ENERGY ECONOMICS

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Writing *Energy Economics* aims to simplify key concepts such as energy demand, supply, pricing, market equilibrium, and sustainability for students, providing a strong foundation in the study of energy and its economic significance. Energy Economics is essential for understanding how individuals, industries, and governments make decisions about energy production and consumption, and how these choices impact growth and the environment. This book presents concepts in a clear and engaging manner, emphasizing their practical relevance. Through illustrations, review questions, and exercises, it bridges theory with real-world applications, helping students develop analytical and decision-making skills vital for academic and professional success.

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PREFACE

It gives me immense pleasure to present *Energy Economics*, my first endeavor in this specialized field of study. This book is designed to provide undergraduate and postgraduate students with a clear and comprehensive understanding of the fundamental concepts of energy economics.

Energy Economics is an emerging and dynamic branch of economics that examines how energy resources are produced, priced, distributed, and utilized within an economy. With this in mind, I have aimed to create a text that is both accessible and informative, enabling learners to explore the intricate relationship between energy, environment, and economic growth.

The content of this book is organized in a systematic and progressive manner, beginning with the basic principles of energy demand and supply, and advancing to topics such as energy pricing, market structure, policy framework, and sustainability. Each chapter includes conceptual discussions, practical examples, case studies, and review exercises to promote better understanding and application.

This book is the outcome of dedicated effort and valuable guidance from mentors, colleagues, and students who have continually encouraged me in this academic journey. I also extend my sincere thanks to my co-authors, whose knowledge and insights have enriched the content of this work.

I hope this book will serve as a useful resource for students, teachers, and researchers in the field of economics and energy studies. Constructive suggestions and feedback are most welcome to help improve future editions and make this work more valuable to the academic community.

Dr.Suvarna Raagavendaran

ENERGY ECONOMICS

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UNIT -1

ENERGY RESOURCES

Introduction

Energy issues have been analysed from an economic perspective for more than a century now. But energy economics did not develop as a specialised branch until the first oil shock in the 1970s (Edwards 2003). The dramatic increase in oil prices in the 1973–1974 highlighted the importance of energy in economic development of countries. Like any branch of economics, energy economics is concerned with the basic economic issue of allocating scarce resources in the economy. Thus, the microeconomic concerns of energy supply and demand and the macro-economic concerns of investment, financing and economic linkages with the rest of the economy form an essential part of the subject.

The reasons for bringing out the importance of energy economics are

1. The **first oil shock** occurred in **1973–1974** and was triggered by the **Yom Kippur War**. In response to Western support for Israel, the **Organization of Arab Petroleum Exporting Countries (OAPEC)**, led by **Saudi Arabia**, imposed an **oil embargo** on the U.S. and other allies of Israel.

Key effects:

- Oil prices quadrupled, from around $3 to nearly $12 per barrel.
- Led to global inflation, recession, and energy crises in many countries.
- Prompted fuel shortages, long lines at gas stations, and government rationing in the West.

- Marked the end of cheap oil and began a shift toward energy conservation and alternative energy research.

2. 1980s. Environmental concerns of energy use and economic development became a major concern and the environmental dimension dominated the policy debate.
    a. **Acid rain**, **air pollution**, and **nuclear accidents** (like the **Chernobyl disaster** in 1986) highlighted the environmental risks of fossil fuels and nuclear energy.
    b. **Chernobyl Nuclear Power Plant** near **Pripyat**, in the former **Soviet Union** (now Ukraine). was a catastrophic nuclear accident that occurred on **April 26, 1986**
    c. The **Brundtland Report** (1987) (was published by the **World Commission on Environment and Development (WCED)**, chaired by **Gro Harlem Brundtland**, the former Prime Minister of Norway.) introduced the idea of meeting "the needs of the present without compromising the ability of future generations to meet their own needs."
3. In the 1990s, liberalisation of energy markets and restructuring swept through the entire world although climate change and other global and local environmental issues also continued
4. In 2000s The Kyoto Protocol (effective 2005) pressured nations to reduce greenhouse gas emissions

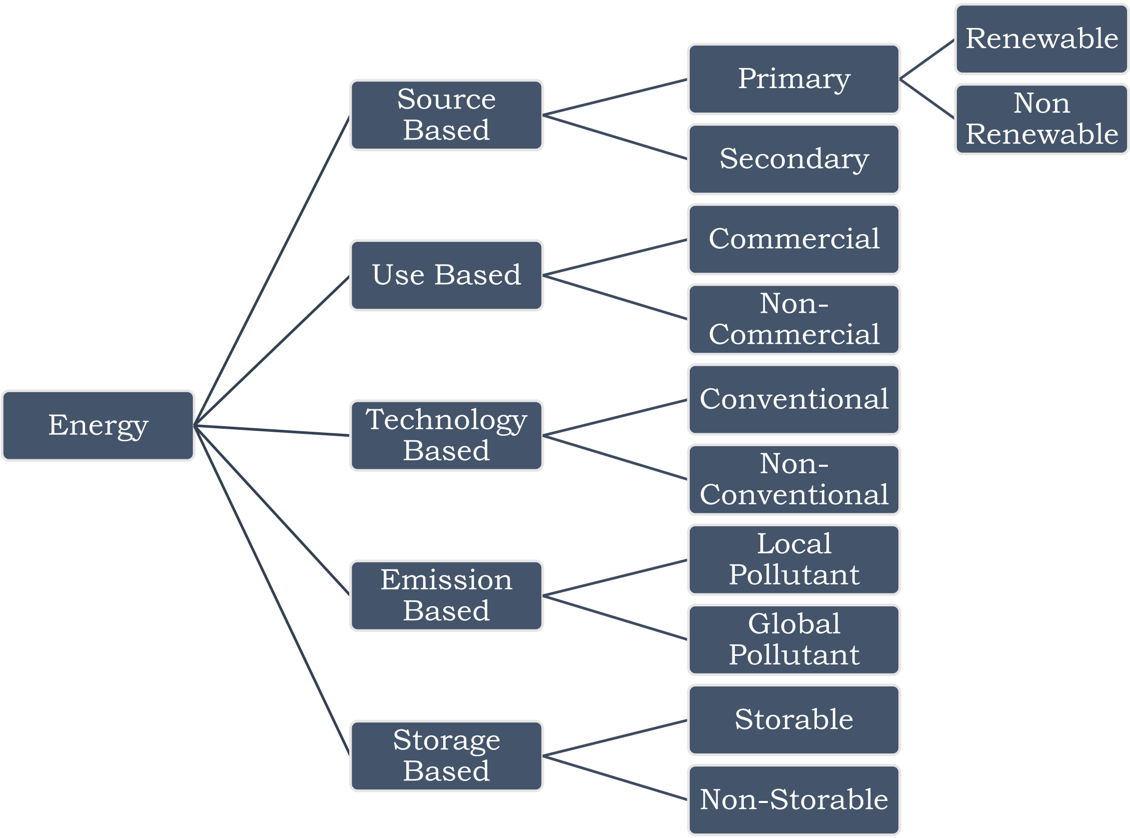
Definitions

Paul Stevens, professor of Oxford Institute of Energy Studies in 2000 defines energy economics as "the study of human utilization of energy resources and commodities and the consequences of that utilization.'

David Newbery, Professor Emeritus, University of Cambridge — a leading energy economist and policy advisor defined energy economics as **"Energy economics is the study of how scarce energy resources are allocated over time and space, how markets for energy operate, and how public policy can be used to improve economic efficiency and address environmental externalities."**

Classification of Energy Resources

Energy resources can be classified on the basis of source, usage, technology, emissions, and storability. Each type of classification has its own significance in economics and policy-making.



A. Source-based Classification

1. **Primary Energy:** Primary energy refers to energy that is directly extracted or captured from natural resources, without undergoing any transformation except basic processes such as separation or cleaning. Examples of primary energy include coal, crude oil, natural gas, solar energy, and wind energy.
   - **Renewable Energy:** Renewable energy comes from resources that are naturally replenished and are available in an infinite flow. Examples are solar energy, wind energy, hydro power, and biomass when used sustainably.
   - **Non-renewable Energy:** Non-renewable energy is obtained from resources that exist in a finite stock and are depleted once used. Examples include coal, petroleum, and natural gas.
2. **Secondary Energy:** Secondary energy is derived by converting or transforming primary energy into another usable form. For example, electricity generated from coal or petroleum products refined from crude oil.

   Important Note:
   - Electricity and heat may be considered as both primary and secondary energy depending on the context.
   - Fuelwood can be either renewable or non-renewable depending on whether it is collected sustainably or unsustainably.

B. Use-based Classification Commercial Energy: Commercial energy refers to energy that is bought and sold in the market at a specific price. Examples include coal, oil, natural gas, and electricity.

1. **Non-commercial Energy:** Non-commercial energy refers to energy that is not traded in the market and therefore has no specific price. Examples include fuelwood collected from forests, agricultural waste, or animal dung cakes used in rural households.

   <u>Important Note</u>: Whether a particular source of energy is treated as commercial or non-commercial depends upon the location, community, and the period of time. For example, fuelwood may be commercial in urban areas but non-commercial in rural settings.

C. Technology-based Classification

1. **Conventional Energy:** Conventional energy refers to energy harnessed using technologies that are well established and widely used. Examples include large hydro power projects and thermal power plants.
2. **Non-conventional Energy:** Non-conventional energy refers to energy harnessed using relatively new, innovative, and less commonly used technologies. Examples include tidal energy, ocean thermal energy, and wind-solar hybrid systems.

   <u>Important Note</u>: This distinction is somewhat ambiguous, because many sources of energy that were once non-conventional, such as solar or wind, have gradually become conventional as technology has developed and adoption has increased.

D. Emission-based Classification

1. **Local Pollutants:** Local pollutants are those whose harmful effects are felt mainly in the vicinity of the source of emission. Examples include sulphur dioxide and particulate matter. These are largely considered local or national problems.
2. **Global Pollutants:** Global pollutants are those that spread evenly in the atmosphere and have harmful impacts regardless of the place where they are released. Examples include carbon dioxide and other greenhouse gases, which are responsible for climate change.

   Illustrations:

   - Burning of biomass produces high levels of local pollution.
   - Burning of natural gas produces relatively less local pollution.
   - Coal-based power generation contributes heavily to global pollution through greenhouse gas emissions.
   - Hydro power generation does not directly produce global pollutants.

E. Storage-based Classification

1. **Storable Energy:** Storable energy refers to forms of energy that can be stored in physical commodity form for future use. Examples include coal, crude oil, petroleum products, and natural gas.
2. **Non-storable Energy:** Non-storable energy refers to forms of energy that cannot be stored in physical form and must be used as soon as they are produced. The most common example is electricity.

Energy Measurement

In the study of energy economics, it is important not only to classify energy but also to measure it in a way that allows comparison and aggregation. Different forms of energy are available in different physical units, such as kilowatt-hours of electricity, litres of petrol, or kilograms of LPG. To understand the overall demand and supply of energy, these diverse forms must be expressed in comparable units.

For example, an average American consumes around one gallon of petrol per day for automobiles, whereas an average Indian consumes only about 0.05 litre per day. Without converting these into common units, it is difficult to say who consumes more and by how much.

Differences in Units of Measurement

Different fuels are measured in different physical units, which makes direct comparison difficult.

- Coal is usually measured in tonnes.
- Natural gas is measured in cubic metres or kilograms.
- Electricity is measured in kilowatt-hours (kWh).
- Oil is measured in barrels or litres.

Moreover, the units may vary across geographical regions. For instance, the measurement of oil in barrels in the United States may differ in conversion from litres or gallons used elsewhere. Hence, there is a need for standardisation and conversion to common units for aggregation.

Scientific Units of Energy

Scientific units provide exact definitions based on physics and thermodynamics.

- **Calorie (cal):** The amount of heat required to raise the temperature of 1 gram of water by 1°C.
- **British Thermal Unit (Btu):** Equivalent to the calorie but in the British system, defined as heat per pound per degree Fahrenheit.
- **Joule (J):** The standard unit of energy in the metric system.
- **Kilowatt-hour (kWh):** A widely used standard unit for electricity production and consumption.

Some important conversions are:

- 1 calorie = 4.184 joules (approx).
- 1 Btu ≈ 1055 joules.
- 1 kilowatt-hour = 3.6×10^6 joules = 3412 Btu ≈ 860 kilocalories.

These scientific units are essential for precision in research and policy analysis.

Commercial Units of Energy

Commercial units are those used in trade and everyday practice to indicate physical quantities of fuels.

- 1 short ton = 2000 pounds.
- 1 metric tonne = 1000 kilograms.
- 1 barrel of oil = 42 US gallons = 159 litres.
- 1 barrel of crude oil ≈ 0.136 tonne.

Some common conversions:

- 1 US gallon = 3.785 litres.
- 1 UK gallon = 4.546 litres.
- 1 cubic foot = 0.0283 cubic metres.
- 1 tonne ≈ 7.33 barrels of oil.

Heat Content of Fuels

Different fuels contain different amounts of heat energy per unit of weight or volume. Approximate values include:

- Semi-anthracite coal: 7000 kcal/kg.
- Coking coal: 6000 kcal/kg.
- Sub-bituminous coal: 5800 kcal/kg.
- Crude oil: 1×10^7 kcal/tonne.
- Petrol: 1.1×10^7 kcal/tonne.
- LPG: 1.2×10^7 kcal/tonne.
- Electricity: 860 kcal/kWh.
- Natural gas: 39 MJ/m^3.

Note: Fuels such as petrol and LPG consist of mixtures of compounds, so actual values may vary with quality.

Conversion to Tonnes of Oil Equivalent (toe)

To compare energy across different fuels, all sources are often converted to a common unit known as **tonne of oil equivalent (toe)**.

- If *X* tonnes of coal produce the same amount of energy as 1 tonne of oil, then *X* tonnes of coal are considered equivalent to 1 toe.

Standard values:

- According to OECD/IEA:
  - 1 toe = 1.00×10^{10} calories = 41.868 gigajoules (GJ) = 39.68 million Btu (IT basis).
- Alternative definition:
  - 1 toe = 1.07×10^{10} calories = 44.769 GJ = 42.46 million Btu (thermochemical basis).

This conversion allows aggregation of different fuels into one comparable unit for international energy statistics.

Measurement of Emissions

The measurement of energy use is also linked with emission of pollutants, especially carbon dioxide (CO_2). The amount of CO_2 emitted depends on the carbon content of the fuel.

Approximate emissions in pounds of CO_2 per million Btu are:

- Coal (anthracite): 228.6 lbs.
- Coal (bituminous): 205.7 lbs.
- Coal (lignite): 215.4 lbs.
- Diesel fuel and heating oil: 161.3 lbs.
- Petrol (without ethanol): 157.2 lbs.
- Propane: 139.0 lbs.
- Natural gas: 117.0 lbs.

Thus, natural gas is considered a cleaner fuel compared to coal in terms of carbon dioxide emissions.

Energy Accounting

Energy accounting is a framework that helps track the flow of energy from supply sources to end-use. It includes the processes of energy transformation and conversion. The main methods used are Energy Balance Tables, Sankey (Flow) Diagrams, and Reference Energy Systems.

International Recommendations on Energy Statistics (IRES) standardise the format of Energy Balance to ensure uniformity. In such a table, **columns** represent types of energy, while **rows** represent production, transformation, and consumption.

Commercial energy is usually well-documented, while data for non-commercial sources (like firewood or dung) is often lacking. Sometimes, "energy accounting" is also used to describe record keeping of energy consumption and costs at individual, organisational, or regional levels.

Components of Energy Balance

There are three key components in an Energy Balance:

1. **Supply**
    - Domestic production is recorded as (+).
    - Imports are (+) while exports are (–).
    - Bunker fuels used for international transport are (–).
    - Changes in stock (strategic reserves) can be (+) or (–), depending on whether fuel stock increases or decreases.
2. **Conversion/Transformation**
    - Primary energy (like coal, crude oil, natural gas) is converted into secondary energy (like electricity or refined petroleum products).
    - Inputs are shown as (–), while outputs are shown as (+).
    - The energy industry's own use and transmission/distribution losses are also included here.
3. **Demand**
    - Final energy consumption by end-use sectors such as agriculture, industry, transport, and households is shown as (+).
    - Non-energy use (like natural gas used as feedstock in fertiliser) is also included.

