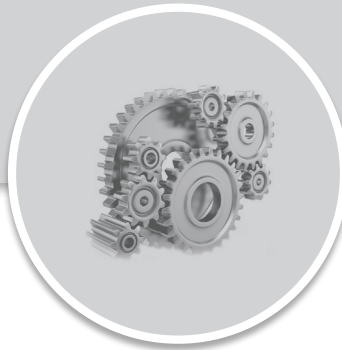


MECHANICAL ENGINEERING

Renewable Sources of Energy



Comprehensive Theory
with Solved Examples and Practice Questions



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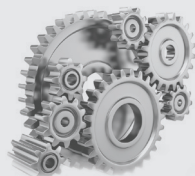
MADE EASY Publications Pvt. Ltd.

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Email : infomep@madeeasy.in | **Web :** www.madeeasypublications.org

Renewable Sources of Energy

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Introduction

1.1 RENEWABLE ENERGY

Renewable energy is the term used for energy flows occurring naturally and repeatedly at a rate such that it is replenished at the same rate as they are used. The ultimate sources of renewable energy are : Sun, gravity and rotation of earth. Energy from these resources is derived in various forms such as solar, wind, tidal, biomass etc.

1.2 DIFFERENCE BETWEEN RENEWABLE AND NON-RENEWABLE SOURCES OF ENERGY

Renewable Sources	Non-Renewable Sources
<ol style="list-style-type: none"> 1. Energy obtained from natural and persistent flows of energy occurring in the immediate environment is renewable energy. 2. Examples: Solar, Wind, Hydro power, Biomass, Tidal, Ocean thermal. 3. This type of energy is already passing through the environment as flow or current, irrespective of the fact that there is any device present to harness this energy or not. 4. Other names : Green Energy, Sustainable energy. 5. Energy Flow Diagram 	<ol style="list-style-type: none"> 1. Energy obtained from static stores of energy that remained underground unless released by human interaction is known as non-renewable energy. 2. Example: Nuclear fuels, fossil fuels of coal, oil, natural gas. 3. This type of energy is initially in the form of isolated source potential. An external (human) action is required to start the supply of energy for practical purposes. 4. Other names: Finite supplies, Brown energy. 5. Energy Flow Diagram
<p>ABC → Environmental energy flow. DEF → Harnessed energy flow.</p>	<p>Mined Source: Brown Energy</p> <p>DEF → Extracted energy from brown energy source.</p>

EXAMPLE : 1.1

For which of the following sources, Sun is not an indirect source of energy?

- (a) Wind energy (b) Tidal energy
(c) Biomass energy (d) Fossil fuels

Solution: (b)

1.3 AVAILABILITY OF RENEWABLE ENERGY ON EARTH

The Energy flux received per square meter on the surface of the earth is 500 W (approximately) from all the sources of renewable energy. The demand of energy per person is 2 kW, considering the requirements of modern society. If renewable energy flux is harnessed at just 4% efficiency, 2 kW of the power required can be drawn from an area of $10 \times 10 \text{ m}^2$ with suitable method of power harnessing. The total energy demand can be fulfilled by using just 5% of the local land area.

The major contribution in the renewable energy comes from solar energy. The total solar flux absorbed at the sea level is about $1.2 \times 10^7 \text{ W}$. Thus, the availability of solar flux per person on Earth's surface is 20 MW which is 10,000 times compared to the requirement of energy per person.

Thus, it can be said that renewable energy source has the potential to cater the demand of energy globally, but only if the technical methods and institutional frameworks exist to extract, use and store the energy in an appropriate form at realistic costs.

EXAMPLE : 1.2

Consider the following statements regarding spectral distribution of solar radiation :

1. Solar flux is non-uniformly distributed over a wave length in which it covers the entire range of visible radiation and some part of ultraviolet and infrared radiation.
2. It is having maximum energy distribution in infrared region.
3. It is having maximum spectral emissive power in the visible radiation region as per Planck's distribution.

Which of the above statements are correct?

- (a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

Solution: (d)

