

Mechanical Engineering

Renewable Sources of Energy

Comprehensive Theory with Solved Examples
and Practice Questions



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Publications



MADE EASY Publications Pvt. Ltd.

Corporate Office: 44-A/4, Kalu Sarai (Near Hauz Khas Metro Station), New Delhi-110016

E-mail: infomep@madeeeasy.in

Contact: 011-45124660, 8860378007

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Renewable Sources of Energy

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CHAPTER

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 resource is derived in various forms such as solar, wind, tidal, biomass etc.

Difference between Renewable and Non-renewable Source of Energy

Renewable	Non-Renewable
<ol style="list-style-type: none"> Energy obtained from natural and persistent flows of energy occurring in the immediate environment is renewable energy. Examples: Solar, Wind, Hydro power, Biomass Tidal, Ocean thermal. 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. Other names : Green Energy, Sustainable energy. Energy Flow Diagram <pre> graph TD A[Source: Natural environment (Green energy)] --> B[Source of continuous energy flow] B --> C[Device] C --> D[Use] D --> E[Sink: Environment] E --> F[Source: Natural environment (Green energy)] F --> C </pre> <p>ABC → Environmental energy flow. DEF → Harnessed energy flow.</p>	<ol style="list-style-type: none"> Energy obtained from static stores of energy that remained underground unless released by human interaction is known as non-renewable energy. Example: Nuclear fuels, fossil fuels of coal, oil, natural gas. 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 purpose. Other names: Finite supplies, Brown energy. Energy Flow Diagram <p>Mined Source: Brown Energy</p> <pre> graph TD D[Source: Natural environment (Brown energy)] --> E[Device] E --> F[Use] F --> G[Sink: Environment] </pre> <p>DEF → Extracted energy from brown energy source.</p>

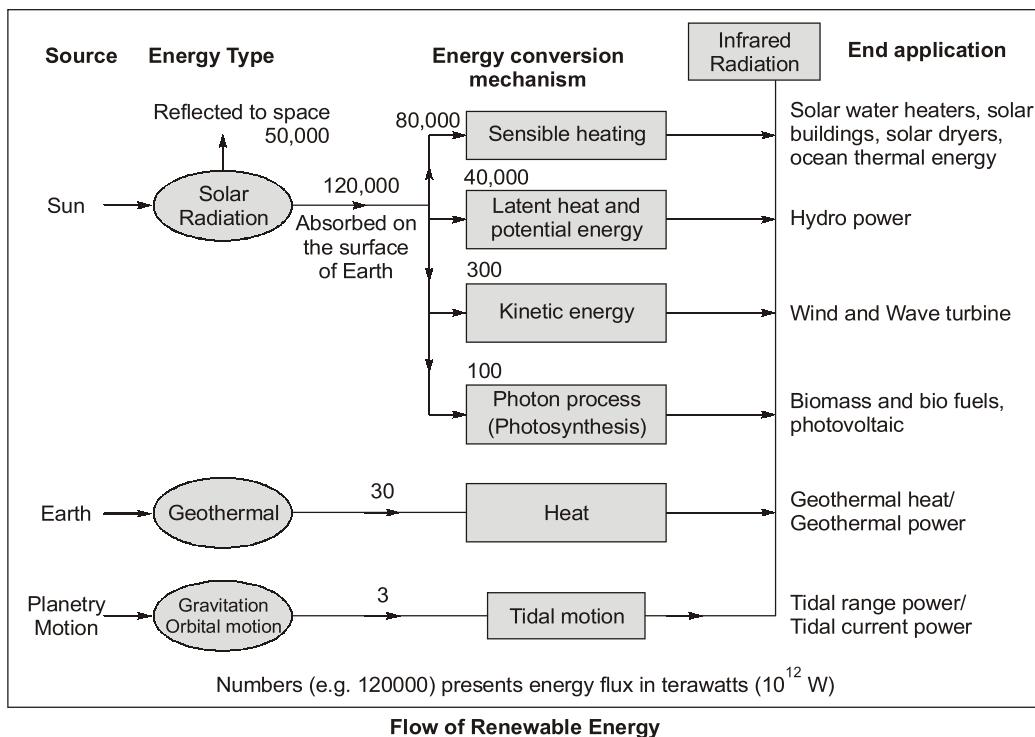
1.2 Availability of Renewable Energy on Earth

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.

1.3 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 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.

