

ESE 2024

UPSC ENGINEERING SERVICES EXAMINATION

Preliminary Examination

General Studies and Engineering Aptitude

Basics of Energy and Environment

Comprehensive Theory *with* Practice Questions
and ESE Solved Questions



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ESE 2024 Preliminary Examination : Basics of Energy and Environment

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Preface

The compilation of this book **Basics of Energy and Environment** was motivated by the desire to provide a concise book which can benefit students to understand the concepts of this specific topic of General Studies and Engineering Aptitude section.



B. Singh (Ex. IES)

This textbook provides all the requirements of the students, i.e. comprehensive coverage of theory, fundamental concepts and objective type questions articulated in a lucid language. The concise presentation will help the readers grasp the theory of this subject with clarity and apply them with ease to solve objective questions quickly. This book not only covers the syllabus of ESE in a holistic manner but is also useful for many other competitive examinations. All the topics are given the emphasis they deserve so that mere reading of the book clarifies all the concepts.

We have put in our sincere efforts to present detailed theory and MCQs without compromising the accuracy of answers. For the interest of the readers, some notes, do you know and interesting facts are given in the comprehensive manner. At the end of each chapter, sets of practice question are given with their keys and detailed explanations, that will allow the readers to evaluate their understanding of the topics and sharpen their question solving skills.

Our team has made their best efforts to remove all possible errors of any kind. Nonetheless, we would highly appreciate and acknowledge if you find and share with us any printing and conceptual errors.

It is impossible to thank all the individuals who helped us, but we would like to sincerely thank all the authors, editors and reviewers for putting in their efforts to publish this book.

With Best Wishes

B. Singh

CMD, MADE EASY Group

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1

Energy Resources : Conservation & Utilisation

1.1 Introduction

- The word 'energy' is derived from the Greek word "*en-ergon*" which means "*in-work*" or "*work content*". Therefore, energy may be defined as the capacity of doing work.
- All living things possess some form of energy and simultaneously witness the flow of energy from one form to another form, i.e. mechanical to electrical, thermal to chemical, tidal to electrical, etc. These forms of energy differ from one another, but constitute the physical reality of the universe.
- Energy is an important input for the overall development and is, therefore, vital for improvement in quality of life. Its use in sectors such as industries, commerce, transports, telecommunications, and wide range of agriculture and household activities has compelled to meet ever increasing demands which can not be fulfilled by conventional sources of energy alone, like coal, petroleum, gas, etc. Hence, there is need to explore the possibilities of harnessing energy from renewable sources of energy like solar energy, wind energy, tidal energy, geothermal energy, etc.
- The phrase 'conservation of energy' was coined and made popular by German physicists Helmholtz and Joule. They demonstrated that energy could not be annihilated but only be transformed.

The different types of energy and their conversion from one form to another are given below:

- **Heat Energy** : Heat is an intrinsic energy of all the combustible substances. It is basically the kinetic energy of molecules.
- **Chemical Energy** : Chemical energy is trapped in fossil fuels such as coal, oil and natural gas. Fossil fuels are used to generate electricity, power vehicles and railway engines.
- **Nuclear Energy** : Matter can be changed into energy when larger atoms are split into smaller ones (Atomic Fission) or when smaller ones combine to form larger atoms (Atomic Fusion).
- **Radiant Energy** : Solar radiation is the manifestation of radiant energy that is received on the earth. Radio waves, X-rays, infrared and ultraviolet electromagnetic radiations contain radiant energy.
- **Electrical Energy** : Electrical energy arises out of the movement of electrons to produce heat, magnetic field and electromagnetic radiations. It is a highly versatile form of energy, and can be easily converted to other forms for utilization.
- **Kinetic Energy** : The energy of an object in motion is called kinetic energy. If the mass of an object is m and the object is moving with a velocity v , then its kinetic energy is expressed in Joules as :

$$KE = (1/2)mv^2, \text{ where } m \text{ is in kg and } v \text{ is in m/s.}$$

- **Potential Energy** : The energy which a body possesses as a result of its position in the earth's gravitational field is called 'potential energy' and is expressed in Joules as:

$$PE = mgh$$

Where the mass m is in kg, g is the acceleration due to gravity in m/s^2 , and h is the height in metre.

