

ENVIRONMENTAL SCIENCE

LECTURE NOTES

UNIT-II

ENERGY

INTRODUCTION

The word 'energy' itself is derived from the Greek word 'en-ergon', which means 'in-work' or 'work content'. The energy of a body is its capacity to do work. It is measured the total amount of work that the body can do.

Energy is the primary and most universal measure of all kinds work by human beings and nature. Every thing what happens the world is the expression of flow of energy in one of its forms.

Different forms of energy

1. Mechanical energy (kinetic and potential)
2. Thermal (or) Heat energy
3. Chemical energy
4. Electrical energy
5. Nuclear energy
6. Electromagnetic energy
7. Gravitational energy

The S.I unit of energy is Joule or KJ or Watt.h

1 .Primary Energy Sources

Primary energy sources can be defined as sources which provide a net supply of energy Coal, Oil, Uranium etc., are examples of this type. The energy required to obtain these fuels is much use than what they can produce by combustion or nuclear reaction. The supply of primary fuels is limited. It becomes very essential to use these fuels sparingly.

Examples: Coal, natural gas, oil and nuclear energy

2. Secondary Energy sources

Secondary fuels produce no net energy. Though it may be necessary for the economy, these may not yield net energy. Secondary sources are like sun, wind, water (tides), etc. Solar energy can be used through plants, solar cells, solar heaters and solar collectors.

Example: Wind energy solar energy, hydro energy

Energy sources and their availability

Today every country draws its energy needs from a variety of sources. We can broadly categorize these sources as commercial and non commercial. The commercial sources include

the fossil fuels (coal, oil and natural gas), hydro-electric power and nuclear power, while the non commercial sources include wood, animal waste and agricultural wastes.

Conventional and non-conventional sources energy

Conventional energy sources

Conventional sources of energy are the ones that are commonly used, and generally **non-renewable sources of energy**, which are being used since a long time. Examples of conventional sources of energy include **oil, natural gas, coal, biomass, and electricity**.

Non conventional energy sources

Renewable energy sources also called non-conventional energy, are sources that are continuously replenished by natural processes. For example, **solar energy, wind energy, bio-energy bio-fuels grown sustain ably), hydropower** etc., are some of the examples of renewable energy sources

CONVENTIONAL ENERGY SOURCES

FOSSIL FUELS

- Coal, petroleum, and natural gas are called Fossil fuel as these are formed by the decomposition of the remains of dead plants and animals buried under the earth for a long time.
- These are non-renewable sources of energy, which, if exhausted, can not be replenished in a short time.
- Their reserves are limited and are considered very precious. These should be used with care and precaution to let them last long. These are also contributing to the global environmental pollution.

COAL

- Coal is a combustible black or brownish-black sedimentary rock that occurs in seas. The heat and pressure of deep burial turn dead plant materials into peat, which is eventually changed into coal over millions of years.
- Coal is largely utilized as a source of energy. Coal usage surged after the introduction of the steam engine. Coal was responsible for nearly a quarter of the world's primary energy and more than a third of its electricity in 2020.

Advantages

- Large supply across the globe
- High energy density
- Well built and established infrastructure
- Economic benefits and job opportunities
- Relatively cheap energy source
- Base load power generation

Limitation

- Environmental impact and greenhouse gas emissions
- Health risks from pollution
- Coal mining can be hazardous
- Destruction of habitats, forest and local ecosystem
- Mining and power generation requires significant amount of water
- Generation of waste such as ash and sludge.

Petroleum

Crude oil, commonly known as petroleum oil, is the only non renewable resource that can be extracted as a liquid.

It's located between layers of the earth's crust or between rocks, and it's extracted by digging a vertical well into the ground or ocean floor. Half of the world's petroleum is used for conversion to gasoline.

The crude oil is then pumped to the surface, processed at a refinery, and utilized to make a variety of goods. It is used to make gasoline and diesel for automobiles, as well as plastics, heating oil, propane, jet fuel, and artificial food tastes.

