherein Hydrogen reacts with Oxygen in an electrolyte bath to produce H2O, and releases electricity and heat. The reaction is non- polluting, but currently has problems, such as safely storing and distributing compressed hydrogen gas, and producing hydrogen efficiently.

Biomass Energy is another example. It involves burning (a chemical reaction) of wood, or other organic byproducts. Such organic material is produced by photosynthesis, a chemical process which derives energy from the Sun and stores that energy until the material is burned.

Fossil Fuels - Biomass energy that is buried within the Earth where it is stored until humans extracts and burns it to release the energy. Among these sources are petroleum (Oil & natural gas), oil shale, tar sands, and coal. All of which will be one of the primary topics of our discussion here.

**Geology and Energy Resources**

Exploitation for human use of nearly all of the energy sources listed above requires geologic knowledge. While using direct solar energy to heat water and homes does not require geologic knowledge, the making of solar cells does, because the material to make such cells requires knowledge of specific mineral deposits. Chemicals to produce wires (iron, copper, gold), batteries, (Li, Cd, Ni), and electric motors (Fe, Cu, Rare Earth Elements) all must be extracted from the Earth using geologic knowledge. Hydroelectric energy requires geologic

knowledge in order to make sure that dams are built in areas where they will not collapse and harm human populations. Finding fossil fuels and geothermal energy certainly requires geologic knowledge. Nuclear energy requires geologists to find deposits of uranium to generate the fuels, geologists to find sites for nuclear power plants that will not fall apart due to such things as earthquakes, landslides, floods, or volcanic eruptions, and requires geologists to help determine safe storage sites for nuclear waste products.Again, here will concentrate on the fossil fuels.

**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. The chemical reaction is so important, that everyone should know it .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.

**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.

**GEOTHERMAL ENERGY** is thermal energy generated and stored in the Earth. Thermal energy is the energy that determines the temperature of matter. The geothermal energy of the Earth's crust originates from the original formation of the planet and from radioactive decay of materials (in currently uncertain but possibly roughly equal proportions). The geothermal gradient, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface. Earth's internal heat is thermal energy generated from radioactive decay and continual heat loss from Earth's formation. Temperatures at the core-mantle boundary may reach over 4000 °C (7,200 °F).The high temperature and pressure in Earth's interior cause some rock to melt and solid mantle to behave plastically, resulting in portions of mantle convecting upward since it is lighter than the surrounding rock. Rock and water is heated in the crust, sometimes up to 370 °C (700 °F).

**Advantages of Geothermal Energy:**

1. Significant Cost Saving : Geothermal energy generally involves low running costs since it saves 80% costs over fossil fuels and no fuel is used to generate the power. Since, no fuel is require so costs for purchasing, transporting and cleaning up plants is quite low.

2. Reduce Reliance on Fossil Fuels: Dependence on fossil fuels decreases with the increase in the use of geothermal energy. With the sky-rocketing prices of oil, many countries are pushing companies to adopt these clean sources of energy. Burning of fossil fuels releases greenhouse gases which are responsible for global warming.

3. No Pollution: This is one of the main advantages of using geothermal energy since it does not create any pollution and help in creating clean environment. Being the renewable source of energy, geothermal energy has helped in reducing global warming and pollution. Moreover, Geothermal systems does not create any pollution as it releases some gases from deep within the earth which are not very harmful to the environment.

4. Direct Use: Since ancient times, people having been using this source of energy for taking bath, heating homes, preparing food and today this is also used for direct heating of homes and offices. This makes geothermal energy cheaper and affordable. Although the initial investment is quite steep but in the long run with huge cost saving it proves quite useful

5. Job Creation and Economic Benefits: Government of various countries are investing hugely in creation of geothermal energy which on other hand has created more jobs for the local people Though above said advantages prove that geothermal energy has big capability in itself in creating clean and safe environment and also it is an excellent source of cheap, reliable, simple, clean and renewable power.

**Disadvantages of Geothermal Energy**

Energy created from geothermal power is safe, clean, simple, reliable and environment friendly as it is extracted from deep within the earth's surface. But despite these advantages, geothermal energy is not being used widely. Geothermal energy suffers from its disadvantages as described below.