1.2 Types of Energy Resources

- Energy resources can be classified into two types:
 - (i) Renewable energy resources
 - (ii) Non-renewable energy resources

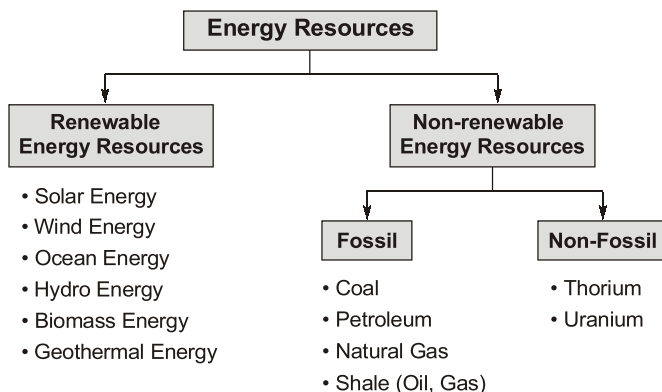


Fig: 1.1 Types of Energy Resources

- The renewable energy resources, such as wind, water, solar, geothermal, etc., come from sources that regenerate as fast as they are consumed and are continuously available.
- The non-renewable energy resources, such as fossil fuels and nuclear materials, are extracted from the earth and can be depleted in near future. These resources have been the most used type of energy in the modern era.
- In the early part of the 21st century, renewable energy resources have become more popular as non-renewable energy resources have begun to be depleted.
- Thermal plants (coal, oil, gas), nuclear and hydropower stations are the major conventional methods of generating electrical energy. Rise in the cost of fossil fuels has created an urgency to conserve these fuels, and engineers across the world are looking for alternative renewable sources of energy.

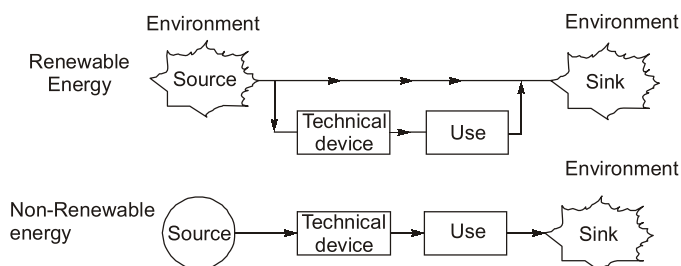


Fig: 1.2 Energy Conversion

1.3 Renewable Energy Resources

- The energy sources which can be renewed by nature again and again, and their supply is not affected by the rate of their consumption are called renewable energy resources. These are environment friendly and have potential to replace non-renewable energy resources. These are also known as inexhaustible sources of energy. The examples of renewable energy resources are solar, wind, ocean, hydro, biomass, geothermal, etc.
- Renewable energy resources are available in unlimited amount in nature and can be renewed over relatively shorter period of time. Most of the renewable sources of energy are fairly non-polluting and considered as clean.
- India is implementing one of the world's largest programmes in renewable energy sector. The Government of India is on its way to achieving 175 GW target for installed renewable energy capacity by 2022.

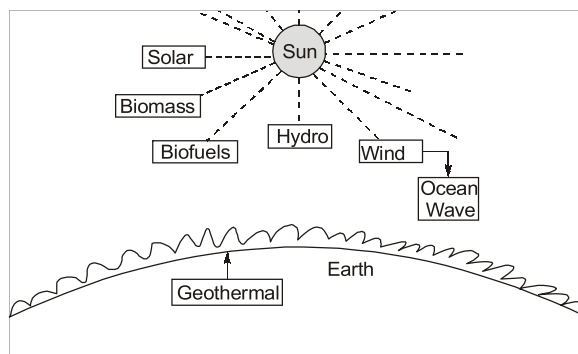


Fig: 1.3 Renewable Energy Resources

- Large hydropower is also renewable in nature, but has been utilized all over the world for many decades and hence not included in the term 'renewable'. However, small hydropower comes under renewable source category.
- Municipal and industrial waste is also a useful source of energy, but these are different forms of biomass.
- The Ministry of New and Renewable Energy (MNRE) has made efforts during the past few decades to develop and utilize various renewable energy resources in the country. Consequently, wind electric generators, solar water heaters, solar lanterns, street lights, biogas plants, biomass gasifiers and small hydroelectric generators have become commercially available.