Advantages of petroleum

- High energy density oil has one of the highest energy densities which means that a small amount of oil can produce a large amount of energy
- Constant power source and reliability oil engines are a mature technology and highly reliable to work with.
- Petroleum is used in different industry such as dyes, pharmacy and agriculture.

Disadvantage of petroleum

- **Pollution of water and earth:** oil spills have caused massive pollution of water bodies as huge oil tankers lead oil. This leads to the death of thousands of animals and fishes every year beside damage the local ecology.
- **Greenhouse gas emissions:** one of the biggest disadvantage of oil is that it emission carbon dioxide.
- **Emission of harmful substances:** like sulphur dioxide, carbon monoxide, acid rain such as sulphur dioxide which cause health danger among the population.

Natural gas

Natural gas is a non renewable gaseous resource that may be discovered beneath the earth's crust, alongside crude oil reserves. Natural gas is primarily made up of methane, but it can also include propane, ethane, and butane.

Natural gas is utilized in gas ovens, stoves, and grills, as well as for heating houses. Natural gas is a "cleaner" fossil fuel than oil or coal, and it may be obtained at a low cost.

Advantages

- Reduced environmental impact compared to other fossil fuels
- Power generation efficiency and economic viability
- Versatility of application beyond power generation
- Natural gas is an abundant resource
- Existing infrastructure makes it easy to harness
- Easier to transport than other fossil fuels
- Pairs well with renewable energy at the grid level.

Limitation

- Environmental concerns such as methane leaks and fracking
- Geopolitics and energy security
- Uncertainty of future role as renewable increase
- Non-renewable source of energy
- Price volatility due to weather

Solar Energy

Solar energy is the most readily available and free source of energy since prehistoric times. It is estimated that solar energy equivalent to over 15,000 times the world's annual commercial energy consumption reaches the earth every year. India receives solar energy in the region of 5 to 7 kWh/m² for 300 to 330 days in a year. This energy is sufficient to set up 20 MW solar power plant per square kilometre land area. Solar energy can be utilised through two different routes, as solar thermal route and solar electric (solar photovoltaic) routes. Solar thermal route uses the sun's heat to produce hot water or air, cook food, drying materials etc. Solar photovoltaic uses sun's heat to produce electricity for lighting home and building, running motors, pumps, electric appliances, and lighting.

Solar Energy Application

Solar water heaters

Solar Cooker

Positioning of solar panels or collectors

Solar Photovoltaic (PV)

Solar Water Pumps

Advantages of Solar Energy

Lower electricity bills: Solar panels generate cost-free electricity, reducing overall energy costs.

Earn money back: Sell surplus energy to the grid for compensation through the Smart Export Guarantee (SEG).

Reduce carbon footprint: Sustainable energy reduces reliance on fossil fuels.

Year-round efficiency: Effective even in cloudy UK weather, especially with advancements in technology.

Low maintenance: Minimal upkeep required post-installation.

Independence from the grid: Generate your own electricity, reducing dependence on the grid.

Affordability: Solar panels are increasingly cost-effective.

Cost savings: Utilise solar energy to save money.

Grid independence: Keep your lights on during grid outages.

Increased home value: Installing solar energy can boost your property's value.

Climate versatility: Solar systems work well in various climates, including the UK.

Disadvantages of solar energy

High initial cost: The initial investment for solar panels is substantial, including expenses for panels, inverters, batteries, wiring, and installation.

Weather dependence: Solar panels rely on sunlight, so their efficiency decreases on cloudy or rainy days, and they cannot generate energy at night. This limitation affects the overall energy output, especially in regions with less consistent sunlight.

Expensive energy storage: To use solar energy at night, it must be stored in batteries, which can be quite expensive. Often, it is more economical to use grid electricity at night if the solar system is grid-connected.

Space requirements: Installing enough solar panels to meet energy needs requires a significant amount of space. Not all roofs can accommodate the necessary number of panels, and additional space may be required in yards.

Pollution concerns: Although solar energy is cleaner than many alternatives, its production and installation involve emissions and the use of hazardous materials. The manufacturing process can produce pollutants, and solar panel disposal must be managed carefully to avoid environmental harm.