1.4 FLOW OF RENEWABLE ENERGY

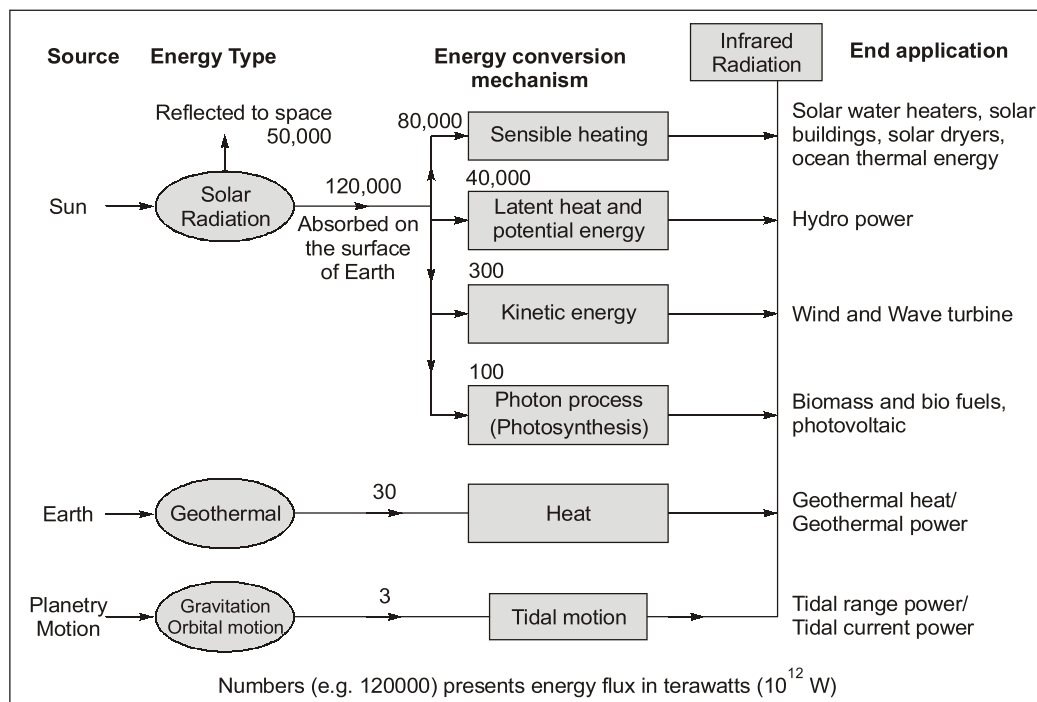


Figure: Flow of Renewable Energy

The dominance of solar energy is clearly visible from the renewable energy flow diagram. Although, flow energy diagram gives a glimpse of available energy yet the information has little practical engineering applications. It is because of rapid change in geographical conditions. Suitability of a renewable energy source is decided based on availability and economy of energy production, e.g., flat regions or shore areas are suitable for wind energy but not for hydro energy. Similarly hilly areas with rivers are suitable for hydropower and not for wind power. Tropical rain forest regions are good for harnessing biomass energy but not good for wind and solar.

1.5 RENEWABLE ENERGY SCENARIO IN INDIA

India is world's 3rd largest consumer of electricity and world's 3rd largest renewable energy producer with 40% of energy capacity installed in the year 2022 (160 GW of 400 GW) coming from renewable sources. Ernst and Young's 2021 Renewable Energy Country Attractiveness Index (RECAI) ranked India 3rd behind USA and China. In 2016, Paris agreement's intended nationally determined contributions targets, India made commitment of producing 50% of its total electricity from non-fossil fuel sources by 2030. India has also set a target of producing 175 GW by 2022 and 500 GW by 2030 from renewable energy.

The following table shows the breakdown of existing installed capacity in August 2022 from all the resources, including solar and non-solar. (Source : Central Electricity Authority, CEA)

Installed Generation Capacity (Fuel wise) as on 31.08.2022

Category	Installed generation Capacity (G/W)	% Of share in Total
Fossil Fuel		
Coal	204.080	50.3%
Lignite	6.620	1.6%
Gas	24,856	6.1%
Diesel	0.510	0.1%
Total Fossil Fuel	2 36,065	58.2%
Non-Fossil Fuel		
RES (Incl. Hydro)	162.928	40.2%
Hydro	46.850	11.5 %
Wind, Solar & Other RE	116.078	28.6 %
Wind	41.205	10.2 %
Solar	59.303	14.6 %
BM Power/Cogen	10.206	2.5 %
Waste to Energy	0.477	0.1 %
Small Hydro Power	4.888	1.2 %
Nuclear	6.780	1.7%
Total Non-Fossil Fuel	169.708	41.8%
Total Installed Capacity (Fossil Fuel & Non-Fossil Fuel)	405.773	100%

1.6 UTILITIES OF RENEWABLE ENERGY

There are numerous applications where renewable energy can be utilized. Broadly these segments can be categorized as:

1. Electricity generation.
2. Air and water heating/cooling.
3. Transport (Biodiesel, Biogas, Ethanol, Solar vehicles).
4. Rural (off-grid) applications (cooking).