1.4 Energy Demand of World and Contribution of Renewable Energy

World energy consumption is the total energy used by human civilization. It involves all energy harnessed from every energy source applied towards humanity's endeavours across every single industrial and technological sector, across every country. It is usually measured per year. World energy consumption has a deep implication for humanity's social-economic-political sphere. Majority of the world energy consumption is harnessed from fossil fuel i.e. oil, coal and natural gas.

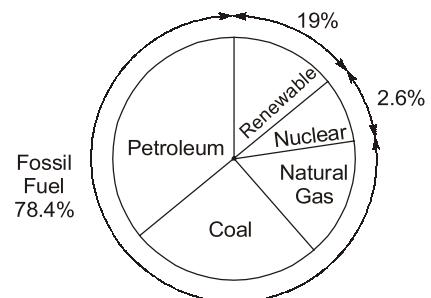
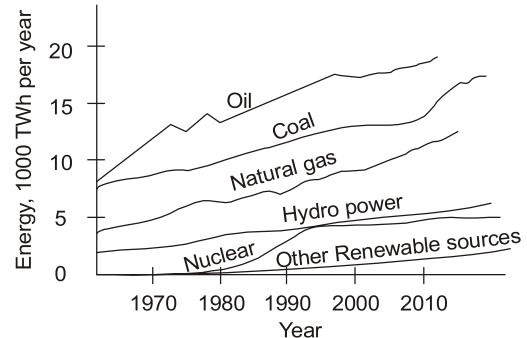
International Energy Agency (IEA) estimated an average power consumption of 12.3 Terawatts (TW) for the year 2013. World's energy consumption and the source from which it was obtained, are shown in figure given below.

Hydropower is one form of renewable energy, which contributes slightly more than nuclear energy. It can also be observed that renewable energy resources are contributing least but their share is increasing now a days.

The electricity production by various energy sources worldwide is depicted by pi-diagram given.

Renewable energy sources included :

1. Traditional Biomass	9%
2. Hydropower	3.8%
3. Bio-heat	2.6%
4. Wind	0.39%
5. Ethanol	0.34%
6. Bio-power generation	0.25%
7. Solar heating/cooling	0.16%
8. Biodiesel	0.15%
9. Solar-PV	0.077%
10. Geothermal Heat + Electricity	(0.061 + 0.049)%

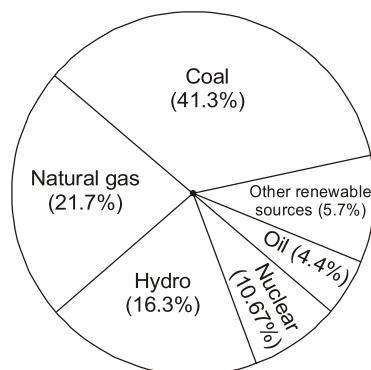


1.4.1 World Energy Consumption : Share of Energy Resources

From these charts it is clear that fossil fuels are major sources of energy. But fossil fuels are depleting at a faster rate and cannot meet the energy requirement in future. Environmental pollution is another major concern when fossil fuels are used.

The contribution of renewable energy is 19% in world power consumption and 22% in the world electricity generation. Since, renewable energy is replenished at the same rate at which it is consumed hence it is grabbing attention worldwide. Moreover, it is the clean or green energy which is not causing pollution like fossil fuel.

Some of the countries are getting most of power from renewable energy sources. The leading countries are listed below :