Table 1.1: Renewable energy installed capacity in India (As on February 28, 2023)

Renewable Energy Source	Installed Capacity (MW)
Solar Power	64,381
Wind power	42,015
Biomass power	10,218
Small Hydro Power (up to 25 MW)	4,943
Waste to energy (Urban & Industrial)	523
Total	122,080

1.3.1 International Energy Agency (IEA)

- International Energy Agency is an inter-governmental organization established in 1974 as per framework of the Organisation for Economic Co-operation and Development (OECD).
- Its prime focus is on the "3Es" of effectual energy policy: energy security, economic development and environmental protection.
- It also seeks to promote alternate energy sources (including renewable energy), rational energy policies and multinational energy technology co-operation.
- It acts as energy policy advisor to 30 member countries. India has become Associate Member of IAE.
- It publishes World Energy Outlook report.

Headquarters: Paris, France.

1.3.2 The Energy and Resources Institute (TERI)

- TERI is a leading think tank dedicated to conducting research for sustainable development in India.
- It was established in 1974 as an information centre on energy issues.
- TERI's key focus lies in promoting:

(i) Clean Energy	(ii) Water Management
(iii) Pollution Management	(iv) Sustainable Agriculture
(v) Climate Resilience	

Headquarters: New Delhi, India.

1.3.3 International Renewable Energy Agency (IRENA)

- The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation on renewable energy.

- IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean energy, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.
- It encourages governments to adopt enabling policies for renewable energy investments, provides practical tools and policy advice to accelerate renewable energy deployment, and facilitates knowledge sharing and technology transfer to provide clean, sustainable energy for the world's growing population.
- It has 160 Member States actively engaged, IRENA promotes renewable resources and technologies as the key to a sustainable future and helps countries achieve their renewable energy potential.

Headquarters: Abu Dhabi, United Arab Emirates.

1.3.4 Renewable Energy and Energy Efficiency Partnership (REEEP)

- REEEP is an international multilateral partnership that works to accelerate market-based deployment of renewable energy and energy efficient systems in low- and middle-income countries.
- It invests in clean energy markets in low and middle income countries to reduce CO₂ emissions and build prosperity.
- It creates, adapts and shares knowledge to build sustainable markets for renewable energy and energy efficient solutions; advance energy access, improve lives and economic opportunities; and reduce climate and environmental damage.

Headquarters: Vienna, Austria.

1.3.5 REN21 (Renewable Energy Policy Network for the 21st Century)

- REN21, an international non-profit association, is the global renewable energy policy multi-stakeholder network that connects a wide range of key actors from including Governments, International organisations, Industry associations, science and academia and civil society to facilitate knowledge exchange, policy development and joint action towards a rapid global transition to renewable energy.
- It promotes renewable energy to meet the needs of both industrialized and developing countries that are driven by climate change, energy security, development and poverty alleviation.

Objectives of REN21:

- Providing policy-relevant information and research based analysis on renewable energy to decision makers, multipliers and the public to catalyse policy change.
- Offering a platform for interconnection between multi-stakeholder actors working in the renewable energy field worldwide and identifying barriers as well as working to bridge existing gaps to increase the large-scale deployment of renewable energy worldwide.

Headquarters: Paris, France.

1.4 Solar Energy

- Solar energy is a primary source of energy which directly obtained from the sun by capturing the solar radiation and converting it into another form of energy to perform various useful activities.
- For receiving the solar radiation, it is necessary for the collectors to be able to track the sun to ensure a maximum and continuous reception.