Energy accounting is essential for several reasons, including:

1. **Saving costs:** By tracking and measuring energy usage, businesses can identify where there is energy wastage and enforce measures to decrease consumption. *Save more money by doing this!*

2. **Enhanced energy efficiency:** Energy accounting helps organizations understand energy consumption patterns, spot inefficiency areas, and implement strategies to boost all-around energy efficiency.
3. **Reduced carbon footprint:** Energy accounting helps organizations reduce their carbon footprint by recognizing ways to reduce energy consumption and shift towards more sustainable energy sources.
4. **Compliance:** Since companies need to track and report energy usage, energy accounting can help them to meet these requirements and avoid penalties.
5. **Transparency and accountability:** Energy accounting provides organizations with energy consumption data and insights on how to improve operations, track their progress, and set energy reduction targets, leading to transparency and accountability.
6. **Sustainability:** Energy accounting is vital for organizations to implement *sustainable energy management practices*, which reduce their environmental impact and contributes to a more sustainable future.

Different types of energy accounting

There are several different types of energy accounting, including:

- **Building energy accounting** involves measuring and handling building energy consumption. This includes commercial, residential, retail, and industrial buildings. In addition, building energy accounting monitors heating and cooling systems (such as HVAC), lighting, and appliances.

- **Industrial energy accounting** focuses on measuring and managing energy consumption in *industrial environments*, such as manufacturing plants and mines. This includes overseeing energy consumption in specific industrial processes and their respective equipment.
- **Energy accounting for transportation** deals with the energy consumption in transportation systems like cars, trucks, buses, and trains. This involves gauging fuel consumption, emissions, and other factors.
- **Energy accounting for renewable energy systems** handles energy consumption in renewable energy systems, such as solar, wind, and hydroelectric power. This process includes surveying energy generation, consumption, and renewable energy systems efficiency.
- **Energy accounting for the grid** measures and manages grid energy consumption like electricity transmission and distribution. This includes energy generation monitoring, consumption, and the efficiency of the grid.
- **Energy accounting for carbon:** focuses on carbon emissions and includes implementing strategies to reduce emissions, such as *carbon offsetting and carbon credits*.

Energy accounting process

The energy accounting process is the organized and systematic approach to tracking, measuring, and analyzing energy usage within a particular system or organization.

The energy accounting process commonly involves six steps:

Step 1: Collecting data

The first step includes measuring the energy consumption for different systems and equipment, such as lighting, heating, cooling, and appliances. This data is collected using energy meters, building automation systems (BAS), building management systems (BMS), or energy management software.

Step 2: Energy consumption analysis

After data collection, it needs to be analyzed to determine energy consumption patterns, identify areas of inefficiency, and gauge the potential for energy conservation. This includes creating energy consumption profiles, identifying peak energy usage times, and likening energy consumption data to industry standards.

Step 3: Identifying energy conservation opportunities

This step includes identifying systems or equipment that consume more energy than necessary, identifying areas of energy wastage, and determining opportunities to shift to more energy-efficient methods and equipment.

Step 4: Implementation of energy conservation measures

The next step is to implement energy conservation measures. This includes upgrading equipment, installing energy-efficient lighting, implementing energy-efficient building practices, and executing a comprehensive *energy management program.*

Step 5: Monitoring and reporting

The final step involves monitoring and reporting on energy consumption, energy conservation measures, and their efficacy. This includes creating regular energy consumption reports, conducting energy audits, and monitoring energy consumption over time to identify trends and areas where further conservation measures are needed.

Step 6: Continuous improvement

Energy accounting is a continuous process. Therefore, it is essential to regularly repeat it and ensure that the energy conservation measures implemented are still effective and that new opportunities are being identified and acted on.

Tools used for energy accounting

There are several tools that organizations can use during energy accounting, including:

- **Energy management software** helps organizations track and analyze energy consumption data in real-time. This includes energy consumption, identifying areas of inefficiency, and generating reports on energy usage and costs.
- **Energy audits** assess an organization's energy use, costs, and potential savings. These include thoroughly examining the energy systems and equipment, identifying energy-efficient opportunities, and recommending energy conservation measures.
- **Energy modeling software** simulates and predicts energy consumption and evaluates the energy efficiency of a building, process, or equipment.
- **Building automation systems (BAS)** allow for the remote monitoring and control of building systems, such as heating, ventilation, air conditioning (HVAC), lighting, and security.
- **Smart meters** measure and record energy consumption in real time and can communicate the data to the utility or energy management software.
- **Carbon accounting tools** help organizations measure and report on their carbon emissions, identify areas of high

emissions, track progress in reducing emissions and report to regulatory bodies or for sustainability reporting.

Benefits of energy accounting

Some of the benefits of energy accounting are as follows:

1. **Increased awareness:** Energy accounting helps raise awareness among employees, management, and stakeholders about energy consumption and costs. This leads to better decision-making and improved energy management.
2. **Improved asset management:** Energy accounting provides data on the energy consumption of specific systems and equipment. This information is used to optimize these assets' maintenance and replacement schedules, leading to more efficient and cost-effective management.
3. **Better budgeting:** Energy accounting provides a clear picture of energy costs. It helps organizations set realistic energy budgets and track actual energy costs against budget, which helps to identify areas of overspending and take corrective actions.
4. **Better negotiation of energy contracts:** Energy accounting provides data on energy consumption patterns and costs. This information is used to negotiate better energy contracts with suppliers, including arrangements for renewable energy sources.
5. **Improved communication and reporting:** Energy accounting provides data on energy consumption. You can use it to communicate energy performance to stakeholders, report on energy performance to regulatory bodies, and for sustainability reporting.

6. **Improved energy procurement:** Energy accounting helps organizations identify energy consumption patterns and costs. Use this to identify opportunities for energy procurement from more cost-effective and sustainable energy sources.
7. **Improved energy security:** Energy accounting helps organizations identify energy consumption patterns and costs. Leverage this to identify opportunities for energy procurement from more cost-effective and sustainable energy sources and to recognize opportunities for on-site energy generation.

Challenges and limitations of energy accounting

Energy accounting has some challenges and limitations that include:

Data accuracy: Energy accounting relies on accurate data, which can lead to incorrect conclusions and decision-making if inaccurate. Data accuracy is affected by various factors, such as meter and entry errors and inaccuracies in energy consumption data.

Difficulty in obtaining data : Collecting energy consumption data is difficult and time-consuming, especially in large organizations with multiple locations and various energy-consuming systems and equipment.

Limited understanding of energy accounting by management : Energy accounting is a complex process requiring expertise and knowledge, and if the administration of an organization needs to understand the process, it can be challenging to implement and maintain.

Implementation and maintenance costs : Energy accounting requires significant investment in time and money, including the cost of energy management software, energy audits, energy modeling, and building automation systems.

Data management and analysis : Energy accounting generates a large amount of data, requiring efficient data management and analysis. However, mishandling this leads to information overload and difficulty extracting actionable insights.

Resistance to change : Energy accounting can reveal areas of inefficiency, and it also requires significant changes to systems and processes. If employees or management are resistant to change, it can be challenging to implement energy conservation measures.

Data privacy and security : Energy accounting sometimes requires collecting sensitive data, such as data on the energy consumption of individual buildings or equipment. That's why it is vital to ensure that this data is protected from unauthorized access and misuse.

Table-I: Energy Balance of India for 2020-21 (Final)

All figures in KToE

	Coal #	**Crude Oil**	**Oil Products**	**Natural Gas**	**Nuclear**	**Hydro**	**Solar, Wind, Others**	**Electricity**	**Total**
Production	297,775	31,165	0	26,522	11,214	12,955	13,279	0	392,909
Imports	115,541	200,783	42,915	30,554	0	0	0	821	390,614
Exports	-2,026	0	-59,090	0	0	0	0	-823	-61,939
Stock changes	11,521	0	0	0	0	0	0	0	11,521
Total primary energy supply	**422,811**	**231,947**	**-16,174**	**57,076**	**11,214**	**12,955**	**13,279**	**-2**	**733,105**
Statistical differences	-6,473	18,012	-23,136	194	0	0	0	-1,285	-12,687
Main activity producer electricity plants	-243,521	0	-769	-10,023	-11,214	-12,926	-12,663	118,094	-173,021
Autoproducer electricity plants	0	0	0	0	0	-29	-616	19,335	18,690
Oil refineries	0	-226,652	237,827	0	0	0	0	0	11,175
Energy industry own use	0	0	0	-16,844	0	0	0	-6,921	-23,765

Losses	0	-23,308	0	-62	0	0	0	-23,424	-46,794
Final consumption	**172,818**	**0**	**197,748**	**30,341**	**0**	**0**	**0**	**105,798**	**506,704**
Industry	**172,818**	**0**	**47,051**	**513**	**0**	**0**	**0**	**43,755**	**264,137**
Iron and steel	36,805	0	984	0	0	0	0	0	37,790
Chemical and petrochemical	806	0	12,923	0	0	0	0	0	13,729
Non-ferrous metals	0	0	348	0	0	0	0	0	348
Machinery	0	0	149	0	0	0	0	0	149
Mining and quarrying	0	0	1,792	0	0	0	0	0	1,792
Paper, pulp and print	680	0	0	0	0	0	0	0	680
Construction	3,860	0	1,256	0	0	0	0	0	5,116
Textile and leather	108	0	57	0	0	0	0	0	165
Non-specified (industry)	130,558	0	29,542	513	0	0	0	43,755	204,368
Transport	**0**	**0**	**38,331**	**8,944**	**0**	**0**	**0**	**1,261**	**48,537**
Road	0	0	31,608	8,538	0	0	0	0	40,146
Domestic aviation	0	0	3,941	0	0	0	0	0	3,941
Rail	0	0	1,264	0	0	0	0	1,261	2,526
Pipeline transport	0	0	0	406	0	0	0	0	406
Domestic navigation	0	0	1,517	0	0	0	0	0	1,517
Non-specified (transport)	0	0	0	0	0	0	0	0	0
Other	**0**	**0**	**112,365**	**996**	**0**	**0**	**0**	**60,782**	**174,143**
Residential	0	0	29,963	0	0	0	0	28,450	58,413
Commercial and public services	0	0	68	0	0	0	0	7,478	7,546
Agriculture/forestry	0	0	719	164	0	0	0	19,032	19,915
Non-specified (other)	0	0	81,615	832	0	0	0	5,822	88,269
Non-energy use	**0**	**0**	**0**	**19,887**	**0**	**0**	**0**	**0**	**19,887**
Non-energy use industry/transformation/energy	0	0	0	19,887	0	0	0	0	19,887
Non-energy use in transport	0	0	0	0	0	0	0	0	0
Non-energy use in other	0	0	0	0	0	0	0	0	0
Elect. output in GWh	**0**	**0**	**0**	**0**	**43,029**	**150,639**	**154,405**	**0**	**348,073**
Elec output-main activity producer ele plants	0	0	0	0	43,029	150,300	147,248	0	340,576
Elec output-autoproducer electricity plants	0	0	0	0	0	339	7,158	0	7,497

Final consumption refers to End Use Consumption									
# Includes lignite									

- ✓ Provides a **comprehensive overview** of a country's energy profile, including supply and consumption.
- ✓ Helps derive indicators for **energy security, market analysis, emissions, and renewable share**.
- ✓ Enables comparison across countries and over time.
- ✓ Disaggregated data helps identify **major energy sources and key consumer sectors**, guiding policy interventions.
- ✓ In India, the **Central Statistical Organisation (MoSPI)** publishes Energy Statistics annually.

Energy and Environmental Sustainability

On 25th September 2015, during its 70th Session, the United Nations (UN) General Assembly adopted the document titled *"Transforming Our World: The 2030 Agenda for Sustainable Development."* This agenda consists of 17 Sustainable Development Goals (SDGs) and 169 associated targets. The SDGs represent a comprehensive set of global goals that integrate the social, economic, and environmental dimensions of development. Recognising that energy is critical for people who are deprived of access to sustainable energy, **Goal 7** was adopted with the objective of ensuring access to affordable, reliable, sustainable, and modern energy for all. This goal emphasises the need to expand access to clean and safe cooking fuels and technologies, enhance energy efficiency, promote renewable energy sources, and encourage sustainable and modern energy solutions. Renewable resources such as wind, water, solar, biomass, and geothermal energy are highlighted as being inexhaustible and clean alternatives.

The specific targets under **Goal 7 of the SDGs (2030 Agenda)** are as follows:

1. By 2030, ensure universal access to affordable, reliable, and modern energy services.
2. By 2030, substantially increase the share of renewable energy in the global energy mix.
3. By 2030, double the global rate of improvement in energy efficiency.
4. By 2030, strengthen international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency, and advanced cleaner fossil-fuel technologies, and promote investment in energy infrastructure and clean energy technologies.
5. By 2030, expand infrastructure and upgrade technology to provide modern and sustainable energy services in developing countries, particularly in least developed countries, small island developing states, and land-locked developing countries, in line with their respective programmes of support.

Metric	**Value / Achievement**
Households using clean fuel for cooking	63.4% of households use clean fuel for cooking.
Urban vs Rural clean cooking usage	Urban: 92.9% households use clean fuel; Rural: ~ 49.5% households do so.

Metric	Value / Achievement
Relying on biomass for cooking	41% of the population still uses biomass (wood, cow dung, etc.) for cooking.
CO_2 emissions from biomass cooking	Biomass cooking in India emits about **340 million tonnes of CO_2** annually.
Non-fossil installed electricity capacity	India has reached **50% of its installed electricity capacity** from non-fossil fuel sources (renewables + nuclear + large hydro), ahead of its 2030 target under the Paris Agreement.
Installed renewable energy capacity	**198,213 MW** installed renewable energy capacity by 2024.
Electricity from renewables (generation)	Renewable electricity generation rose from 205,608 GWh in 2014-15 to 370,320 GWh in 2023-24.
Per capita energy consumption	18,410 MJ per person.

Case Study

A household uses the following electrical appliances in one day:

- 2 LED bulbs (10 watts each) used for 5 hours
- 1 fan (60 watts) used for 8 hours
- 1 refrigerator (150 watts) running for 24 hours

Calculate the total energy consumed in kilowatt-hours (kWh) for that day.

Step-by-step Solution:

1. LED Bulbs:

- Power = 10 watts × 2 bulbs = 20 watts = 0.020 kW
- Time = 5 hours
- Energy = Power × Time = 0.020 kW × 5 h = **0.1 kWh**

2. Fan:

- Power = 60 watts = 0.060 kW
- Time = 8 hours
- Energy = 0.060 kW × 8 h = **0.48 kWh**

3. Refrigerator:

- Power = 150 watts = 0.150 kW

Time = 24 hours

- An Indian consumes only **0.05 litres** per day.

From this comparison, it is clear that petrol consumption is highest in Britain, followed by the United States, while Indian consumption is very small in comparison.

Exercise: Collect data on per capita average petrol or diesel consumption for private automobiles across different countries and prepare a ranking.

Problem 3: Impact of Carbon Tax on Petrol

Carbon content of petrol is about **0.64 kg of carbon per litre**. If a carbon tax of ₹1750 per tonne of CO_2 is imposed in the country, the question is: what additional cost will a consumer pay per litre of petrol?

- Carbon content in 1 litre petrol = 0.64 kg.
- CO_2 emission per litre petrol = (0.64 × 44) / 12 = **2.3467 kg of CO_2**.
- Carbon tax per kg of CO_2 = ₹1750 ÷ 1000 = **₹1.75**.
- Carbon tax for 2.3467 kg of CO_2 = 2.3467 × 1.75 = **₹4.11 per litre**.