Wind Energy

Wind energy is basically harnessing of wind power to produce electricity. The kinetic energy of the wind is converted to electrical energy.

When solar radiation enters the earth's atmosphere, different regions of the atmosphere are heated to different degrees because of earth curvature. This heating is higher at the equator and lowest at the poles. Since air tends to flow from warmer to cooler regions, this causes what we call winds, and it is these airflows that are harnessed in windmills and wind turbines to produce power.

Wind power is not a new development as this power, in the form of traditional windmills -for grinding corn, pumping water, sailing ships - have been used for centuries. Now wind power is harnessed to generate electricity in a larger scale with better technology.

Applications

- Utility interconnected wind turbines generate power which is synchronous with the grid and are used to reduce utility bills by displacing the utility power used in the household and by selling the excess power back to the electric company.
- Wind turbines for remote homes (off the grid) generate DC current for battery charging.
- Wind turbines for remote water pumping generate 3 phase AC current suitable for driving an electrical submersible pump directly. Wind turbines suitable for residential or village scale wind power range from 500 Watts to 50 kilowatts.

Advantages of wind power energy

Good for the environment

Wind energy is environmentally friendly because it doesn't release harmful gases or pollutants into the air. Unlike burning fossil fuels like coal or oil, wind turbines generate electricity without causing air pollution or contributing to climate change.

Energy independent

Using wind power can reduce a country's dependence on imported fossil fuels. By generating electricity using wind, which is a local resource, countries can rely less on buying energy from other places. This can be especially important for national security and economic stability, as it reduces the impact of fluctuating oil and gas prices and ensures a more consistent energy supply.

Unlimited energy source

Wind is a renewable resource, which means it will not run out like oil or gas – non-renewable resources. As long as the wind keeps blowing, we can use it to generate electricity. This makes wind power a sustainable energy source for the future, ensuring that we have a consistent supply of energy without depleting the Earth's resources.

Encourages technological growth

The development of wind power encourages technological advancements. As we look for ways to make wind turbines more efficient and cost-effective, this drives innovation in engineering and technology. These advancements can benefit other areas of renewable energy and technology as well.

Disadvantages of wind power energy

Intermittency issues

One of the main challenges of wind power is its instability. Wind doesn't blow all the time, and it isn't always strong enough to generate electricity. This means that wind power can be unpredictable and unreliable at times.

Environmental and wildlife concerns

Even though wind power is environmentally friendly overall, there can be local environmental impacts. For example, wind turbines can be harmful to birds and bats that might fly into them. Also, building large wind farms can affect local ecosystems, especially if they're in sensitive areas.

Noise and visual impact

Wind turbines can be quite noisy, which can be a problem for people living nearby. They also change the look of the landscape, which some people might not like. The appearance and noise of wind turbines can sometimes lead to local opposition to new wind farms.

Challenges in remote locations

Wind turbines tend to be located in remote or inconvenient locations. This includes offshore wind farms, which can be particularly costly to set up and maintain. These logistical challenges can make wind power less feasible in certain areas.

Setting up wind power can be also expensive. The cost of building wind turbines and setting up a wind farm can be high, although these costs have been decreasing over time. Additionally, wind farms need ongoing maintenance, which can also be costly.

Bio Energy

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities.

It is derived from numerous sources, including the by-products from the wood industry, agricultural crops, raw material from the forest, household wastes etc.

Biomass does not add carbon dioxide to the atmosphere as it absorbs the same amount of carbon in growing as it releases when consumed as a fuel.

Its advantage is that it can be used to generate electricity with the same equipment that is now being used for burning fossil fuels. Biomass is an important source of energy and the most important fuel worldwide after coal, oil and natural gas.

Bio-energy, in the form of biogas, which is derived from biomass, is expected to become one of the key energy resources for global sustainable development. Biomass offers higher energy efficiency through form of Biogas than by direct burning

Advantages of Bioenergy

- Biomass is a renewable source of energy - if produced in a sustainable manner. Efficient planting guarantees that supply meets demand.
- In most regions of the world, people use wood or some form of biomass fuel. With the right stove, the majority of these fuels can be burned without further processing. Usually biomass fuels are easily accessible.