1.7 BENEFITS OF RENEWABLE ENERGY

Following are the benefits of using renewable energy:

1. Renewable energy is available over wide geographical area. Majority of the population can harness energy from these resources locally.
2. Renewable energy resources are replenishable and hence energy can be taken continuously over longer time. These resources can provide energy security in the era when fossil fuels are depleting at a faster rate.
3. Renewable energy is a clean/green energy which is environmental friendly. It helps in mitigating climate change issues raised by greenhouse gases.
4. Renewable energy provides the opportunity for growth in rural areas and remote areas which are not connected with the urban areas because of geographical challenges. These areas can be electrified and basic amenities and communication networks can be established using renewable energy resources.
5. Operating cost of the renewable energy devices is very low as compared to the conventional devices.
6. Flexible in nature, can be used in rural areas with small capacities.
7. Low operating cost.

EXAMPLE : 1.3

Consider the following statements regarding various non-conventional energy sources :

1. Solar energy has highest predictability among solar, wind and tidal energy.
2. Solar energy has only diurnal availability.
3. Wind energy is erratic and location specific.

Which of the above statements is/are correct?

- (a) 1 and 2 only (b) 2 and 3 only
(c) 3 only (d) 1, 2 and 3

Solution: (b)

Tidal energy is the most predictable among solar, wind and tidal energy. Solar energy has only diurnal availability (only during day time).

1.8 DIFFICULTIES IN HARNESSING RENEWABLE ENERGY

Although renewable energy is non-polluting, economic, emits lesser carbon emissions, still there are some difficulties in harnessing it:

1. Renewable energy is present in dilute form. It is very difficult to extract large amount of energy which is comparable to the energy taken from fossil fuels.
2. Renewable energy is highly fluctuating type of energy. It depends on weather conditions. Hence, continuous supply of such energy cannot be always ensured.
3. Initial investments are quite high in case of building renewable energy plants. These plants require upfront investment to build, require careful planning and implementation.
4. Large tracts of land is required to produce energy for commercial applications.

1.9 CHECKPOINTS BEFORE DEVELOPING TECHNOLOGY FOR RENEWABLE ENERGY SOURCES

Before developing technology on the basis of renewable source of energy, the following questions need to be evaluated carefully:

1. How much energy is available in the immediate environment- what is the source?
2. For what purpose can this energy be used. What is the end use of the energy?
3. What is the environmental impact of the technology? Is it sustainable?
4. What is the cost of the energy? Is it cost effective?

1.10 NEW TECHNOLOGIES

1. **Hydrogen energy systems:** Hydrogen having high energy content, is a clean and efficient energy carrier with a potential to replace liquid fossil fuels. Hydrogen can be converted effectively back to electricity either directly in IC engines or through fuel cells. Hydrogen is also a good fuel for aircraft and automobiles that could encourage its large-scale commercial production, storage and distribution.
2. **Fuel cells:** A fuel cell is an electrochemical device that converts fuel energy into electricity and heat without combustion. A fuel cell is similar to a battery having electrodes, positive and negative terminals and an electrolyte. In a fuel cell, hydrogen and oxygen react to produce water and electricity. A fuel cell continues to work as long as fuel is supplied. Despite their benefits, fuel cells are not in wide use due to their high cost.
3. **Biofuels:** The organic material of plants is called biomass, which may be converted by anaerobic digestion into methane, and through fermentation process into alcohol. Biofuels are environment friendly source of energy, which can reduce the import of crude oil from foreign countries to India.

■■■■

**OBJECTIVE
BRAIN TEASERS**

Q.1 Renewable energy resources supply

1. Continuous energy
2. Intermittent energy
3. Replenishable energy
4. Non-replenishable energy

- (a) 1 and 4 (b) 2 and 3
(c) 1 and 3 (d) 2 and 4

Q.2 Which are the renewable energy resources?

1. Solar energy 2. Natural gas
3. Biogas 4. Geothermal energy

- (a) 1, 2 and 3 (b) 1, 2 and 4
(c) 1, 3 and 4 (d) All of these

Q.3 An erupted volcano is precisely an example of :

- (a) geothermal energy
(b) renewable energy
(c) fossil fuel energy
(d) non-renewable energy

Q.4 Which of the following statements are true regarding a renewable energy resource?

1. It is replenishable and a clean form of energy
2. Available in abundant but in dilute form
3. It can easily be harnessed without investing much money in establishment of plants.
4. Reliable source of energy

- (a) 1 and 2 (b) 1, 2 and 3
(c) 1, 2 and 4 (d) All

Q.5 Which one of the following renewable energy resources have maximum available energy flux

- (a) Solar radiation (b) Wind power
(c) Geothermal (d) Tidal energy

Q.6 The maximum contribution in fulfilling world energy consumption is done by :

- (a) Coal (b) Oil
(c) Natural gas (d) Solar energy

Q.7 The maximum contribution in power production by renewable energy sources comes from :

- (a) Wind (b) Solar
(c) Geothermal (d) Biogas

ANSWERS KEY

1. (b) 2. (c) 3. (a) 4. (c) 5. (a)
6. (a) 7. (a)

■■■■