Thus, every consumer will pay an additional **₹4.11 per litre** of petrol as carbon tax.

Exercise: Read more about the concept of carbon tax. Reflect on whether such a tax would encourage a shift from private transport to public transport in India.

Exercises: Energy Balance of India (2013–14)

Using the provisional Energy Balance of India (2013–14) published by the Ministry of Statistics and Programme Implementation, students are asked to explore the following questions:

1. Was there an increase in the coal stock maintained in India in 2013–14 compared to the previous year?
2. What does the figure **2,21,013 ktoe** (in the balance sheet cell D16) represent?
3. What was the direct coal consumption of the residential sector?
4. How much natural gas was used to produce electricity, and can it be converted into billion cubic metres?

What was the proportional distribution of final energy consumption among the major sectors—agriculture and forestry, industry, transport, residential, and others?

Conclusion

Energy economics has evolved as a vital discipline linking economic growth, resource management, and environmental sustainability. From the oil shocks of the 1970s to the current global climate commitments, energy has remained central to policy debates, industrial development, and social welfare. The study of energy economics involves analysing how scarce energy resources are produced, distributed, and consumed efficiently while minimising environmental externalities. Proper classification and measurement of energy enable better comparison and policy formulation, while energy accounting provides a systematic approach to monitoring energy use, enhancing efficiency, and reducing emissions. As countries strive to achieve Sustainable Development Goal 7—ensuring access to affordable, reliable, sustainable, and modern energy for all—energy accounting and management practices have become essential tools for economic planning, energy security, and global sustainability.

Questions for Practice

Section – A

1. Define energy as a resource.
2. What are renewable and non-renewable energy resources?
3. State the importance of energy in economic development.
4. Write a short note on energy accounting.
5. Mention examples of commercial and non-commercial energy resources.
6. Define energy measurement and list various units of energy.
7. Explain "Primary" and "Secondary" energy sources.
8. What is energy conservation?
9. Why is energy accounting essential?
10. List tools of energy accounting.

Section B

1. Explain classification of energy resources.
2. Discuss methods of energy measurement.
3. Elucidate importance, benefits, and challenges of energy accounting.
4. Calculate daily energy use (numerical).

5. Explain management of energy resources and sustainability roles.
6. Differentiate renewable and non-renewable sources.

Section – c

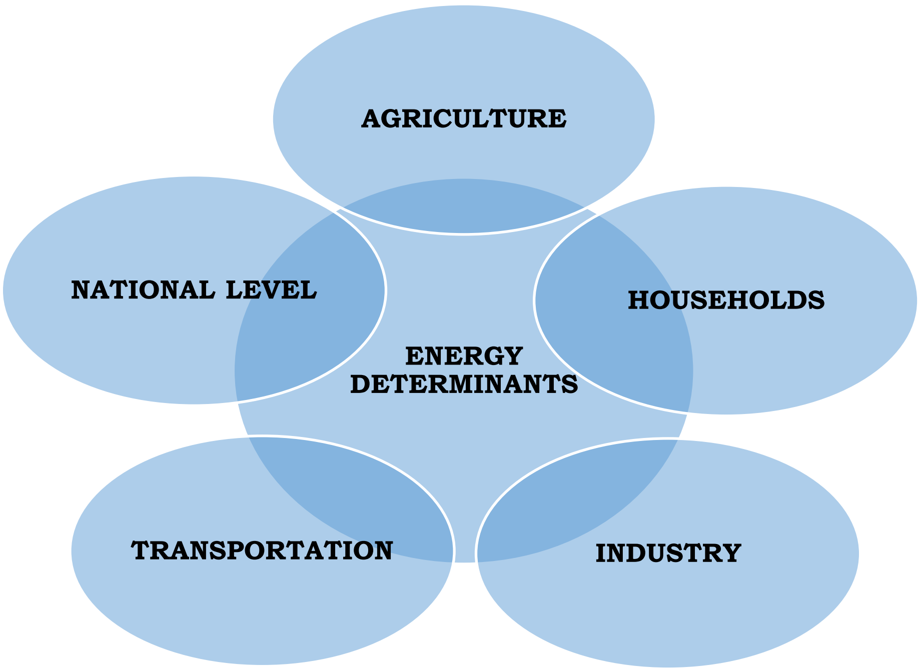
1. Evaluate challenges and opportunities in renewable energy.
2. Explain types and pros/cons of energy accounting.
3. Calculate total household/hostel energy consumption (numerical).
4. Analyze sustainability and role of stakeholders.

UNIT – II

ENERGY DEMAND AND SUPPLY

Energy demand is the term used to describe the consumption of energy by human activity. It drives the whole energy system, influencing the total amount of energy used; the location of, and types of fuel used in the energy supply system; and the characteristics of the end use technologies that consume energy.

ENERGY DETERMINANTS



Energy Demand Determinants in Agriculture

Energy demand in agriculture refers to the amount and type of energy required for carrying out different farming activities such as land preparation, irrigation, sowing, harvesting, post-harvest management, and transportation. The demand for energy in this sector is influenced by a wide range of economic, technological, environmental, and social factors. A detailed discussion of the major determinants is provided below.

1. Size and Intensity of Agricultural Land Use : The energy requirement in agriculture is directly related to the size of land holdings and the intensity of cultivation. Larger farms and farms with multiple cropping cycles require more energy for tillage, irrigation, mechanised sowing, fertiliser application, and harvesting. In contrast, small and subsistence farms usually demand less energy as they rely more on manual labour and traditional methods.

2. Level of Mechanisation: The extent of mechanisation is a crucial determinant of energy demand. Modern agriculture that uses tractors, combine harvesters, threshers, and other machinery requires significant amounts of diesel, electricity, and lubricants. On the other hand, traditional agriculture that depends on human labour and draught animals requires comparatively less commercial energy but more manual effort. Thus, the transition from traditional to mechanised farming significantly increases energy consumption.

3. Irrigation Requirements: Irrigation is one of the most energy-intensive activities in agriculture. The demand for electricity and diesel to operate pumps and tube wells depends on factors such as rainfall availability, type of crop, soil characteristics, and water table depth. Regions dependent on groundwater irrigation show higher energy demand compared to areas with adequate rainfall or canal irrigation facilities.

4. Type of Crops Grown: Different crops have varying energy requirements. For instance, paddy cultivation requires continuous irrigation and therefore consumes more energy, whereas millets and pulses, which are largely rainfed, require relatively less energy. High-yielding varieties of crops also demand more fertilisers, irrigation, and mechanisation, thereby increasing energy consumption.

5. Fertiliser and Pesticide Usage : Chemical fertilisers and pesticides are energy-intensive to manufacture and apply. The use of nitrogenous fertilisers, in particular, contributes significantly to energy demand. A higher level of input-intensive agriculture increases overall energy requirements both directly (for application through machinery) and indirectly (embedded energy in fertiliser production).

6. Climatic and Environmental Conditions : Climatic factors such as rainfall patterns, temperature variations, and frequency of droughts or floods influence the level of irrigation and mechanisation required, thereby affecting energy demand. In dry and arid regions, more energy is required for irrigation, while in fertile and high-rainfall regions, energy demand may be lower.

7. Socio-economic Factors: The socio-economic condition of farmers, including income levels, access to credit, and government subsidies, plays an important role in determining the level of energy demand. Farmers with higher income and better access to institutional credit are more likely to invest in energy-intensive machinery and irrigation systems. Similarly, subsidies on electricity or diesel often led to higher energy consumption in agriculture.

8. Government Policies and Programmes: Energy demand is also shaped by agricultural and energy policies. Policies promoting mechanisation, minimum support prices (MSP), subsidies on irrigation pumps, or incentives for using solar pumps directly influence the type and amount of energy used in agriculture. On the other hand, policies promoting sustainable agriculture and energy efficiency may reduce unnecessary energy consumption.

Energy Demand Determinants in Households

a) Behavioural Dimensions: Energy consumption in households is influenced by behavioural patterns that vary across time, users, and locations.

- **Time Dimension:** Household energy consumption fluctuates across hours, days, months, and years, reflecting changing lifestyle needs and seasonal variations.
- **User Dimension:** The level of energy demand differs according to the type of user, whether it is an individual, a community, or even an entire country.
- **Spatial Dimension:** Energy demand patterns vary across physical locations, such as houses, buildings, cities, and nations, due to climatic conditions, infrastructure, and urbanisation levels.

b) Rational Choice Theory: According to rational choice theory, individuals act rationally by seeking to maximise utility while minimising cost. A well-informed consumer, once aware of the financial implications of energy use, is likely to reduce unnecessary consumption in order to save costs.

c) Income: Household income is a major determinant of energy demand. Higher-income households tend to consume more electricity and modern energy services. However, electricity is considered income inelastic, as it is a basic necessity consumed even by low-income households. Poorer households are more sensitive to changes in energy prices and often switch to alternatives such as firewood, charcoal, or kerosene when electricity prices increase.

d) Technology and Building Age: The age and efficiency of buildings play a significant role in determining energy demand. Older buildings generally lack energy-efficient technology and therefore consume more energy. In contrast, newly constructed buildings equipped with modern technologies require less energy for activities such as cooking, heating, and lighting. Retrofitting old structures with energy-efficient systems can significantly reduce household energy demand.

e) Age of Household Members: The age composition of a household affects its energy use. Young adults between 20 and 30 years often consume less energy due to simpler lifestyles and smaller homes. Energy consumption usually peaks between 30 and 50 years as family responsibilities grow and household size increases. After 50 years, energy use gradually declines, but it may rise again after 80 years due to health-related requirements and medical equipment needs.

Energy Demand Determinants in Industry

a) Energy Intensity: Energy intensity is defined as the amount of energy used per unit of production. Lower energy intensity reflects higher efficiency. Industries often invest in research and development to reduce energy intensity through improved technologies and production processes.

b) Technological Development: Technological advancement in machinery and processes can reduce the energy required for producing one unit of output. However, in many cases, new technology also enables large-scale production, which can lead to an overall increase in energy demand despite efficiency gains.

c) Product Demand: The demand for industrial products directly affects industrial energy consumption. When product demand rises, industries increase production, which leads to higher energy usage.

d) Government Policy and Environmental Regulations: Energy demand in industries is shaped by government policies and environmental regulations. Policies designed to reduce carbon emissions and promote efficiency encourage industries to adopt cleaner technologies. For example, in Greece between 1985 and 2003, industrial energy consumption declined due to the introduction of stricter policy measures.

Energy Demand Determinants in Transportation

a) Vehicle Ownership: The number of registered private vehicles in a country is one of the strongest indicators of transportation-related energy demand. A rise in private vehicle ownership increases the consumption of petrol and diesel.

b) Income Levels: Higher household incomes enable people to purchase private cars and to travel more frequently, including air travel, thereby raising energy demand. In contrast, lower-income groups rely more on public transport, which is more energy efficient on a per-person basis.

c) Car Prices: The affordability of cars affects transportation energy demand. Higher car prices discourage ownership, thereby reducing energy consumption, while lower car prices encourage more purchases and increase energy demand.

d) Electric Vehicles (EVs): The increasing popularity of electric vehicles reflects both cost efficiency and environmental concerns. While EVs reduce fossil fuel use, they create additional demand for electricity. However, petrol and diesel vehicles still dominate the market, which keeps overall energy demand high.

e) Public Transport Quality: The reliability and quality of public transport strongly influence energy use in transportation. When public transport systems are inefficient, people prefer private vehicles, which increases energy demand. Efficient and reliable public transport reduces the need for private vehicles and leads to lower energy use.

f) Public Transport Fare: Public transport demand is price elastic. If fares increase, people may switch to private transport, raising overall energy demand. Conversely, lower fares encourage greater use of public transport, which reduces per capita energy use even if total system energy use increases.

Energy Demand Determinants at the National Level

a) Population Size : Countries with large populations naturally require more energy to meet the needs of households, industries, and transportation. There is generally a direct positive relationship between population size and total energy demand.

b) Industrial Composition: The structure of a nation's economy influences its energy demand. Countries dominated by heavy industries such as steel and automobile production consume more energy, whereas countries with light industries like textiles have relatively lower energy requirements.

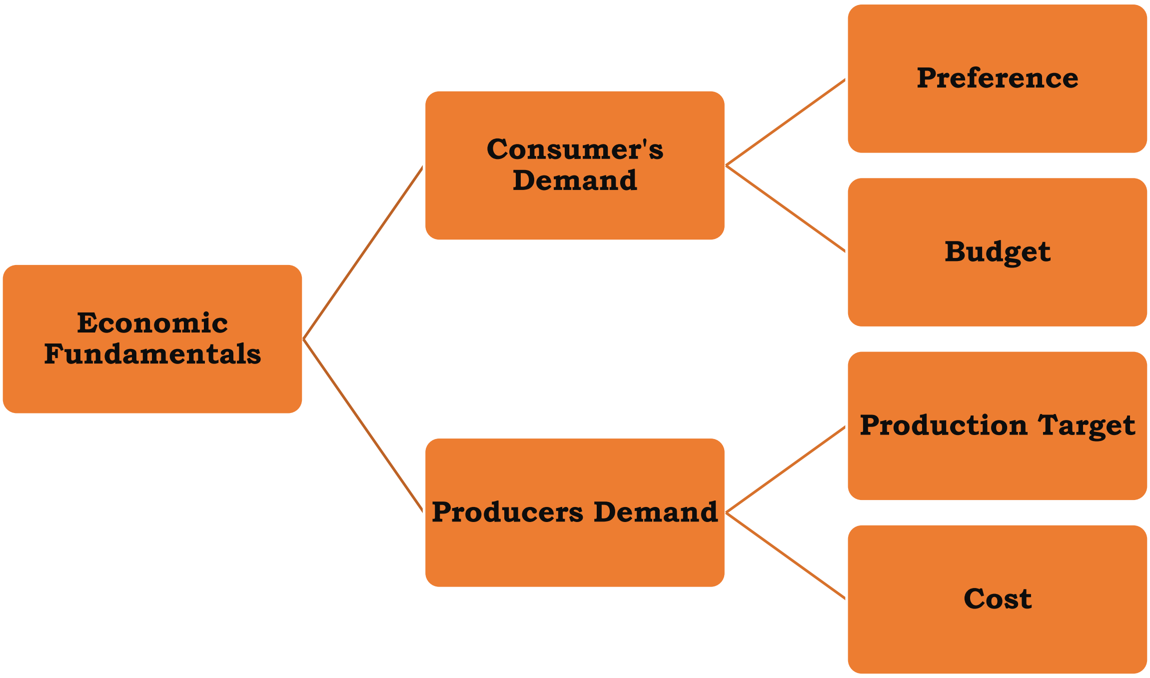
c) Level of Economic Development: Economic development strongly shapes energy demand. Developed countries usually show stable consumption patterns, whereas developing countries experience rapid increases in demand due to industrialisation and infrastructure expansion. China is a leading example where rapid development has resulted in massive growth in energy consumption.

d) Trade Openness: Trade policies also affect energy demand. Economies that are open to international trade attract foreign investment in industries, which raises production and energy use. Export-oriented economies require more energy compared to import-oriented economies that depend on foreign goods rather than local production.

e) Environmental Policies : International agreements such as the Kyoto Protocol and national environmental policies influence energy demand at the country level. Governments often impose fuel taxes, encourage the adoption of fuel-efficient vehicles, and promote renewable energy technologies. Concerns about pollution and climate change push countries to adopt cleaner and more sustainable energy sources.