- Collecting firewood seems to be cheaper than alternative fuels such as gas, paraffin, and electricity. Thus, biomass fuels are more affordable to the poor.
- Biomass is within reach of users. Users do not depend on providers, utilities or imports as for fossil fuels.
- Fuel preparation behaviour is often more important in reducing emissions than the technology itself

Disadvantage of Bioenergy

- Biomass fuels are mainly burned on inefficient open fires and traditional stoves.
- In many cases, the demand for biomass fuels far outweighs sustainable supply. This can contribute to deforestation, land degradation and desertification. Unclean burning leads to emissions.
- Dwindling resources lead to an additional workload for women and children as they have to spend more time searching for firewood. The fuel they find is often of a lower grade and thus burns with more smoke and less heat.
- Every year, the smoke from open fires and traditional stoves - leading to Indoor Air Pollution (IAP) - kills about 4.3 million people. Thus, every 8 seconds, someone (mostly women and children) is dying due to inefficient use of biomass fuel.
- Fuelwood is often collected on a daily basis and has no time to dry before use. This makes the use less efficient as some heat is wasted to drive the moisture out of the wood. Moist fuel results in more smoke.

Biogas Plants

Biogas is a clean and efficient fuel, generated from cow-dung, human waste or any kind of biological materials derived through anaerobic fermentation process. The biogas consists of 60% methane with rest mainly carbon-di-oxide. Biogas is a safe fuel for cooking and lighting. By-product is usable as high-grade manure.

Advantages

Biogas is Environment-friendly

Biogas is a clean source of energy, as no combustion takes place in the process. Therefore zero emissions of greenhouse gasses into the atmosphere. Hence using biogas as a source of energy can reduce Global warming to an extent.

Biogas reduces Soil and water pollution

About 3.5 million tons of garbage is discarded in landfills every day. These landfills not only spread foul smell but also contaminate underground water sources. Segregating organic waste from the garbage to generate Biogas considerably reduces wastes from landfills. This may improve water and soil quality.

Biogas produces Organic manure

The enriched organic manure is the by-product of Biogas generation which is a perfect supplement for crops, and plants. This organic manure acts as a perfect substitute for chemical fertilizers that can cause potential harm to crops and plants in different ways. They not only harm plants but also pollute water and soil and also cause chemical burns to crops.

Biogas generation is cheap and economic

Setting up a Biogas plant is cheap and economic that requires low to little investment. A small food waste treatment system can be installed at homes that feed on your kitchen waste and animal waste to produce Biogas required for cooking and electricity.

Biogas offers a healthy cooking alternative

Using Biogas as fuel for cooking saves women from the hassle of firewood collection. Biogas in the kitchen emits less to no smoke hence it prevents your family from being exposed to smoke and deadly respiratory disease.

Disadvantages

Lack of technology development

The major disadvantage of the Biogas plant is that the system used is not much efficient as they can produce Biogas sufficient for some energy needs. Large-scale sourcing of Biogas is still not available today hence governments are willing to invest in this sector. Still, advancement in technology is needed in Biogas plants to increase their capacity of production of Biogas, at low-cost investment.

Traces of impurities

Biogas contains impurities even after refinement, and compression. These impurities can corrode some parts of the engine in vehicles. Hence it is inappropriate to use it as fuel for the vehicle. Whereas, it is ideal for cooking, boilers, and lamps.

Effects of temperature

Bacteria digest food waste at an optimal temperature of 37%. Unlike other renewable energies, Biogas production is affected by the weather. Hence in cold climates, heat energy is needed to maintain a constant Biogas supply.

Hydroelectric

Hydroelectric energy, also called hydroelectric power or hydroelectricity, is a form of energy that harnesses the power of water in motion—such as water flowing over a waterfall—to generate electricity.

Water gains potential energy just before it spills over the top of a dam or flows down a hill. The potential energy is converted into kinetic energy as water flows downhill. The water can be used to turn the blades of a turbine to generate electricity, which is distributed to the power plant's customers.