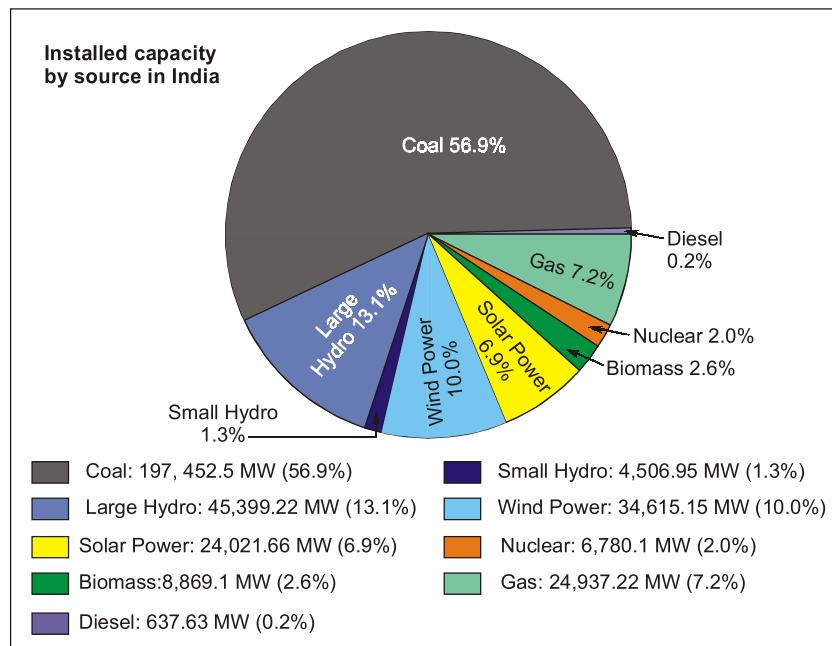


Sl. No.	Country	% of power generation from renewable source
1.	Iceland	100
2.	Norway	98
3.	Brazil	86
4.	Austria	62
5.	New Zealand	65
6.	Sweden	54

1.5 Present Power Scenario of India

In India, total power production installed capacity is 263.66 GW (Gigawatt) and renewable energy capacity is 34.35 GW i.e. 13% of the installed capacity and 7% of the electricity produced, as on march 2015 by Ministry of New and Renewable Energy (MNRE) report.

Total installed capacity is shown by Pi-chart given below:

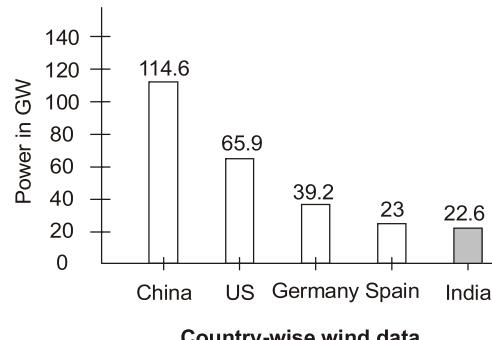
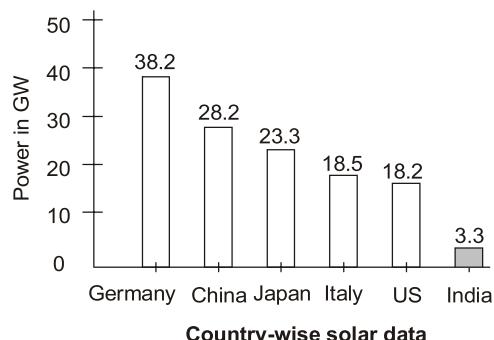


Revised power scenario of India

Renewable energy constitutes :

1. Wind 8.6%
 2. Solar Heating/Cooling 1.5%
 3. Solar PV 1.3%
 4. Biomass 0.5%
 5. Biogas 1.1%
- India is 5th largest country producing wind energy (22.6 GW out of 370 GW) (By report : Global Wind Energy Council as on 2014)
 - India is 11th largest country in solar power production (3.3 GW out 177 GW) (As on Jan 2014, IEA report)

Country-wise Solar & Wind data are given in graphs below :



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

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.

1.8 Difficulties in Harnessing Renewable Energy

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 ensured always.
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?



Objective Brain Teasers

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
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
3. An erupted volcano is precisely an example of :
 - (a) geothermal energy
 - (b) renewable energy
 - (c) fossil fuel energy
 - (d) non-renewable energy
4. Human efforts are required to initiate the supply of energy in the case of :
 - (a) Renewable energy source
 - (b) Non-renewable energy source
 - (c) Both (a) and (b)
 - (d) Neither (a) nor (b)
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
6. The maximum contribution in fulfilling world energy consumption is done by :
 - (a) Coal
 - (b) Oil
 - (c) Natural gas
 - (d) Solar energy
7. The maximum contribution in power production by renewable energy sources comes from :
 - (a) Wind
 - (b) Solar
 - (c) Geothermal
 - (d) Biogas
8. Which of the following statements are true regarding of renewable energy resource?
 1. It is replenishable and 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 sources of energy
 - (a) 1 and 2
 - (b) 1, 2 and 3
 - (c) 1, 2 and 4
 - (d) All

ANSWERS

- | | | | | |
|--------|--------|--------|--------|--------|
| 1. (b) | 2. (c) | 3. (a) | 4. (a) | 5. (a) |
| 6. (a) | 7. (a) | 8. (c) | | |