Economic Foundations of Energy Demand

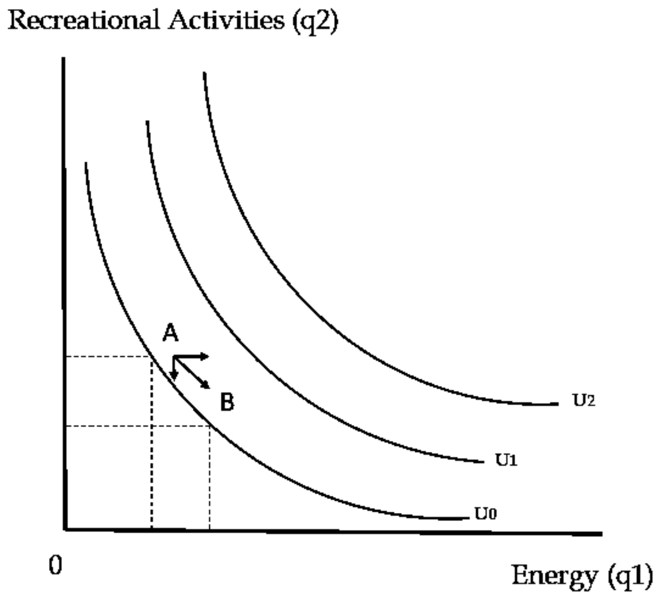
The economic principles for analyzing energy demand are like other commodities, but with specific considerations for energy markets.



Consumer's Demand

Consumers have limited **budget/income** but unlimited wants. Their main objective is to **maximise utility (satisfaction)** subject to the budget constraint. This can be illustrated using Indifference Curve.

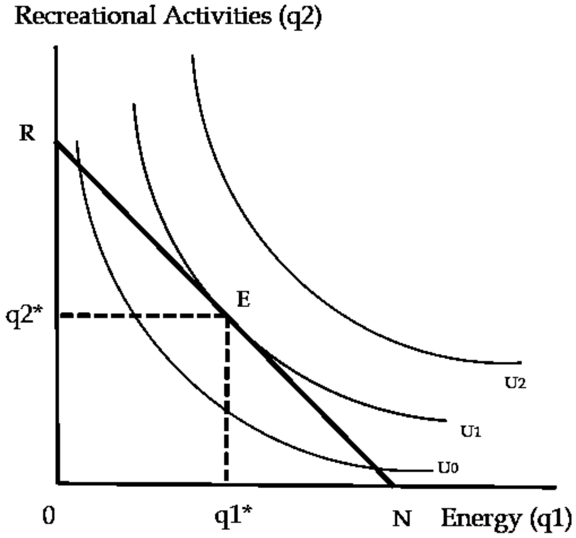
Indifference Curve: An indifference curve represents all combinations of two goods that provide the same level of satisfaction (utility) to consumers. From example if a consumer may have to compare energy and recreation. The Mathematical Representation would be $\mathbf{u=u(q_1,q_2)}$ where U is Utility q_1 is quantity of energy, $q_2$is recreation.



Properties of Indifference Curve : The Properties of Indifference curve are as follows

- They are continuous and smooth.
- They slope downwards because if you consume more of one good, you must consume less of the other to maintain the same utility.
- They are convex to the origin, showing diminishing Marginal Rate of Substitution (MRS). Marginal Rate of Substitution (MRS) means The amount of one good (say, recreation in our example) a consumer is willing to give up to gain an additional unit of another good (say, energy in our example), while keeping total satisfaction constant. It is the slope of the indifference curve.
- Higher indifference curves indicate higher satisfaction.

Budget Line: Budget line Represents all possible combinations of two goods that a consumer can afford given prices and income. The consumer preference and decision on a commodity purchase can be explained with budget line and indifference curve. Let us illustrate this by considering above example of energy and recreation.



Total money (M) is spent on two commodities: energy and recreational activities. Price of energy (q_1) is p_1 and that of recreational activities (q_2) is p_2. Budget line: $p_1q_1+p_2q_2=M$.

Slope of the budget line = $dq_2/dq_1= -p_1/p_2$

At N, $q_1= M/p_1$, $q_2=0$ (only energy)

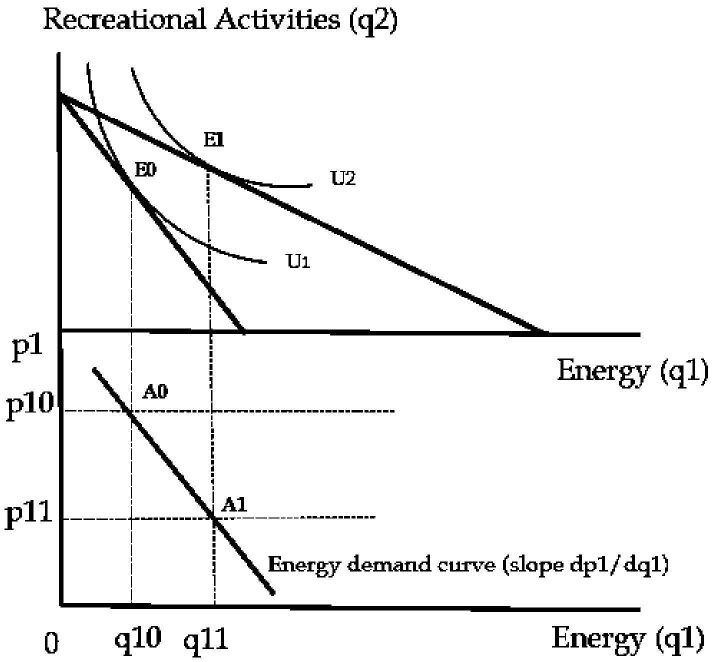
• At R, $q_1=0$, $q_2 = M/p_2$ (no energy)

Consumer's objective is to attain the highest IC given in the budget line. So, this is a problem of constrained optimization:

• Max $u = u\ q_1, q_2$ subject to $p_1q_1+p_2q_2=M$

At equilibrium, slope of IC=slope of budget line. So, at E, Marginal rate of substitution (MRS) = relative price (p_1/p_2). It can also be extended to a multiple commodity framework.

<u>Derivation of Demand Curve</u>

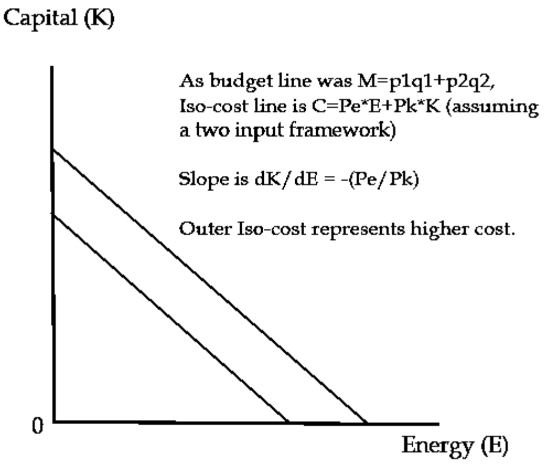


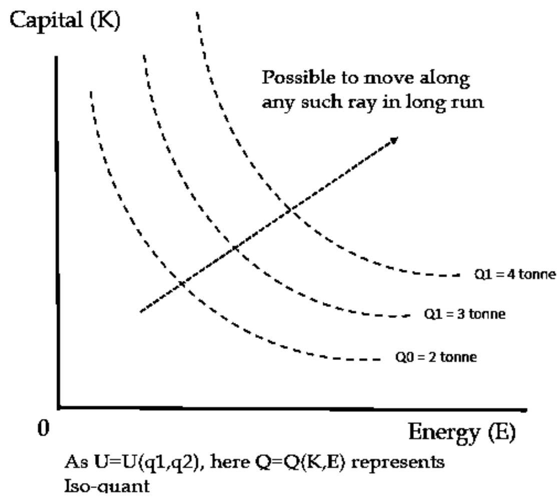
Demand curve represents the correspondence between price and quantity demanded. Suppose, initially the price of energy is p_{10} and the price of recreational activities is p_2 (fixed). Resulting Budget has the slope $-p_{10}/p_2$. Given the preference pattern, the equilibrium is at E_0 and energy demand is q_{10}. Fix the value of P_2 and reduce P_1 from P_{10} to P_{11}. New Equilibrium is E_1, energy demand is q_{11}. The line A_oA_1 represents the energy demand curve – shows that as price of energy declines, demand for energy increases The impact of price change on demand will depend on the slope of the demand curve and can be captured by the concept of price elasticity. The impact of change in p_2 on q_1 can be captured by the concept of cross price elasticity – extremely important to understand fuel substitution.

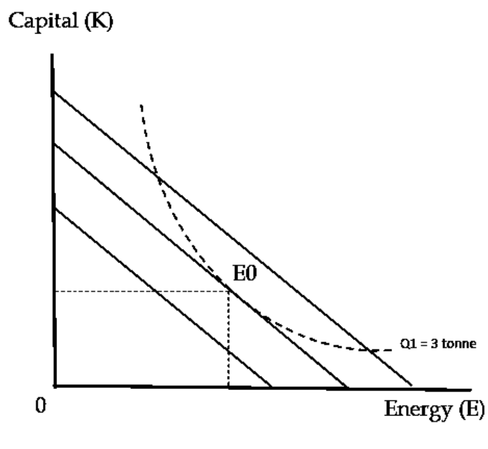
Producer Demand

Producers aim to minimise cost while meeting production requirements. Their demand for energy is called **derived demand**, since it depends on production output. In production theory, an

isoquant is a curve that shows all possible combinations of two or more inputs that yield the **same level of output**. It is analogous to the concept of an **indifference curve in consumption**, but instead of preferences, it represents **technical efficiency in production**. An **isoquant curve** represents all possible combinations of two inputs (usually **labour (L)** and **capital (K)**) that produce the **same level of output**. Absolute slope of Iso-quant is Marginal Rate of Technical Substitution (MRTS): amount of capital that you need to add to production process to maintain the same level of output, if there is marginal decline in energy input or the other way.



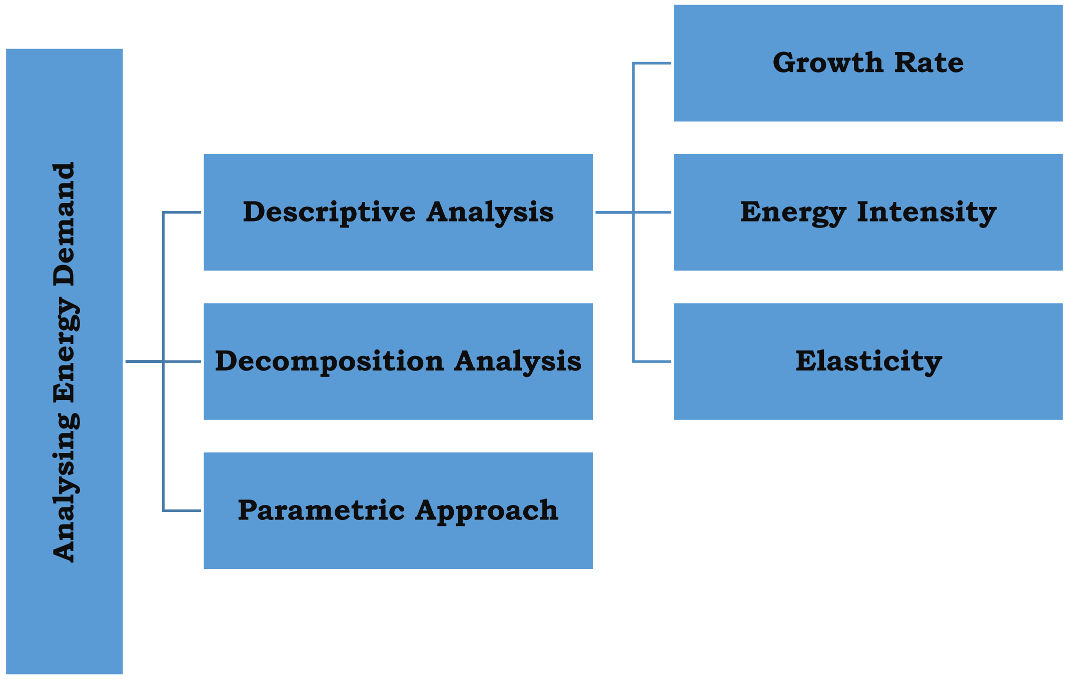




The objective is to Min C=Pe*E+Pk*K, Subject to $Q=Q_1$. So, at equilibrium (E0), MRTS = Pe/Pk. Similar to consumer's demand curve, one can obtain the demand curve of the producer for energy. Since the demand is derived based on the target production, such input demand is called derived demand.

Estimating Energy Demand

Energy Demand can be analysing can be done through three types as discussed below



I. Descriptive Analysis: This is the starting point for demand analysis, providing a qualitative characterization of demand patterns and identifying periods of significant change.

Growth Rate: Growth rate shows how much energy use increases or decreases over time. The Formula to used to calculate the growth rate is as follows

$$G = \frac{E_r - E_0}{E_0}$$

where E_T = energy in final year, E_0 = energy in base year.

Average annual growth rate:

$$g = \left(\frac{E_T}{E_0}\right)^{1/T} - 1$$

For Example: The energy statistics of India is given below

Year	Coal	Lignite	Crude Petroleum	Natural Gas	Electricity	Total
2007-08	7608	394	6536	1533	1807	17878
2008-09	8315	362	6731	1533	1994	18936
2009-10	8856	391	7811	2144	2206	21408
2010-11	8925	429	8248	2357	2500	22458
2011-12	9723	476	8547	2299	2827	23872
2012-13	10421	523	9178	2038	2967	25128
2013-14	10957	499	9316	1836	3147	25755
2014-15	12435	534	9347	1859	3415	27589
2015-16	12660	480	9750	1843	3604	28337

Coal consumption in India grew **0.58%** between 2014–15 and 2015–16.

From 2007–08 to 2015–16, coal consumption grew **66%** in total, with an average annual growth of **6.57%**.

Energy Intensity: Energy intensity means how much energy is used to produce one unit of output. The measures of energy intensity are

- **E1** = Energy used / Physical output (e.g., kWh per tonne of steel).
- **E2** = Energy used / Value of output (e.g., kWh per rupee).
- **E3** = Energy expenditure / Value of output (e.g., energy intensity of GDP).

✓ Choice of energy intensity indicator depends on the purpose and availability of data.

- ✓ Energy intensity and energy productivity are reciprocal concepts.
- ✓ Higher the energy intensity, lower will be the energy efficiency and energy productivity.

Demand Elasticities: Measure the responsiveness of demand to changes in economic variables

Income Elasticity of Energy Demand

This measures the **rate of change of energy demand for every 1% change in economic output (GDP or value-added)**. It indicates how responsive energy demand is to economic growth. GDP growth is **positively related** to energy demand.

1. **Developed countries** tend to have an **inelastic demand** with respect to income (i.e., the elasticity is **less than 1**). This means energy demand grows at a slower rate than the economy.
2. **Developing countries** typically have an **elastic energy demand** with respect to income (i.e., the elasticity is **greater than 1**). This indicates that energy demand grows faster than the economy as these countries develop.
3. **Example Calculation**: If China's primary energy consumption increased by 12.9% while its GDP increased by 9.9% in a given year, the GDP elasticity of energy demand would be 1.31 (12.9% / 9.9%).

Price Elasticity of Energy Demand

The price elasticity of energy demand refers to the responsiveness and sensitiveness of energy demand to the changes in its price. This measures how much demand changes for every percent change in the energy price. It can be mathematically represented as

$$Ep = \frac{\text{Proportionate change in Quantity of Energy Demand}}{\text{Proportionate change in Energy Price}}$$

Types of Price Elasticity

Relatively in-elastic demand

Consider the energy demand increased by 5% due to change in 10% change in price. Therefore, the value of price elasticity is relatively inelastic demand. The price elasticity is $E_p = \partial d / \partial p$ in which $\partial d = 5\%$ and $\partial p = 10\%$. Therefore, $Ep = 5\% / 10\% < 1$. In the diagram, proportionate change in energy demand is less than proportionate change in Price

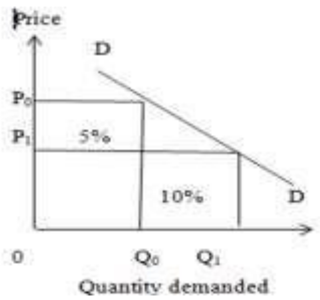


Fig 2. Relatively inelastic demand

Relatively elastic demand

Consider the energy demand increased by 10% due to change in 5% change in price. Therefore, the value of price elasticity is relatively elastic demand. Price elasticity $E_p = \partial d / \partial p$ in which $\partial d = 10\%$ and $\partial p = 5\%$. Therefore, the value is $E_p = 10\% / 5\% > 1$. In the diagram, proportionate change in energy demand is greater than proportionate change in Price.