Advantages of Hydroelectric Energy

1. Renewable

Hydropower is completely renewable, which means it will never run out unless the water stops flowing.

2. Emission Free

The creation of hydroelectricity does not release emissions into the atmosphere. This is, of course, the biggest appeal of any renewable energy source.

3. Reliable

Hydropower is, by far, the most reliable renewable energy available in the world. Unlike when the sun goes down or when the wind dies down, water usually has a constant and steady flow 24/7.

4. Adjustable

Since hydropower is so reliable, hydro plants can actually adjust the flow of water. This allows the plant to produce more energy when it is required or reduce the energy output when it is not needed. This is something that no other renewable energy source can do.

5. Faster Developed Land

Since hydro dams can only be built in specific locations, they can help develop the land for nearby towns and cities. This is because it takes a lot of equipment to build a dam. To transport it, highways and roads must be built, which helps open new paths for rural towns.

Disadvantages of Hydroelectric Energy

1. Impact on Fish

To create a hydro plant, a running water source must be dammed. This prevents fish from reaching their breeding ground, which in turn affects any animal that relies on those fish for food. As the water stops flowing, riverside habitats begin to disappear. This can even remove animals from accessing water.

2. Limited Plant Locations

While hydropower is renewable, there are limited places in the world that are suitable for plant construction. On top of this, some of these places are not close to major cities that could fully benefit from the energy.

3. Higher initial Costs

While no power plant is easy to build, hydro plants do require you to build a dam to stop running water. As a result, they cost more than similarly sized fossil fuel plants. Although, they will not need to worry about purchasing fuel later on. So it does even out over the long-term.

4. Carbon and Methane Emissions

While the actual electricity generation in the plant does not produce emissions, there are emissions from the reservoirs they create. Plants that are at the bottom of a reservoir begin to decompose. And when plants die, they release large quantities of carbon and methane.

5. Susceptible to Droughts

While Hydropower is the most reliable renewable energy available, it is dependent on the amount of water in any given location. Thus, the performance of a hydro plant could be significantly affected by a drought.

6. Flood Risk

When dams are built at higher elevations, they pose a serious risk to any town nearby that is below it. While these dams are built very strong, there are still risks. The biggest dam failure in history is the Banqiao Dam failure. Due to excess rainfall from a typhoon, the dam collapsed. This resulted in the deaths of 171,000 people.

Geothermal energy

Geothermal energy is heat that is generated within Earth. (Geo means “earth,” and thermal means “heat” in Greek.) It is a renewable resource that can be harvested for human use. A small portion of the core’s heat comes from the friction and gravitational pull formed when Earth was created more than four billion years ago. However, the vast majority of Earth’s heat is constantly generated by the decay of radioactive isotopes, such as potassium-40 and thorium-232.

Advantages of geothermal energy

Environmentally friendly

Geothermal energy is generally considered environmentally friendly. The carbon footprint of a geothermal power plant is minimal. An average geothermal power plant releases 99% less carbon dioxide (CO₂) for every megawatt-hour (MWh) of electricity it generates, according to the EIA.

Renewable and sustainable

Geothermal reservoirs come from natural resources and are naturally replenished. Geothermal energy is therefore a renewable energy source. According to scientists, the energy in our geothermal reservoirs will literally last billions of years.

Massive potential

Geothermal power plants across the world currently deliver just 12.7 gigawatts (GW) of electricity, with installed geothermal heating capacity a bit higher at 28 GW. This means there is a lot of scope for additional geothermal energy generation.

Stable

Geothermal energy is a reliable source of energy. We can predict the power output of a geothermal power plant with remarkable accuracy. This is not the case with solar and wind, where weather plays a huge part in power production. Geothermal power plants are therefore excellent for meeting the baseload energy demand.