Terrestrial Solar Radiation

- Solar radiations that pass through the earth's atmosphere and are subjected to scattering and atmospheric absorption, are known as Terrestrial Solar Radiation.
- Short wave ultraviolet rays are absorbed by ozone and long wave infrared rays are absorbed by CO₂ and water vapour. A part of scattered radiation is reflected back into space. This scattering is due to air molecules, dust particles and water droplets that cause attenuation of radiation.

- There are two ways of solar energy utilization:
 1. Conversion of solar energy into thermal energy
 2. Photovoltaic cells
- The conversion of solar energy into thermal energy can be done by using solar collectors, whereas in photovoltaic cells the direct sunlight is used to generate electricity.

The given schematic diagram of solar power plant depicts four processes:

- (i) Photovoltaic (PV) cells convert sunlight to Direct Current (DC) electricity.
- (ii) The inverter converts Direct Current (DC) into Alternating Current (AC) electricity.
- (iii) The electrical panel sends power to be consumed within property as lights and in other appliances.
- (iv) The distribution board supplies electricity to grid.

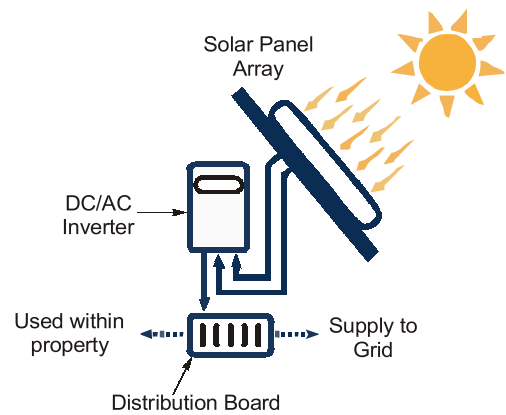


Fig. 1.4: Working of Solar Power Plant

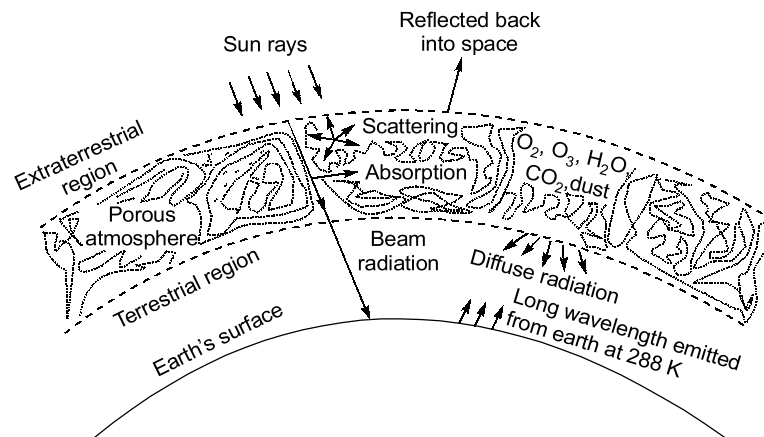


Fig: 1.5 Solar Radiation Atmospheric Mechanisms

1.4.1 Types of Radiation

- **Beam radiation (I_b):** Solar radiation received on the earth's surface without change in direction, is called beam or direct radiation.
- **Diffuse radiation (I_d):** The radiation received on a terrestrial surface (scattered by aerosols and dust) from all parts of the sky, is known as diffuse radiation.
- **Total radiation (I_T):** The sum of beam and diffuse radiations is referred as total radiation. When measured at a location on the earth's surface, it is called solar insolation at that place. When measured on a horizontal surface, it is called global radiation (I_g).
- **Irradiance:** The rate of incident energy per unit area of a surface is termed as irradiance. It is also known as Solar Constant. Based on the experimental measurements, the standard value of the Solar Constant is 1.367 kW/m^2 .
- **Albedo:** The earth reflects back nearly 30% of the total solar radiant energy to the space by reflection from clouds, scattering and reflection at the earth's surface. This is called the albedo of the earth's atmosphere system.
- **Insolation:** Insolation is the solar radiation that reaches the earth's surface. It is measured by the amount of solar energy received per square centimeter per minute. Insolation is directly proportional to

- The establishment of a Bureau of Energy Efficiency (BEE) in place of the existing Energy Management Centre (EMC) to implement the provisions of the Act. BEE to act as a facilitator for the evolution of a self-regulatory system and organizations to regulate on their own with a view to save energy and thereby bring the commercial concept in the organization.