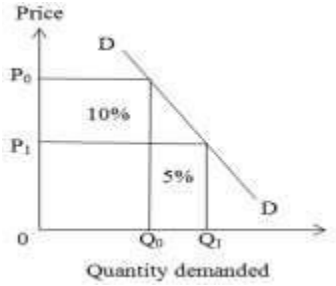


Fig 3 . Relatively elastic demand

Unity Elasticity of demand

Consider the energy demand increased by 10% due to change in 10% change in price. Therefore the value of price elasticity is unity. The formula for price elasticity is $E_p = \partial d / \partial p$ in which ∂d = 10% and ∂p = 10%. Therefore E_p = 10% / 10% = 1.This can be diagrammatically represented by measuring the price in the Y axis and demand in X axis.

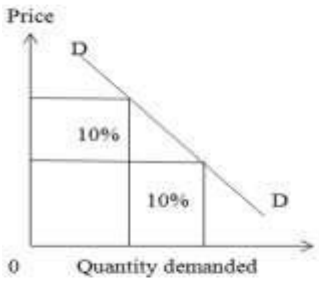


Fig 1.Unity price elasticity of demand

Short-run vs. Long-run Price Elasticities:

Short-term price elasticity captures the **instantaneous reaction to price changes**. In the short run, consumers primarily adjust their *consumption behavior* because they typically cannot immediately change their capital stock (e.g., appliances or vehicles). Thus, the scope for short-term response is limited.

Long-term elasticity captures the **effect of adjustments over a longer period**. Over the long run, consumers have the flexibility to adjust both their *capital stock* (e.g., buying more energy-efficient appliances or vehicles) and their consumption behavior, leading to a more significant reaction to price changes.

II. Decomposition Analysis

Energy demand can be broken into **three main effects**:

1. **Activity Effect (AE):** If overall activity or production increases, energy demand goes up.
2. **Structural Effect (SE):** If economy shifts towards less energy-intensive sectors, energy demand falls.
3. **Energy Intensity Effect (IE):** If energy used per unit of output reduces, demand also reduces.

Example: In Indian industries, aluminium, cement, steel, fertilizer, etc. are **energy-intensive sectors**, while textiles and others are less energy-intensive.

If share of energy-intensive industries increases → energy demand rises (structural effect).

If efficiency improves (energy intensity falls) → energy demand reduces.

Index Decomposition Analysis (IDA): IDA is used to separate changes in energy demand into AE, SE, and IE. To study, industries are divided into energy-intensive and non-energy-intensive groups. For Example (India, 1990–91 to 2010–11):

- Total industrial energy use rose from **8,819 → 17,200 Rs. lakhs**.
- But energy intensity (energy per output) declined from **0.07 → 0.02**.

This shows decoupling – economic growth increased faster than energy demand because of efficiency gains.

III. Parametric/Econometric Approach: Relies on economic principles to analyze energy demand and the effects of price and policy changes.

Structural Models: Explicitly consider the derived nature of energy demand by specifying separate demand functions for appliance stock and utilization rate. These require extensive data on equipment stocks.

Reduced Form Models: More commonly used, combining effects of inter-fuel substitution, stock adjustment, and utilization rates when detailed stock information is unavailable.

- **Specifications**: Log-linear forms (e.g., log Et = a + b log(PE) + c log(Yt) + ut) are common, providing direct estimation of price and output elasticities.
- **Dynamic Adjustment**: Lagged demand variables (e.g., log E_t = a + b log PE_t + c log Y_t + d log E_(t-1) + u_t) are often included to capture the time-lagged adjustment process in the energy sector, allowing for short-run and long-run elasticity estimations.
- **Time Series Models**: Rely on past behavior of the dependent variable (e.g., ARMA, ARIMA, Box-Jenkins) for short-term demand analysis and forecasting.
- **Cointegration Analysis**: Addressed the issue of "stationarity" in economic data during the 1990s to avoid spurious regression results when variables show strong, stochastically changing trends.
- **Advantages**: Can capture price effects, inter-fuel substitution, identify determinants, and be used for energy-economy interactions.

- **Difficulties**: Requires experienced econometricians and consistent, quality data, which may be scarce in developing countries. Relies on past behavior, making it less suitable for structural changes or new technologies. Basic theoretical assumptions may not hold due to government intervention or supply constraints.

Demand estimation under administered price regimes

- ✓ Administered prices are prices **fixed or controlled by the government**, not determined by free market forces.
- ✓ In the energy sector, governments often regulate the prices of **electricity, petroleum products, natural gas, and coal** to ensure affordability, control inflation, or achieve social objectives.
- ✓ This creates a situation where prices may not reflect **true scarcity, production costs, or international market signals**.

Nature of Administered Prices and Their Impact on Demand: Administered prices in the energy sector arise from government intervention and market imperfections, which cause prices to deviate from those in a perfectly competitive market. These interventions directly influence how much energy people consume and how demand patterns evolve.

1. Subsidies and Price Controls

- Governments often set energy prices **below market-clearing levels** to promote economic development or make energy affordable for the poor (e.g., lifeline tariffs for basic household use).
- **Impact on Energy Demand:**

- Low prices encourage **over-consumption** of electricity, fuels, or gas.
- Consumers receive the wrong price signals, leading to wasteful energy use.
- Subsidies reduce incentives to adopt **energy-efficient technologies** or shift to **alternative energy sources**.
- Artificially cheap energy raises demand for additional capacity, especially during peak hours, but since suppliers are not adequately compensated, this results in **shortages and unreliable supply**.

Monopoly Pricing

- In many energy sectors (like electricity transmission or gas distribution), natural monopolies exist. Prices may be set either to recover average costs or to maximize profits for a state-owned monopoly.
- **Impact on Energy Demand:**
    - Monopoly pricing often leads to **higher prices** than in a competitive market.
    - This restricts the quantity of energy demanded, as some consumers are priced out.
    - Society bears a **deadweight loss**, where potential consumption that could have benefited both consumers and producers does not occur.

Traditional Regulation

- In regulated energy industries, tariffs are often designed to ensure that utilities can cover their costs and continue service, rather than being based on marginal cost pricing.
- **Impact on Energy Demand:**

- If tariffs do not reflect the real marginal cost of supplying energy, consumers make **distorted consumption choices**.
- For example, uniform tariffs across regions or times of day may encourage **excessive use during peak hours** and discourage efficient load management.
- This results in **inefficient demand patterns** that do not match the true cost of energy provision.

Challenges in Demand Estimation under Administered Prices

- **Unfulfilled Demand**: In many developing countries, **supply shortages** imply that actual energy consumption may not represent the true underlying demand, as a portion of demand remains unfulfilled. This makes it difficult to assess consumer responsiveness to price changes accurately.
- **Data Limitations**: There can be a lack of reliable data, especially for traditional energies widely used in rural areas, which might not enter commercial energy statistics.
- **Distorted Price Signals**: When prices are administered, they do not accurately reflect the true economic costs or benefits, making it difficult to use price as a direct determinant of demand in models. This complicates the estimation of price elasticities, which measure consumer responsiveness to price changes.

Demand Side Management

Demand-side management (DSM) in energy refers to the **systematic utility and government activities designed to change the amount and/or timing of customer's use of energy for the overall benefit of society**

Importance of DSM

• **System Loss Reduction**: Saving one MWh of energy is more beneficial than producing one MWh, as it reduces pressure on system expansion by avoiding transmission and distribution losses.

• **Resource Requirement Reduction**: Lower demand reduces the need for additional resources, infrastructure, and associated environmental damage, especially given the typically low technical efficiency of conversion processes.

• **Improved Infrastructure Utilization**: DSM can distribute demand over time, leading to better utilization of existing infrastructure and potentially reducing congestion or improving supply reliability.

• **Reduced Import Dependence**: Lower demand can decrease a country's reliance on energy imports, enhancing supply security and reducing vulnerability to price fluctuations.

• **Better Market Operation**: Integrating demand-side response in market operations leads to more efficient resource utilization.

Key Categories of DSM Activities:

• **Load Management**:

Load management refers to controlling and shifting electricity use across different times of the day in order to reduce stress on the power system. The major load management techniques include:

1. **Peak Clipping:** This strategy reduces electricity consumption during peak hours when demand is very high.
2. **Valley Filling:** This strategy encourages more electricity use during off-peak hours when demand is low.

3. **Load Shifting:** This strategy shifts electricity usage from peak periods to off-peak periods without reducing total consumption.
4. **Conservation:** This involves reducing overall electricity consumption through energy-saving practices.
5. **Load Building:** This strategy increases electricity demand in areas or times where it is lower than the system's capacity.
6. **Flexible Load:** This involves using smart meters and automation that allow utilities to adjust consumer demand as per system requirements.

Utilities use tools such as **time-of-use tariffs**, **real-time pricing**, and **incentives** to motivate consumers to follow load management practices.

Load management can be achieved through two main approaches:

• **Direct Load Control (DLC)**: The utility directly controls end-use devices (e.g., air conditioners, water heaters) by sending signals to disconnect, reconnect, or modify their operation. Utilities often offer incentives for customer participation. An extreme form is load shedding, where supply is cut to an area to manage demand, common in developing countries with chronic shortages. Price-based mechanisms, like tariffs for interruptible loads or demand bidding programs, also offer incentives for consumers to reduce demand.

• **Indirect Load Control (ILC)**: Provides price signals to consumers to induce changes in energy demand patterns. This involves designing appropriate energy charges, such as time-of-day (TOU) tariffs, which reflect the varying costs of supply. While some past experiences with ILC have been uneven due to traditional regulation not based on marginal cost, recent experience shows these rates can be effective in managing demand.

DSM in India

India has launched several **Demand Side Management (DSM)** programs across different sectors to promote efficient energy use, reduce subsidies, and support sustainable development. The important initiatives are as follows:

1. Agricultural DSM (AgDSM)

Agriculture is one of the largest energy-consuming sectors in India, particularly because of the widespread use of electric pumps for irrigation. Most of these pump sets are highly inefficient, consuming more electricity than required.

- The AgDSM program focuses on replacing these inefficient agricultural pump sets with energy-efficient models.
- This replacement helps in saving a large amount of electricity, reducing transmission and distribution losses, and lowering the subsidy burden on state electricity utilities.
- In addition, energy-efficient pumps also help farmers by reducing operating costs and providing reliable water supply.
- Studies show that replacing inefficient pumps can save **over 430 crore kWh of electricity annually** and cut down significant amounts of greenhouse gas emissions.
- Pilot projects have been implemented in states such as **Maharashtra, Karnataka, and Andhra Pradesh** through the Bureau of Energy Efficiency (BEE) and Energy Efficiency Services Limited (EESL).

Municipal DSM (MuDSM)

Municipal services such as street lighting, water pumping, and sewage treatment account for a significant share of electricity consumption in urban areas.

- The MuDSM program aims to reduce electricity consumption in municipalities by introducing **energy-efficient technologies** and better management practices.
- For example, replacing conventional street lights with LED lights results in major electricity savings and lower maintenance costs.
- Energy audits are carried out in municipalities to identify areas where efficiency improvements can be made, and Detailed Project Reports (DPRs) are prepared for implementation.
- The Bureau of Energy Efficiency has initiated programs to cover more than **175 municipalities** across India.
- Successful implementation of MuDSM helps reduce peak load on distribution companies, cut energy bills for municipalities, and improve urban service delivery.

Industrial and SME Programs

The industrial sector consumes a large portion of electricity in India, and small and medium enterprises (SMEs) often use outdated and inefficient machinery.

- DSM programs in industries and SMEs promote the use of **energy-efficient motors, boilers, compressors, and other industrial equipment**.
- Special focus is given to SMEs because they face financial constraints in adopting modern technology. Government and

utility-backed programs provide financial support, technical assistance, and awareness campaigns.

- These programs not only lower the electricity bills of industries but also enhance productivity and competitiveness in the market.
- By reducing industrial energy demand, these initiatives also help in decreasing the overall carbon footprint of the economy.

DISCOM Initiatives

Distribution companies (DISCOMs) play a central role in implementing DSM measures since they directly interact with consumers.

- DISCOMs encourage **time-of-use tariffs** where electricity prices are higher during peak hours and lower during off-peak hours to motivate consumers to shift their usage.
- They also promote the installation of **smart meters and automated systems**, which allow consumers to monitor and manage their electricity use more effectively.
- Consumer awareness campaigns are conducted to educate people about energy efficiency practices such as using LED bulbs, star-rated appliances, and energy-saving techniques.
- By implementing DSM measures, DISCOMs can reduce peak demand, improve reliability of supply, and reduce their financial losses due to subsidies and inefficiencies.

Energy Efficiency Improvements and Energy Conservation:

• **Definition**: Energy conservation is the "deliberate reduction in the use of energy below some level that would prevail otherwise".

Energy efficiency is defined as the ratio of useful output to energy input in a process, often adjusted by energy analysts to measure energy services provided per unit of input (e.g., tonnes of product, ton-kilometers of freight).

• **Opportunities for Energy Saving**: These include improving lighting efficiency (e.g., replacing incandescent lamps), enhancing insulation for space heating/cooling in buildings, increasing the efficiency of domestic appliances, and promoting fuel efficiency in transport. Improving electricity generation efficiency is also a supply-side activity with significant energy-saving potential.

• **Economics**: Energy efficiency improvements involve substituting capital for energy, leading to lower energy input per unit of output. Technological change can also shift the production possibility to a different isoquant, resulting in greater energy efficiency. Cost-benefit analysis is used to evaluate these investments, comparing total system costs with total benefits over the project's lifetime. The choice of discount rate significantly influences the decision, as a lower discount rate makes future cost-savings more attractive.

Debate Around Energy Efficiency:

• **Market Barriers and Intervention**: Proponents argue that market failures (e.g., misplaced incentives, financing barriers, information asymmetry, pricing issues) justify government intervention to promote energy efficiency. Governments can use information and labeling programs, standards and regulations, and financial and fiscal mechanisms.

• **Energy Efficiency vs. Economic Efficiency**: Some economists argue that energy efficiency, an engineering concept focusing on a single factor, might not always align with economic efficiency, which seeks the most appropriate combination of all factor inputs to produce output. Policies should promote energy efficiency that is consistent with economic efficiency.

• **Rebound Effect**: This refers to the phenomenon where energy savings from efficiency improvements are partially or fully offset by increased energy consumption due to behavioral changes or economic adjustments. The efficacy of energy efficiency programs depends on the magnitude of this effect.

• **Market-Based Incentives**: Tools like white certificates, based on the Cap and Trade principle, can be used to promote energy efficiency by providing flexibility and allowing participants to decide their strategy, often leading to lower costs.

DSM is a crucial part of energy system management, especially in the context of demand analysis and forecasting. While demand forecasting helps predict future energy needs, DSM aims to actively shape that demand to achieve economic, environmental, and social benefits.

Conclusion

The study of energy demand highlights the complex relationship between economic growth, technological progress, and consumption patterns across various sectors. It emphasizes that energy demand is influenced by income levels, prices, industrialization, and population growth. Efficient energy use, demand-side management, and the promotion of renewable sources are crucial to achieving sustainable energy security. Understanding demand through econometric and decomposition analyses helps policymakers design strategies that balance economic development with environmental preservation. In conclusion, optimizing energy demand requires integrated policies, innovation, and public awareness to ensure a reliable, affordable, and cleaner energy future for all.