Great for heating and cooling

Generating electricity with geothermal energy requires high water temperatures — of more than 150°C (about 300°F) or greater — in order to effectively turn the power-generating

turbines. Earth is generally more resistant to seasonal temperature changes than air. Consequently, the ground only a few feet below the surface can act as a heat sink/source with a geothermal heat pump — much in the same way an electrical heat pump uses the heat present in the air.

Disadvantages of geothermal energy

Environmental issues

There is an abundance of greenhouse gases below the surface of the earth. When geothermal energy is used, some of these gases escape towards the surface and into the atmosphere. These emissions tend to be higher near geothermal power plants.

Surface instability (earthquakes)

The construction of geothermal power plants can affect the stability of the land. In fact, geothermal power plants have led to subsidence (sinking of the Earth's surface). Earthquakes can be triggered due to hydraulic fracturing, which is an intrinsic part of developing enhanced geothermal system (EGS) power plants. In 2006, the construction of a geothermal power plant in Switzerland triggered an earthquake with a magnitude of 3.4 on the Richter scale.

Location-specific

Good geothermal reservoirs are hard to come by. Some countries have been blessed with great resources – Iceland and Philippines, for instance, meet nearly one-third of their electricity demand with geothermal energy. If geothermal energy is transported long distances by means of hot water (not electricity), significant energy losses have to be taken into account.

Sustainability issues

Rainwater seeps through the earth's surface and into the geothermal reservoirs over thousands of years. Studies show that the reservoirs can be depleted if the fluid is removed faster than replaced. Efforts can be made to inject fluid back into the geothermal reservoir after the thermal energy has been utilized (the turbine has generated electricity).

Nuclear energy

Nuclear energy is the energy in the nucleus, or core, of an atom. Atoms are tiny units that make up all matter in the universe, and energy is what holds the nucleus together. There is a huge amount of energy in an atom's dense nucleus. In fact, the power that holds the nucleus together is officially called the "strong force." Nuclear energy can be used to create electricity, but it must first be released from the atom. In the process of nuclear fission, atoms are split to release that energy.

Advantages of nuclear energy

Carbon-free electricity

While traditional fossil fuel generation sources pump massive amounts of carbon dioxide (the primary cause of global climate change) into the atmosphere, nuclear energy plants do not produce carbon dioxide, or any air pollution, during operation.

Small land footprint

Nuclear energy plants take up far less physical space than other common clean energy facilities (particularly wind and solar power). According to the Department of Energy, a typical nuclear facility producing 1,000 megawatts (MW) of electricity takes up about one square mile of space

High power output

Nuclear power plants produce high energy levels compared to most power sources (especially renewables), making them a great provider of baseload electricity. "Baseload electricity" simply means the minimum level of energy demand on the grid over some time, say a week. Nuclear has the potential to be this high-output baseload source,

Reliable energy source

nuclear energy is a reliable renewable energy source based on its constant production and accessibility. Nuclear power plants produce their maximum power output more often (93% of the time) than any other energy source, and because of this round-the-clock stability, makes nuclear energy an ideal source of reliable baseload electricity for the grid.

Disadvantages of nuclear energy

Uranium is non-renewable

nuclear energy is a "clean" source of power, it is technically not renewable. Current nuclear technology relies on uranium ore for fuel, which exists in limited amounts in the earth's crust. The longer we rely on nuclear power (and uranium ore in particular), the more depleted the earth's uranium resources

High upfront costs

Operating a nuclear energy plant is a relatively low-cost endeavor, but building it in the first place is very expensive. Nuclear reactors are complex devices that require many levels of safety built around them, which drives up the cost of new nuclear plants.

Nuclear waste

nuclear waste is a complicated issue, and we won't claim to be anything near experts. Nuclear waste is radioactive, making it an environmental and health catastrophe waiting to happen. These reasons are exactly why governments spend tons of money to safely package and dispose of used-up nuclear fuel.

Malfunctions can be catastrophic

A nuclear meltdown occurs when the heat created by a nuclear reactor exceeds the amount of heat being transferred out by the cooling systems; this causes the system to exceed its melting point. If this happens, hot radioactive vapors can escape, which can cause nuclear plants to melt down fully and combust, releasing harmful radioactive materials into the environment.