Previous ESE Prelims Questions

Q.1 Consider the following statements regarding solar energy:

1. To encourage the adoption of solar energy production, many State Governments and the Centre have announced plans by way of buy back as well as subsidies for installation.
2. Land acquisition of several hectares is a bottleneck in implementing this programme.
3. Considerable *R & D* effort is needed to bring down the cost of P-V cells.

Which of the above statements are correct?

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

[ESE Prelims : 2017]

Ans. (c)

Q.2 Which one of the following statements is correct?

- (a) The end product of fossil fuels is in the form of electrical energy.
- (b) Watershed protection increases the rate of surface runoff of water.
- (c) If timber is overharvested, the ecological functions of the forest are improved.
- (d) Rivers change their course during floods and lots of fertile soils are lost to the sea.

[ESE Prelims : 2017]

Ans. (d)

Directions: Each of the next items consists of two statements, one labelled as '**Statement (I)**' and the other as '**Statement (II)**'. You are to examine these two statements carefully and select the answers to these items using the code given below:

Code:

- (a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
- (b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I)
- (c) Statement (I) is true but Statement (II) is false
- (d) Statement (I) is false but Statement (II) is true

Q.3 **Statement (I):** Increased cloud cover will lead to warmer winters due to clouds reflecting more intense solar energy.

Statement (II): Overcast cloud conditions result in decrease in the day-night temperature difference.

[ESE Prelims : 2017]

Ans. (d)

Q.4 **Statement (I):** Green energy refers to one which does not harm the ecosystem of planet Earth.

Statement (II): All renewable energy is green energy.

[ESE Prelims : 2018]

Ans. (c)

Q.15 Which one of the following is NOT correct?

- The formation of a mountain chain by the compression of crustal rocks is known as an orogeny
- Rock between the two extremes is called mesocratic
- Sediments are deposited in horizontal layers called clay plates
- Particles deposited as sediments are changed into rock by the pressure of later deposits at low temperature is called diagenesis

[ESE Prelims : 2023]

Ans. (c)



Objective Brain Teasers

Q.1 Hydrogen fuel cell vehicles produce which of the following as exhaust?

- NH_3
- CH_4
- H_2O
- H_2O_2

Q.2 Given below are the names of four energy crops. Which one of them can be cultivated for ethanol?

- Jatropha
- Sugarcane
- Pongamia
- Sunflower

Q.3 In the context of alternating sources of energy, biofuels can be obtained from

- Jatropha
- Rice
- Bamboo
- Wheat

Select the correct answer using the codes given below:

- 1 only
- 1 and 2 only
- 1, 2 and 3
- All of the above

Q.4 With reference to technologies for solar power production, consider the following statements:

- Photovoltaics is a technology that generates electricity by direct conversion of light into electricity.
- Photovoltaics generates alternating current (AC), while Solar Thermal generates direct current (DC).
- India has manufacturing base for Solar Thermal technology, but not for Photovoltaics.

Which of the statements given above is/are correct?

- 1 only
- 2 and 3 only
- 1, 2 and 3
- None of these

Q.5 Consider the following statements regarding 'biogas':

- This is a mixture of different gases which is formed after breakdown of an organic compound.
- This is produced by decomposition by fungi and algae in an open system where sufficient oxygen supply is available.
- This gas can be also compressed same like CNG and used for energy needs.

Select the correct answer using the codes given below:

- 1 and 2 only
- 2 and 3 only
- 1 and 3 only
- All of the above

Q.6 Which of the following are components of biogas?