Section – A

1. Define energy demand.
2. State determinants of energy demand.
3. Define price and income elasticity of energy demand.
4. Write a note on demand-side management (DSM).
5. Mention policies for energy efficiency.
6. Define administered price regime.
7. Explain short-run energy demand and its importance.
8. Give reasons and methods for estimating energy demand.
9. Define econometric model and energy load management.

Section – B

1. Explain concept and determinants of energy demand.
2. Discuss elasticity of demand and demand forecasting.
3. Calculate price and income elasticity
4. Illustrate methods of estimating energy demand.
5. Explain DSM policies and link with economic growth.
6. Case study: implications of increasing energy demand.

Section – C

1. Examine determinants of forecasting energy demand.
2. Interpret forecasting methods and challenges.
3. Elucidate demand side management and price elasticity estimation.

UNIT – III

ENERGY SUPPLY

Introduction

The availability of energy resources plays a vital role in a nation's economic and social development, particularly in reducing poverty and enhancing living standards. Having timely and reliable data on energy availability is essential for effective decision-making and long-term planning. Regular monitoring of energy resources helps evaluate their availability, usage, and rate of depletion, which is crucial for ensuring energy security and promoting sustainable development.

Significance of Energy Availability

Energy availability is a key driver of improved living conditions, economic growth, and industrial and household development. For developing countries like India, keeping track of energy resources and their depletion is essential to evaluate long-term sustainability. In recent years, there has been a strong shift towards renewable and cleaner sources of energy to balance the gap between energy demand and supply while reducing environmental impact. Moreover, universal access to affordable and clean energy has been identified as a critical objective under the United Nations Sustainable Development Goals (SDGs), with a target to achieve it by 2030.

Energy availability holds immense importance in the economic, social, and environmental progress of any nation. It acts as a foundation for development, enabling industries to function, transportation systems to operate, and households to access basic needs such as lighting, cooking, and communication. The following points highlight its key significance in detail:

1. Driver of Economic Growth: nergy is a critical input for all sectors of the economy—agriculture, manufacturing, transport, services, and infrastructure. Adequate and reliable energy supply supports industrialization, increases productivity, and attracts investment. In developing countries like India, energy availability ensures smooth operation of factories, efficient movement of goods and services, and continuous economic activity. Without sufficient energy, economic growth slows down, affecting employment and income levels.

2. Improvement in Quality of Life : Access to energy directly enhances the quality of life. Electricity enables lighting, education, healthcare, communication, and entertainment, while clean cooking fuels reduce indoor air pollution and improve health conditions. Rural electrification and affordable energy access help bridge the urban-rural divide, empowering people with better living standards, access to technology, and social development.

3. Support for Industrial and Technological Development: Industries are major consumers of energy. A steady and affordable supply of energy ensures uninterrupted production and technological advancement. Energy availability also encourages innovation in sectors such as manufacturing, information technology, and transportation. It supports the adoption of modern equipment, automation, and digitalization, which are essential for national competitiveness.

4. Reduction of Poverty and Social Inequality: Energy access has a direct link with poverty reduction. When households have access to affordable electricity and clean fuels, they can improve education outcomes, start small businesses, and reduce health hazards from traditional energy sources like firewood or kerosene. This helps uplift communities, particularly women and children, who spend less time on fuel collection and more time on productive activities.

5. Ensuring Energy Security and Sustainability: Monitoring and managing energy resources helps a country maintain energy security—ensuring that energy is available at all times, at affordable prices, and from reliable sources. Sustainable energy use also helps protect the environment by reducing dependency on non-renewable and polluting energy sources like coal and petroleum. Promoting renewable energy such as solar, wind, and hydro power ensures a stable and cleaner energy future.

6. Achievement of Sustainable Development Goals (SDGs) : Energy availability is directly linked to **SDG 7 – Affordable and Clean Energy**, which aims to ensure access to reliable, sustainable, and modern energy for all by 2030. It also contributes indirectly to other SDGs related to poverty eradication, education, health, gender equality, and climate action. A well-developed energy sector thus supports comprehensive sustainable development.

7. Environmental Protection and Climate Change Mitigation : Energy generation and consumption significantly impact the environment. The availability and use of clean and renewable energy sources help reduce greenhouse gas emissions, control air pollution, and mitigate the effects of climate change. A sustainable energy transition supports India's commitment to reducing carbon intensity and achieving net-zero emission goals.

8. National Development and Global Competitiveness: Countries with stable and diverse energy sources can maintain consistent economic progress and compete globally. Energy availability strengthens national resilience against external shocks such as oil price fluctuations or geopolitical tensions. For India, achieving energy self-sufficiency through renewable sources also enhances its strategic and economic independence.

This chapter presents an overview of the current status of energy availability in India, with a specific focus on coal, crude oil, petroleum products, and electricity.

Table : Yearwise Availability of Major Energy Resources in India (2014–15 to 2023–24)

Year	Coal (MT)	Lignite (MT)	Crude Oil (MT)	Petroleum Products (MT)	Natural Gas (BCM)	Electricity (GWh)
2014–15	821.85	46.95	226.90	178.50	51.30	1,054,355
2015–16	835.63	42.21	239.79	200.84	52.51	1,104,228
2016–17	836.46	43.17	249.94	214.32	55.70	1,163,290
2017–18	896.06	46.32	256.12	223.03	59.17	1,232,505
2018–19	967.16	45.76	260.70	234.61	60.79	1,307,685
2019–20	954.59	42.23	259.12	241.04	64.14	1,323,048
2020–21	900.76	38.24	226.95	219.99	60.82	1,314,025
2021–22	1,025.68	49.08	242.07	230.57	64.14	1,413,903
2022–23	1,114.18	45.55	261.88	250.12	59.95	1,535,665
2023–24 (P)	1,236.48	42.64	263.62	262.19	67.47	1,646,998

Source: Ministry of Statistics and Programme Implementation. (2024), e*nergy Statistics India 2024* (pp. 45–52). Government of India

Table: Growth Trends of Energy Resources (2023–24 over 2022–23)

Resource	Growth Rate (%)	CAGR (2014–15 to 2023–24) (%)	Remarks

Coal	**+10.98**	**4.64**	Consistent rise in production; import dependency remains.
Lignite	**–6.38**	**–1.06**	Gradual decline; limited use and focus shifting to renewables.
Crude Oil	**+0.66**	**–2.67**	Declining domestic output; increasing import reliance.
Petroleum Products	**+4.82**	**2.50**	Higher domestic refining capacity reduced import dependency.
Natural Gas	**+12.54**	**3.09**	Strong growth in production and imports; supports cleaner energy.
Electricity	**+7.25**	**5.08**	Continuous growth in generation and availability.

Source: Ministry of Statistics and Programme Implementation. (2024), e*nergy Statistics India 2024* (pp. 45–52). Government of India

The data presented in the tables show the trend of energy resource availability in India over the period 2014–15 to 2023–24 (Provisional). The figures highlight both domestic production and import dependence across major energy sources like Coal, Lignite, Crude oil, Petroleum products, natural gas, and electricity.

Coal remains the dominant source of energy in India. Its availability has shown a steady upward trend, reaching 1,236.48 million tonnes in 2023–24, marking a 10.98% growth over the previous year. This reflects an expansion in domestic coal mining and increased production to meet the country's growing energy demand.

In contrast, lignite production has declined, showing a 6.38% decrease in 2023–24. This indicates a gradual shift away from lignite due to environmental concerns and the growing emphasis on cleaner energy alternatives.

Crude oil availability has remained almost stable, increasing marginally by 0.66% in 2023–24. However, its CAGR of 2.67% reveals a long-term decline in domestic production, making India increasingly dependent on crude oil imports to satisfy its energy needs.

Petroleum products have shown improvement in availability due to the enhancement of domestic refining capacity, leading to a 4.82% increase in 2023–24 and a reduction in net imports.

Natural gas availability has grown significantly, recording a 12.54% increase in 2023–24. This growth supports India's clean energy transition as natural gas is considered a less polluting fuel.

Finally, electricity generation and availability have consistently improved, with a 7.25% growth in 2023–24 and a CAGR of 5.08% over the past decade. This growth reflects the country's expanding power infrastructure and progress toward energy access for all.

Brief Summary on Availability of Energy Resources

In the financial year 2023–24, India witnessed steady and healthy growth in both energy supply and consumption, successfully overcoming the after-effects of the global pandemic. The Indian economy continued to display a strong appetite for energy to support rapid urbanisation, industrialisation, and the national vision of achieving *Viksit Bharat* (Developed India) by 2047. The key highlights of India's energy sector performance during FY 2023–24 are as follows:

Energy Reserves: As on 31 March 2024, India's total coal reserves stood at **389.42 billion tonnes**. Odisha held the largest share at **25.47%**, followed by Jharkhand (**23.58%**), Chhattisgarh (**21.23%**), West Bengal (**8.72%**), and Madhya Pradesh (**8.43%**).

The *proved reserves* (economically mineable portion) accounted for around **55%** of the total coal reserves. The country's estimated *crude oil reserves* were **671.40 million tonnes**, primarily located in the Western Offshore (**32%**), Assam (**21.66%**), Rajasthan (**19.59%**), and Gujarat (**17.70%**). The *natural gas reserves* were estimated at **1,094.19 billion cubic metres (BCM)**, concentrated mainly in the Western Offshore (**31.28%**), Eastern Offshore (**24.07%**), and Assam (**15.03%**).

Renewable Energy Potential: As of 31 March 2024, India's estimated renewable energy generation potential reached **2,109,655 MW**. The largest share came from *wind energy* at **1,163,856 MW (55.17%)**, followed by *solar energy* at **748,990 MW (35.50%)** and *large hydro* at **133,410 MW (6.32%)**.

Coal Washeries and Production: The capacity of coal washeries in India increased from **131.4 MTY** in 2015 to **257.79 MTY** in 2024. Meanwhile, coal production grew by **389 million tonnes** between FY 2014–15 and FY 2023–24, reflecting substantial growth in domestic extraction capacity.

Coal as the Energy Backbone: Coal continued to be the backbone of India's energy supply, accounting for nearly **79%** of total domestic energy availability in FY 2023–24. Production rose by **11.71%**, reaching **997.83 million tonnes**, up from **893.19 million tonnes** in the previous year. Non-coking coal dominated production, contributing about **93.3%** of the total output.

Growth in Renewable Electricity Generation: The gross generation of electricity from renewable sources (including both utility and non-utility) increased significantly from **205,608 GWh**

in FY 2014–15 to **370,320 GWh** in FY 2023–24 reflecting a **CAGR of 6.76%** over the decade.

Import Dependency: To meet domestic energy needs, India continued to rely on imports of coal, crude oil, and natural gas. In FY 2023–24, the *net import of coal* rose by **11.2%** to **262.99 million tonnes**, while *natural gas imports* increased by nearly **21%**, reaching **31.8 BCM**. *Crude oil imports* also grew from **232.70 million tonnes** to **234.26 million tonnes** over the previous year.

Electricity Supply and Losses: Electricity availability in India showed marked improvement. Transmission and distribution losses stood at **17.08%** in FY 2023–24, while the *net electricity available for supply* grew by **7.25%**, reaching **1,646,998 GWh**.

Total Primary Energy Supply (TPES): India's TPES grew by **7.8%** in FY 2023–24, reaching **9,03,158 KToe**. Coal remained the primary energy source, contributing **60.21%**, followed by crude oil (**29.83%**) and natural gas (**6.99%**).

Growth in Renewable Energy Supply: Energy supplied from renewable sources increased steadily—from **17,682 KToe** in FY 2014–15 to **31,847 KToe** in FY 2023–24, achieving a **CAGR of 6.76%**. Energy generation from solar, wind, and other non-hydro sources rose by nearly **210%**, from **6,555 KToe** in 2014–15 to **20,289 KToe** in 2023–24.

Total Final Energy Consumption (TFC): TFC across end-use sectors grew by **38%** since 2014–15, reaching **6,13,605 KToe** in FY 2023–24. The *industrial sector* registered the highest annual growth at **13.2%**, followed by *transport* (**10.7%**) and *commercial/public services* (**6.6%**). The *residential sector* also showed steady growth, driven by rapid urbanisation and improving living standards.

<u>Agriculture and Forestry:</u> Energy consumption in the agriculture and forestry sectors increased from **15,347 KToe** in FY 2014–15 to **22,564 KToe** in FY 2023–24, with a **CAGR of 4.38%**.

<u>Per Capita Energy and Electricity Consumption:</u> India's *per capita energy consumption* rose from **14,682 megajoules per person** in FY 2014–15 to **18,410 megajoules per person** in FY 2023–24—an increase of over **25%**. *Per capita electricity consumption* grew by around **48%**, from **748 kWh/person** to **1,106 kWh/person** during the same period.

<u>Energy Intensity:</u> Energy intensity showed a marginal improvement in FY 2023–24. It required **0.2180 megajoules of energy** to generate one rupee of GDP, compared to **0.2192 MJ/INR** in FY 2022–23. Industrial energy intensity declined from **361.47 MJ per ₹1,000 of GDP** to **284.20 MJ per ₹1,000 of GDP** in FY 2023–24.

<u>Import Dependency:</u> India's dependence on imported energy sources remained substantial in FY 2023–24. Import dependency stood at **89% for crude oil**, **46.6% for natural gas**, and **25.86% for coal**, highlighting the need for continued efforts toward energy self-sufficiency and diversification.

Renewable Resources Availability Summary

- **India's Progress**:
  - By March 2024, India's total installed power capacity reached **441.97 GW**, of which **190.57 GW** (43.12%) came from renewable energy (RE).

- Renewable capacity grew by **134.6%** since 2014-15, much faster than non-renewable capacity.
- Solar and wind are the dominant sources—solar alone grew nearly **20 times** in nine years.

 Energy Generation:

- In 2023-24, RE sources produced **359.89 billion units (BU)**, making up **20.75%** of India's total power generation.
- Solar power has become the largest contributor, followed by wind.

 Top States:

- Gujarat, Rajasthan, Tamil Nadu, Karnataka, and Maharashtra account for around **61%** of India's RE capacity.
- Rajasthan leads in solar, while Tamil Nadu and Gujarat lead in wind.

 Global Standing:

- India ranks **4th globally** in renewable capacity and **5th in generation**.
- By 2023, global RE capacity touched **3,864 GW**, with solar overtaking hydro as the largest renewable source.
- China leads the world, followed by the US, Brazil, and India.

 Future Targets & Policies:

- India aims for **500 GW of non-fossil fuel capacity by 2030**.
- Key schemes include PM-KUSUM (solar for agriculture), Rooftop Solar, Solar Parks, Green Energy Corridor, and the National Green Hydrogen Mission.

Economic Analysis of Energy Investments

The purpose of economic analysis is to rank and select projects that offer the highest economic effectiveness and social welfare, ensuring better resource allocation. This is especially important in the energy sector, where markets are often non-competitive and project impacts extend beyond direct boundaries.

According to the World Bank (1996)**,** economic analysis helps determine:

- Whether a project should be implemented by the public or private sector**,**
- The fiscal implications for the government,
- The efficiency and fairness of cost recovery, and
- The environmental effects of the project.

In essence, economic analysis evaluates the welfare impact of a project. It involves three main steps (Lovei, 1992; ADB, 1997; World Bank, 1996):

1. Identifying and estimating the costs of the investment,
2. Identifying and estimating the benefits expected, and
3. Comparing costs and benefits to judge the project's viability — if benefits exceed costs, the project is considered acceptable.

The first two steps require careful investigation and valuation. Costs and benefits are determined by comparing two situations the "with-project" and **"without-project"** cases. The difference between the two reflects the real economic impact.

A distinction is made between incremental and non-incremental inputs and outputs**:**

- *Incremental outputs/inputs* add to existing supply,

- *Non-incremental outputs/inputs* replace or compete with existing ones.

Finally, economic analysis often starts from the financial statements but makes adjustments by: (a) **Including or excluding certain items**, and (b) **Revaluing items** from financial to economic terms to reflect their true cost or benefit to society. In other words, Economic and financial valuations are two essential approaches used in assessing the feasibility of energy investments. Both aim to evaluate the profitability and sustainability of a project, but they differ in scope and perspective.