1. Not Widespread Source of Energy: Since this type of energy is not widely used therefore the unavailability of equipment, staff, infrastructure, and training pose hindrance to the installation of geothermal plants across the globe. Not enough skilled manpower and availability of suitable build location pose serious problem in adopting geothermal energy globally.

2. High Installation Costs : To get geothermal energy, requires installation of power plants, to get steam from deep within the earth and this require huge one time investment and require to hire a Certified installer and skilled staff needs to be recruited and relocated to plant location. Moreover, electricity towers, stations need to set up to move the power from geothermal plant to consumer.

3. Can Run Out Of Steam : Geothermal sites can run out of steam over a period of time due to drop in temperature or if too much water is injected to cool the rocks and this may result huge loss for the companies which have invested heavily in these plants. Due to this factor, companies have to do extensive initial research before setting up the plant.

4. Suited To Particular Region: It is only suitable for regions which have hot rocks below the earth and can produce steam over a long period of time. For this great research is required which is done by the companies before setting up the plant and this initial cost runs up the bill in setting up the geothermal power plant. Some of these regions are near hilly areas or high up in mountains.

5. May Release Harmful Gases: Geothermal sites may contain some poisonous gases and they can escape deep within the earth, through the holes drilled by the constructors. The geothermal plant must therefore be capable enough to contain these harmful and toxic gases.

6. Transportation: Geothermal Energy can not be easily transported. Once the tapped energy is extracted, it can be only used in the surrounding areas. Other sources of energy like wood, coal or oil can be transported to residential areas but this is not a case with geothermal energy. Also, there is a fear of toxic substances getting released into the atmosphere.

**Biomass Energy**

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.

**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.

**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. 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.

6. Wind Energy, that is moving air, possesses some kinetic energy due to its high speed. Wind is a result of the solar energy, as heating of land results in movement of air. The most common application of **WIND ENERGY** wind could probably be kite flying! Or even paragliding, sail boats etc. Well these activities are definitely not possible without wind. Ever wondered what else it could be useful for?? Wind energy can be harnessed and used for generating electricity or for other smaller purposes by a windmill. In olden times, windmills were used to draw water out of wells or to grind flour etc. It is the rotatory motion of the shaft in a windmill that is used to rotate the turbine and convert it to the form of energy we need it in.

The main advantage of wind energy is that harnessing it doesn't disrupt natural processes or harm the environment, unlike a lot of other energy sources. To generate electricity on a large scale, a number of windmills are set up over a large area, called a wind energy farm. Such areas need a wind speed of 15kmph.



**Advantages and Disadvantages of Wind Energy**

Advantages of Wind Energy

1. Wind Energy is an inexhaustible source of energy and is virtually a limitless resource.

2. Energy is generated without polluting environment.

3. This source of energy has tremendous potential to generate energy on large scale.

4. Like solar energy and hydropower, wind power taps a natural physical resource.

5. Windmill generators don't emit any emissions that can lead to acid rain or greenhouse effect.

6. Wind Energy can be used directly as mechanical energy.

7. In remote areas, wind turbines can be used as great resource to generate energy.

8. In combination with Solar Energy they can be used to provide reliable as well as steady supply of electricity.

9. Land around wind turbines can be used for other uses, e.g. Farming.

Disadvantages of Wind Energy

1. Wind energy requires expensive storage during peak production time. And also maintains cost is high

2. It is unreliable energy source as winds are uncertain and unpredictable.

3. There is visual and aesthetic impact on region.

4. Requires large open areas for setting up wind farms.

5. Noise pollution problem is usually associated with wind mills.

6. Wind energy can be harnessed only in those areas where wind is strong enough and weather is windy for most parts of the year.

7. Usually places, where wind power set-up is situated, are away from the places where demand of electricity is there. Transmission from such places increases cost of electricity.

8. The average efficiency of wind turbine is very less as compared to fossil fuel power plants. We might require many wind turbines to produce similar impact.

9. It can be a threat to wildlife. Birds do get killed or injured when they fly into turbines

**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.

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.