- Methane
- Carbon dioxide
- Nitrous oxide
- Hydrogen sulphide

Select the correct answer using the codes given below:

- 1, 2 and 3
- 1, 2 and 4
- 2, 3 and 4
- All of the above

Q.7 Consider the following statements regarding solar power generation in India:

- Gujarat and Rajasthan are the two major solar power generating states.
- Rajasthan has a natural advantage of more solar radiation and large tracts of land is available.
- There is dominance of private sector in solar energy sector in recent days.

Q.58 'Run of the river' system is usually used for which of the following projects?

- (a) Tidal energy project
- (b) Small-scale hydropower project
- (c) Ocean Thermal Energy Conversion project
- (d) Large reservoir based hydropower project

Q.59 Consider the following statements:

- 1. Biomass can be converted into liquid biofuels by distillation.
- 2. Biomass is renewable form of energy and abundantly available on the earth in the form of firewood, agricultural residues etc.

Which of the above statements is/are correct?

- (a) 1 only
- (b) 2 only
- (c) Both 1 and 2
- (d) Neither 1 nor 2

Q.60 Which of the following may be classified as third generation biofuels?

- 1. Algae-based biofuels
- 2. Jatropha-based biofuels
- 3. Corn-based biofuels

Select the correct option using the codes given below:

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

Answers

- | | | | | |
|---------|---------|---------|---------|---------|
| 1. (c) | 2. (b) | 3. (a) | 4. (a) | 5. (c) |
| 6. (b) | 7. (d) | 8. (b) | 9. (b) | 10. (d) |
| 11. (a) | 12. (d) | 13. (d) | 14. (b) | 15. (b) |
| 16. (b) | 17. (c) | 18. (b) | 19. (d) | 20. (c) |
| 21. (c) | 22. (d) | 23. (d) | 24. (a) | 25. (b) |
| 26. (b) | 27. (b) | 28. (d) | 29. (a) | 30. (a) |
| 31. (a) | 32. (d) | 33. (b) | 34. (b) | 35. (c) |
| 36. (a) | 37. (c) | 38. (a) | 39. (d) | 40. (b) |
| 41. (a) | 42. (d) | 43. (a) | 44. (b) | 45. (b) |
| 46. (d) | 47. (d) | 48. (c) | 49. (d) | 50. (c) |
| 51. (b) | 52. (c) | 53. (d) | 54. (c) | 55. (c) |
| 56. (d) | 57. (c) | 58. (b) | 59. (c) | 60. (a) |

Explanations

1. (c)

A fuel cell is a device that converts chemical potential energy (energy stored in molecular bonds) into electrical energy. A fuel cell uses hydrogen gas (H_2) and oxygen gas (O_2) as fuel. The products of the reaction in the cell are water, electricity, and heat.

4. (a)

Solar cells, also called photovoltaic (PV) cells convert sunlight directly into electricity. It generates direct current. To operate electrical appliances, the inverters are used to convert DC power into AC power.

5. (c)

Biogas is a type of biofuel that is naturally produced from the decomposition of organic waste. When organic matter, such as food scraps and animal waste, break down in an anaerobic environment (an environment absent of oxygen) they release a blend of gases, primarily methane and carbon dioxide. Because this decomposition happens in an anaerobic environment, the process of producing biogas is also known as anaerobic digestion.

9. (b)

Biomass power plants provide electricity as well as manure which can be used in agriculture.

15. (b)

Very little maintenance is required to keep solar cell running as there are no moving parts in it.

17. (c)

- Solar constant is the total radiation energy received on the earth from the Sun per unit time per unit of area on a theoretical surface perpendicular to the Sun's rays. It is most accurately measured from satellites where atmospheric effects are absent.
- The value of the constant is approximately 1.366 kilowatts per square metre.

24. (a)

Compressed Natural gas is primarily composed of methane, but it also contains ethane, propane, small amounts of nitrogen, carbon dioxide, hydrogen sulphide and trace amounts of water.