Aspect	Economic Valuation	Financial Valuation
Cost	Considers cost to society, including pollution and other externalities.	Focuses only on the monetary costs of running a project, excluding environmental costs.
Externality	Takes into account externalities (like pollution) and attempts to internalize them in the production decision.	Externalities are not considered in decision-making.
Benefit	Considers both private (profit) and social benefits.	Considers only private benefits, directly linked to profit.
Valuation	Complex; often uses methods like *Willingness to Pay* or *Willingness to Accept*.	Simpler; based on prevailing market prices.
Inflation	Uses constant prices for valuation.	Uses current market prices.

Unique Characteristics of Energy Projects

1. **Capital Intensive Nature:** Energy projects require very high initial investments. For example, the cost of setting up a 1

MW coal or gas power plant in India is around ₹4–5 crore. Due to such high costs, economies of scale can be achieved only when production occurs on a large scale. Large-scale projects like those under the National Thermal Power Corporation (NTPC), with an installed capacity of about 36,000 MW, reflect this characteristic.

2. **High Running Costs:** A 1 MW thermal power plant consumes approximately 350–600 kg of coal per hour, depending on coal quality. Since coal and fossil fuel extraction are expensive, the operational cost is high for conventional plants. However, renewable energy systems such as solar and wind power have significantly lower running costs once established.
3. **Asset Specificity and Longevity:** The technology used in power plants is often specific and cannot be easily utilized for other purposes. Additionally, power plants have long operational lifespans—thermal plants usually last for around 50 years, while hydropower plants can function efficiently for about 25 years or more.
4. **Gestation Lag :**Energy projects often experience a significant delay between the initial investment and the commencement of power generation. For instance, a conventional thermal power plant takes about 5–6 years to become operational, while a nuclear power plant may take around 10 years. In contrast, solar projects have a much shorter gestation period of less than one year.

Identification of Costs & Production

The term *cost* carries different meanings for different people (refer to Box 7.1 for specific definitions). In economic analysis, it is important to carefully identify which costs are relevant. Generally, only those costs that impose an *additional burden* on resources are considered. The main types of such costs are explained below (ADB, 1997; World Bank, 1996):

(a) Sunk Costs: If a project makes use of facilities or infrastructure that already exist and for which the investment has been made earlier (i.e. sunk costs), these are excluded from economic analysis. Since these costs have already been incurred and the facilities would exist even without the project, they do not represent any additional economic burden.

(b) Contingencies: Only that portion of contingencies which involves an additional claim on resources is included in economic analysis. As economic costs are evaluated at *constant prices* (unlike financial analysis, which uses nominal prices), price-related contingencies are excluded.

(c) Working Capital: A similar principle applies to working capital. Only the portion that represents a *real use of national economic resources* is included. Any *transfer payments* involved, such as interest or taxes, are excluded from the analysis.

(d) Transfer Payments: Transfer payments refer to transactions that merely shift control of resources from one entity to another without changing the total amount of resources in the economy (ADB, 1997). Examples include taxes, duties, and subsidies. Since these do not impose any additional claim on real resources, they are excluded from economic analysis. However, in certain cases such as when the input demand is non-incremental, or output is incremental, or when the government internalizes externalities through taxation these may be included in prices.

(e) Depreciation: In economic analysis, the *initial cost of an asset minus its residual value (discounted)* is considered. This represents the full cost of using the asset. Since economic analysis does not focus on how an asset is financed or repaid, depreciation is not included as a separate cost item.

(f) Depletion Premium: For non-renewable resources, economic analysis incorporates a *depletion rent* or *premium* to reflect the societal cost of using exhaustible resources. This accounts for the opportunity cost, which includes the cost of substitute resources once the current reserves are depleted.

(g) External Costs: Energy projects often generate *externalities*—costs borne by society rather than by the direct users. These external costs, such as environmental damage or pollution, are included in economic analysis to capture the *true economic cost* of the project. Any analysis that omits such externalities would provide an incomplete picture of the project's real impact.

Cost Function

The **cost function** expresses the relationship between the level of production and the total cost of production.

TC=c(Q)

1. Total Fixed Cost (TFC) :Total Fixed Cost refers to the expenses that remain constant irrespective of the level of output.

2. Total Variable Cost (TVC) : Total Variable Cost changes **directly with the level of production**. It includes expenses that increase as more electricity is generated such as operation, labour, and water regulation costs.

3. Total Cost (TC) : Total Cost is the **sum of fixed and variable costs**:

TC = TFC + TVC

4. Average Fixed Cost (AFC): Average Fixed Cost measures fixed cost per unit of output and is obtained by dividing TFC by the number of units produced.

AFC = TFC / Q

5. **Average Variable Cost (AVC**) : Average Variable Cost is the variable cost per unit of output**.**

AVC = TVC/Q

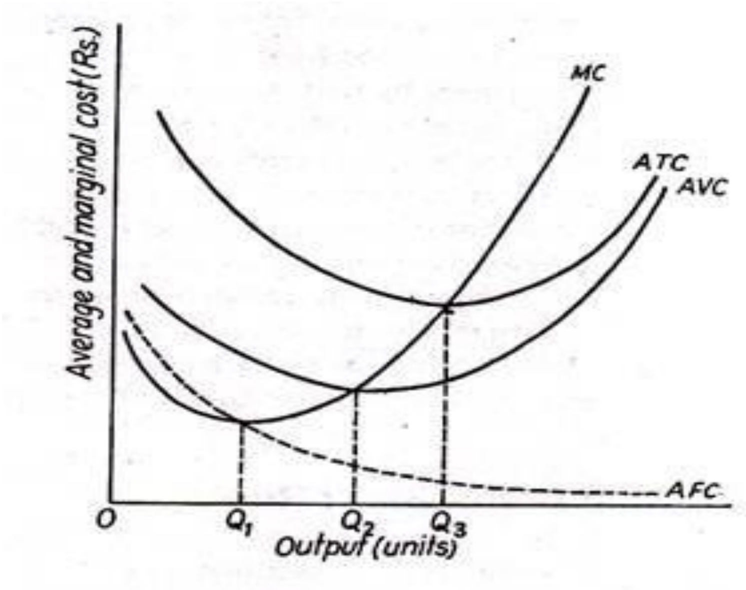
6. Average Cost (AC) :Average Cost, also known as unit cost or cost per unit, is calculated as:

AC =AFC + AVC

7. Marginal Cost (MC) :Marginal Cost represents the additional cost incurred in producing one extra unit of output**.**

MC=ΔTC/ΔQ

The diagrammatically representation of this costs will be below



In the short run, the cost curves have the following relationships:

- The AFC curve continuously declines.
- The AVC and AC curves are U-shaped — they first fall due to increasing returns to the variable factor and later rise due to diminishing returns.
- The MC curve also has a U-shape and cuts both the AVC and AC curves at their minimum points.

Case Study

A small hydro power plant has a **Total Fixed Cost (TFC) of ₹5,000 per month** for salaries, rent, and maintenance. The **Variable Cost per unit of electricity is ₹25 per unit** (mainly operation and water regulation expenses).

You are asked to calculate the following for output levels of **1, 2, 3, 4, and 5 units**:

1. **Total Variable Cost (TVC)** at each output.
2. **Total Cost (TC)** at each output.
3. **Average Fixed Cost (AFC)**, **Average Variable Cost (AVC)**, and **Average Cost (AC)** at each output.

4. **Marginal Cost (MC)** between successive levels of output

Solution:

Output (Units)	TFC (₹)	TVC (₹)	TC (₹)	AFC (₹)	AVC (₹)	AC (₹)	MC (₹)
1	5,000	25	5,025	5,000	25	5,025	–
2	5,000	50	5,050	2,500	25	2,525	25
3	5,000	75	5,075	1,667	25	1,692	25
4	5,000	100	5,100	1,250	25	1,275	25
5	5,000	125	5,125	1,000	25	1,025	25

 Total **Fixed Cost (TFC)**

- Remains constant at ₹5,000 regardless of output.
- Represents costs that do not change with production, such as salaries, rent, and maintenance.

 Total Variable Cost (TVC)

- Increases by ₹25 for each additional unit produced.
- Reflects costs that vary with output, like operation and water regulation expenses.

 Total Cost (TC)

- Sum of TFC and TVC (TC = TFC + TVC).
- Increases as output increases, from ₹5,025 at 1 unit to ₹5,125 at 5 units.

 Average Fixed Cost (AFC)

- Calculated as TFC divided by output (AFC = TFC / Q).
- Decreases as output rises because the fixed cost is spread over more units:
  - ₹5,000 for 1 unit → ₹1,000 for 5 units.

 Average Variable Cost (AVC)

- Calculated as TVC divided by output (AVC = TVC / Q).

- Remains constant at ₹25 per unit, showing constant variable cost per unit.

 Average Cost (AC)

- Calculated as TC divided by output (AC = TC / Q).
- Decreases as output increases, from ₹5,025 at 1 unit to ₹1,025 at 5 units, due to falling AFC.

 Marginal Cost (MC)

- Cost of producing one additional unit (MC = change in TC / change in Q).
- Constant at ₹25 for each additional unit, matching the AVC.

Supply Decision by Producers

Producers make supply decisions based on their primary objective is profit maximization**.** Profit (π) is the difference between total revenue and total cost.

$$\boldsymbol{\pi} = \textbf{Revenue} - \textbf{Cost}$$

A producer aims to choose a level of output that maximizes profit. In a competitive energy market, this decision is influenced by the relationship between inputs, outputs, and costs.

Production Function

The production function describes the relationship between inputs used and output produced. It can be represented as:

$$Q = Q(K, L, E, M, t)$$

Where:

- K= Capital
- L= Labour
- E= Energy
- M= Material
- t= Time (used to capture the effect of technological progress)

In the short run, capital (K) is treated as a fixed input, while labour, energy, and materials are considered variable inputs. For example, in a power plant, the setup of the plant (capital) remains fixed, while the amount of fuel (energy) used to generate electricity can vary.

Two important productivity measures are derived from the production function:

1. **Average Productivity (AP)**

$$AP = \frac{Q}{E}$$

   It measures the output per unit of variable input (e.g., per unit of energy).

2. **Marginal Productivity (MP)**

$$MP = \frac{\Delta Q}{\Delta E}$$

   It measures the additional output produced by using one more unit of the variable input (energy), keeping other inputs constant.

As production increases, **MP** first rises, reaches a maximum, and then declines, showing the **Law of Diminishing Marginal Returns**.

Identification of Benefit

The main benefit of a project usually comes from the output that is sold in the market. If the output is incremental, meaning it adds only a small share compared to the overall market size, it does not influence the market price. In such cases, the project is treated as a *price taker*, especially when the product is tradable. However, for non-tradable goods, the supply is often non-incremental, and the project's output may affect the market price.

Some projects create both direct and indirect benefits. For instance, a dam not only generates electricity, irrigation water, or drinking water but can also provide recreational opportunities. Although these additional benefits are harder to measure in monetary terms, they must still be taken into account.

Project benefits can also arise from changes in **consumer surplus**, the gap between what consumers are willing to pay and what they actually pay. Only the portion that benefits society as a whole should be included. For example, if a hydropower project lowers electricity prices, demand rises, and consumer surplus is created. But since the price drop reduces revenue for the utility, this loss offsets part of the gain. Therefore, the **net surplus** is what should be considered (World Bank, 1996).

Methods of Cost-Benefit Comparison

Simple Payback Period (SPP) : The Simple Payback Period measures the time required to recover the initial investment through net annual benefits.

$$\text{SPP} = \frac{\text{Initial Investment}}{\text{Annual Benefit} - \text{Annual Cost}}$$

Return on Investment (ROI): ROI expresses the annual return as a percentage of the initial investment.

$$\text{ROI} = \frac{\text{Annual Net Cash Flow} \times 100}{\text{Initial Investment}}$$

Net Present Value (NPV): NPV measures the difference between the present value of benefits and the present value of costs.

$$\text{NPV} = \sum \frac{R_t - C_t}{(1+i)^t} - I_0$$

Here, $R_t$is revenue, $C_t$is cost, $i$is the discount rate, and $I_0$is initial investment.

If NPV > 0, the project is considered profitable.

Internal Rate of Return (IRR): IRR is the rate of return at which the NPV becomes zero.

$$\text{NPV} = 0 = \sum \frac{R_t - C_t}{(1+i)^t} - I_0$$

Supply Constraints

 Coal

- Coal continues to be the backbone of India’s energy sector, but its availability is facing multiple constraints.
- Although domestic production has risen (reaching **997.83 million tonnes in FY 2023–24**, an **11.71% increase** over the previous year), the demand for coal still exceeds domestic supply, forcing heavy reliance on imports (**264.53 million tonnes in 2023–24**).
- Environmental concerns, mining inefficiencies, and rising transportation costs add to the supply challenges.
- The long-term dependence on coal imports threatens energy security and exposes the economy to international price volatility.

 Lignite

- Lignite availability has shown a **declining trend**, with a **6.38% fall** in FY 2023–24 compared to the previous year.

- Its low calorific value and higher emissions make it less attractive, and production has stagnated.
- Limited reserves and growing environmental restrictions further constrain its future role in India’s energy mix.

 Crude Oil

- India faces a **serious supply constraint** in crude oil as domestic production has consistently declined over the years, with a long-term **CAGR of -2.67%**.
- In 2023–24, production was only **29.36 million tonnes**, while imports were **234.26 million tonnes**, reflecting a **high import dependency of around 90%**.
- This heavy reliance exposes India to external shocks, global price fluctuations, and geopolitical tensions.

 Petroleum Products

- Although domestic refining capacity has improved, petroleum product consumption continues to rise.
- Net imports have reduced due to increased refining, but India still depends on foreign crude for feedstock, creating a structural supply limitation.

 Natural Gas

- Domestic production of natural gas has increased moderately (**35.68 BCM in 2023–24**), but India still relies on imports (**31.80 BCM**).
- Import dependency for natural gas has been rising, and the supply is constrained by global LNG prices, infrastructure limitations, and domestic reserve depletion.

 Electricity

- Electricity generation has grown steadily (**7.25% increase in 2023–24**), but much of it is still coal-based.
- Supply constraints emerge from rising demand, transmission bottlenecks, and the pressure to decarbonize while ensuring reliable supply.

Role of Renewable Energy in Overcoming Supply Constraints

 Reducing Import Dependency

- Renewable sources like solar, wind, hydro, and biomass are **indigenous** and do not require imports, unlike crude oil and natural gas.
- With renewables contributing **190.57 GW (43.12%) of installed capacity** by March 2024, they are gradually reducing India's dependence on imported fossil fuels.

 Diversification of Energy Mix

- Renewables reduce overdependence on coal and oil, which are subject to both domestic and international supply uncertainties.
- Solar and wind are expanding rapidly, with solar capacity growing almost **20 times in nine years**.

 Enhancing Energy Security

- By harnessing abundant solar and wind potential, India can meet rising energy demand sustainably.
- Decentralized renewable systems, such as rooftop solar and solar pumps under PM-KUSUM, strengthen rural energy security and reduce grid pressure.

 Addressing Environmental and Social Constraints

- Non-renewables face rising environmental restrictions due to emissions, pollution, and land degradation.

- Renewables directly support India's climate commitments and contribute to the **SDG 7 (Affordable and Clean Energy)** and **SDG 13 (Climate Action)** targets.

- **Economic Benefits**
  - Renewable energy reduces the long-term cost burden of imports, stabilizes prices, and creates local employment opportunities.
  - Green Hydrogen, solar parks, and wind corridors are examples where renewables can substitute imported fuels.
- **Future Potential**
  - India targets **500 GW of non-fossil capacity by 2030**, positioning renewables as the primary solution to bridge the supply-demand gap.
  - With states like Gujarat, Rajasthan, Tamil Nadu, and Karnataka leading in RE capacity, renewables are becoming a regional growth driver.

Institutional Policies in the Energy Sector

1. **Central Coordination and Governance**
   - **NITI Aayog** plays a key inter-ministerial role in coordinating energy policy, planning, and data management across central and state levels.
   - The **draft National Energy Policy (NEP)** proposes an overarching framework for secure, sustainable, and affordable energy development
   - **Public Sector Undertakings (PSUs)** like NTPC, ONGC, and PowerGrid remain central actors. The government has reformed PSU governance for transparency, accountability, and efficiency by introducing

independent directors and greater decision-making autonomy

2. **Energy Efficiency Institutions**
    - The **Ministry of Power (MoP)** oversees energy efficiency through the **Bureau of Energy Efficiency (BEE)**, established under the **Energy Conservation Act (2001)**, amended in 2010.
    - States must establish **State Designated Agencies (SDAs)** and **State Energy Conservation Funds (SECFs)** for local implementation
    - **Energy Efficiency Services Limited (EESL)**, a joint venture of four PSUs, executes large-scale energy-saving programmes such as LED distribution (UJALA) and smart metering
3. **Research, Development & Innovation**
    - The government promotes innovation under **Mission Innovation (MI)** and **"Make in India"** initiatives to boost domestic manufacturing in solar PV, batteries, smart grids, and biofuels.
    - The **PM-STIAC (Prime Minister's Science, Technology and Innovation Advisory Council)** and the proposed **National Research Foundation** aim to coordinate energy R&D across ministries

Government Actions and Reforms

1. **Energy Market Reforms**
    - Opening up of **coal mining** and **oil and gas retail markets** to private players.

- Moving towards **market-based energy pricing** and reducing government allocation systems
- Development of a **countrywide wholesale power market** for real-time trading to improve efficiency and competition

2. **Renewable and Sustainable Energy**
    - Ambitious renewable targets: **175 GW by 2022**, expanding to **450 GW by 2030**.
    - Inclusion of **hydropower as renewable** under hydro purchase obligations.
    - National missions such as the **Smart Cities Mission**, **Atal Mission for Urban Rejuvenation and Transformation (AMRUT)**, and **Indian Cooling Action Plan (ICAP)** promote energy efficiency and sustainable urban infrastructure
3. **Energy Efficiency Programmes**
    - **Perform, Achieve, and Trade (PAT)**: market-based mechanism for energy-intensive industries.
    - **UJALA** LED scheme, **Smart Metering**, and **Standards & Labelling Programme**.
    - **Direct Benefit Transfer (DBT) for LPG (PAHAL)** and **#GiveItUp** campaign to rationalise subsidies, saving over USD 9 billion between 2013–2020
4. **Energy Security and Infrastructure**
    - Development of **strategic oil reserves** and diversification of supply routes.
    - Strengthening of the **national electricity grid** into "**One Nation, One Grid**".

- Greater focus on **system flexibility**, storage, and grid reliability to integrate renewable power.

5. **Data, Monitoring, and Transparency**
    - Creation of **cross-ministerial working groups** coordinated by NITI Aayog to enhance energy data collection and transparency.
    - Plans to establish a **national energy data management system** and platform for policy evaluation.

Conclusion

Energy availability plays a fundamental role in driving India's economic growth, social progress, and environmental sustainability. The country has shown steady progress in expanding energy production, particularly through coal and renewable sources like solar and wind power. However, challenges such as high import dependency on crude oil and natural gas, transmission losses, and environmental concerns persist. Economic analysis of energy investments helps ensure efficient allocation of resources and long-term sustainability. Strengthening domestic production, promoting renewable energy, and enhancing efficiency are crucial for achieving India's vision of energy security, inclusive development, and sustainable growth under the SDG framework.

Section – A

1. Define energy supply and production function.
2. Compare fixed and variable costs.
3. Mention constraints and challenges in energy supply.
4. Define energy availability and peak load.

5. Calculate energy supply in kWh (numerical).
6. Summarize fiscal incentives and price instruments.
7. Define marginal cost and cost of exploration.
8. State policies and challenges in Indian power sector.

Section – B

1. Explain challenges in energy supply and power sector reforms.
2. Examine policy instruments and fiscal incentives for renewables.
3. Analyze India's action plan for energy.
4. Illustrate energy supply and cost behavior (short run).
5. Discuss importance of renewable energy and limitations of non-renewables.

Section- C

1. Discuss challenges in renewable adoption and government incentives.
2. Illustrate sources, merits, and demerits of renewable energy.
3. Explain various costs in energy sector and fiscal incentives.

UNIT IV

ENERGY MARKET

In economics, a **market** is a mechanism that facilitates the exchange of goods and services between buyers and sellers. The way in which this market operates depends on its **structure**, which is defined by the number of participants, the nature of the product, and the degree of control that individual firms have over prices and output. This overall pattern of organization is known as the **market form** or **market structure**.

According to **S.C. Bhattacharyya (2011)**, understanding market forms is fundamental for analysing the behaviour of energy industries because the energy sector, unlike many other sectors—exhibits a wide range of market structures. Some segments (like crude oil) show elements of oligopoly, while others (like local electricity distribution) behave like natural monopolies. Therefore, before studying the specific characteristics of energy markets, it is important to understand the basic types of market forms recognised in economic theory. Four principal types of market forms, each differing in terms of competition, pricing power, and market efficiency:

1. **Perfect Competition:** This is the most idealized form of market structure. It assumes a large number of buyers and sellers, each too small to influence the market price. Products are homogeneous, information is complete, and firms can freely enter or exit the market. Under these conditions, both producers and consumers are **price takers**, and the equilibrium price is determined purely by the forces of demand and supply.Perfect competition leads to **allocative**

and productive efficiency, meaning that resources are used in the most optimal way and goods are sold at the lowest possible cost.

2. **Monopoly:** A monopoly exists when there is only one producer and many buyers. The monopolist controls the entire supply and can set prices to maximize profits, subject only to the demand curve. Entry of other firms is restricted by barriers such as large capital requirements, legal restrictions, or control over essential resources.
   In the **energy sector**, monopoly conditions are common in transmission and distribution networks (for example, national electricity grids or gas pipelines), where duplication of infrastructure would be inefficient.
3. **Oligopoly:** An oligopoly is a market with a few large firms, each aware that its actions affect others. Pricing and output decisions are interdependent, and firms often compete strategically.
   Energy markets such as global oil production, refining, and international gas trade typically exhibit oligopolistic features. A few dominant players like OPEC countries, coordinate production or pricing, influencing the entire market.
4. **Monopolistic Competition:** This market structure combines features of monopoly and perfect competition. There are many sellers, but each offers a slightly differentiated product, allowing limited control over prices. In the energy context**,** renewable energy providers or retail electricity suppliers offering different service packages may resemble monopolistic competition.

Features of a Perfectly Competitive Market

A perfectly competitive market is characterized by the following essential features:

1. **Large Number of Buyers and Sellers:**There are so many buyers and sellers that the action of any single participant cannot affect the market price. Every firm contributes only a small portion of the total supply.
2. **Homogeneous Product:** The goods offered by all firms are identical in quality and features. Consumers have no preference for one firm over another based on product differentiation.
3. **Free Entry and Exit of Firms:** Firms can freely enter or leave the market without any restriction. In the long run, this ensures that no firm can earn supernormal profits permanently.
4. **Perfect Knowledge:** Both buyers and sellers possess complete and accurate information about market conditions, prices, and production techniques.
5. **Price Takers:** Since no single firm has the power to influence price, each one accepts the prevailing market price determined by overall demand and supply.
6. **Mobility of Factors:** Factors of production such as labour and capital can move freely between firms and industries, ensuring efficiency in resource allocation.

Under these conditions, prices in a perfectly competitive market are determined purely by the forces of **demand and supply**, ensuring that resources are used in the most efficient manner possible.

In a **perfectly competitive energy market**, each firm is considered a **price taker**. This means that an individual firm cannot influence the prevailing market price of energy; it must accept the market-determined price and adjust its **level of output** to maximize profit. In the **short run**, the number of firms operating in the energy sector and the size of their plants remain fixed. Energy producers—such as small independent power producers or renewable energy firms—can increase their output only by using more **variable inputs** such as labour, raw materials, or fuel. Entry of new firms or exit of existing ones is not possible in the short run because of fixed infrastructure and regulatory commitments.

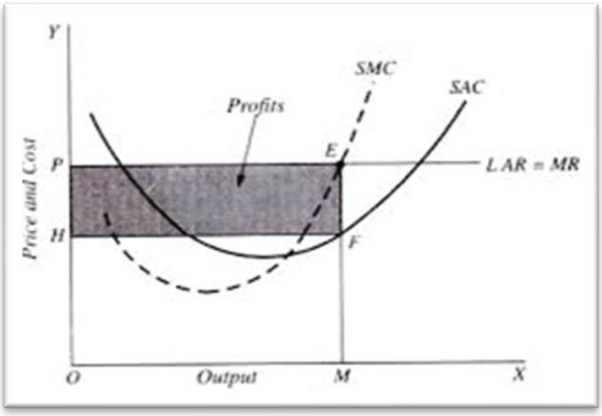
Therefore, in the short run, an energy-producing firm operating under perfect competition can experience one of the following three outcomes:

1. **Supernormal Profit**
2. **Normal Profit**
3. **Loss**

In the short run, three situations may arise:

1. **Normal Profit:** When $P = MC = AC$, the firm covers all its costs, including opportunity costs. This ensures long-run stability.
2. **Supernormal Profit:** When $P > AC$, the firm earns profits above the normal level. These arise due to innovation, favourable market conditions, or risk-bearing.
3. **Loss:** When $P < AC$, the firm incurs losses. However, as long as $P \geq AVC$, the firm continues production to minimize losses by covering variable costs.

In energy production, supernormal profits may occur temporarily due to new technology, efficiency gains, or sudden market shortages, but in the long run, these tend to normalize.

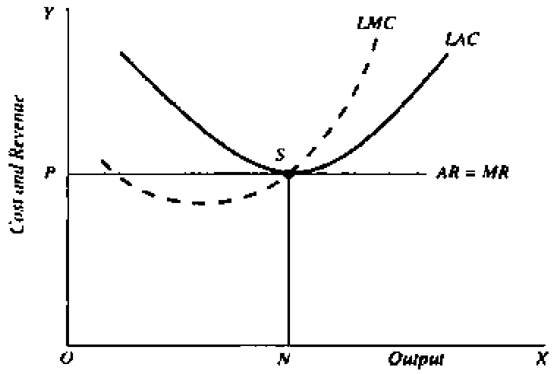


In the long run, all factors of production become variable, and firms can freely enter or exit the market. If firms in the industry are making **supernormal profits**, new firms are attracted to the market. The increase in supply causes the market price to fall. Conversely, if firms are making losses, some firms will exit the market, reducing supply and raising prices.

Equilibrium is achieved when:

$$\boldsymbol{P = MC = AC_{\min}}$$

At this point, all firms earn only **normal profits**. The long-run supply curve in a perfectly competitive industry is **horizontal** at the equilibrium price P^*, showing that supply is perfectly elastic at that level. The equilibrium output depends on overall market demand.



This situation represents **productive efficiency** (firms produce at the lowest possible cost) and **allocative efficiency** (resources are allocated in a way that maximizes social welfare).

Case Study: 1

Suppose a producer produces in a perfectly competitive market. The cost of production in the short run is given by $C(Q)= 50+Q^2$.

a. What are the short-run average cost, short-run average variable cost and short-run marginal cost?
b. If the price of the product is Rs 20 /-, what should be the optimal level of production? What is the profit?

Solution: Here, the **Total Fixed Cost** is 50 and the **Total Variable Cost** is Q^2.
Thus,

- **AFC** = 50 / Q
- **AVC** = Q
- **AC** = (50 / Q) + Q
- **MC** = 2Q

If the price of the product is Rs. 20, the firm will produce where **P = MC**,
so 20 = 2Q ⇒ **Q = 10.**
At this output, AC = (50 / 10) + 10 = 5 + 10 = 15.
Since **P > AC**, the firm earns **supernormal profit**.
Profit = (P − AC) × Q = (20 − 15) × 10 = **Rs. 50.**
Hence, the firm produces 10 units and earns Rs. 50 as economic profit.

Case Study: 2

Suppose there are two firms supplying in the competitive market (this can be extended for n firms without loss of generality) whose Marginal Cost functions are $MC_1\ Q_1 = Q_1 + 10$ and $MC_2\ Q_2 = 0.8Q_2 + 14$

If price is equal to P= 20, then what is the market output? How much will each firm produce?

Solution:

At equilibrium, $P = MC1\ Q1 = MC2\ Q2$

$P = MC1\ Q1$ implies $20 = Q1 + 10$ i.e. $Q1 = 10$

$P = MC2\ Q2$ implies $20 = 0.8\ Q2 + 14$ i.e. $Q2 = 7.5$

Industry output = 17.5

Case Study 3

A firm operates in a perfectly competitive market where the total cost of production in the short run is given by **$C(Q) = 100 + 4Q + Q^2$.**

Here, the **Total Fixed Cost (TFC)** is 100 and the **Total Variable Cost (TVC)** is $4Q + Q^2$. Therefore,

- **Average Fixed Cost (AFC)** = $100 / Q$
- **Average Variable Cost (AVC)** = $4 + Q$
- **Average Cost (AC)** = $(100 / Q) + 4 + Q$
- **Marginal Cost (MC)** = $4 + 2Q$

Under perfect competition, a firm maximizes profit when **Price = Marginal Cost**.

If the market price (P) is Rs. 24, then: $24 = 4 + 2Q \Rightarrow 2Q = 20 \Rightarrow$ **$Q = 10$**

At this output, $AC = (100 / 10) + 4 + 10 = 10 + 4 + 10 = 24$. Since **Price = AC**, the firm earns **normal profit** — it neither makes profit nor incurs loss.

Why the Energy Market is Not Perfectly Competitive - Discussion

The reasons why the structure and characteristics of the energy sector prevent it from being perfectly competitive. Unlike industries that easily adjust output or entry, the energy sector faces several rigidities that cause deviations from the assumptions of perfect competition.

1. Indivisibility of Capital : Investment in the energy sector is **lumpy in nature**. This means that capacity expansion cannot be done in small or continuous amounts—it happens in large, discrete units according to the size of the plant or facility. For example, in the case of coal mines, oil fields, refineries, and power plants, the entire capacity is added in large chunks rather than small incremental changes. As a result, the **supply curve becomes discontinuous**.

A real example is **the Singrauli plant of NTPC**, which has an installed capacity of 2000 MW distributed across seven units, each ranging between 200 MW and 500 MW. Such indivisibility makes it impossible to increase output continuously in response to small changes in price or demand.

2. Boom–Bust Cycles : Because investment occurs in large units, it can lead to **periods of excess capacity** followed by shortages. This cyclical pattern is called a **boom–bust cycle**.

For instance, during the shale boom in the United States, the year 2017 marked the first time since 1957 that natural gas exports exceeded imports. However, despite optimistic forecasts by major companies like Shell and ExxonMobil, the global natural gas market soon faced a glut of Liquefied Natural Gas (LNG). This oversupply pushed prices downward as producers from countries such as Qatar, Australia, Russia, Iran, and the U.S. competed aggressively for market share.

Analysts, such as those from Statoil, identified this as a **classic boom–bust cycle**, where excessive investment during the boom period leads to low prices and a market correction later.

3. Asset Specificity and Capital Intensiveness: The assets used in the energy sector—such as oil rigs, refineries, and power plants—are **highly specific** to their particular use and have **very limited alternative applications**. For example, a power plant cannot easily be converted for another purpose, and oil field investments are tied to specific geographic and geological conditions.

Additionally, the **capital cost (fixed cost)** forms a major portion of total production costs in energy industries. Because of this, **economies of scale** are significant; as production increases, the average cost per unit decreases.

Consequently, firms in this sector often use **average cost pricing** instead of **marginal cost pricing**, since pricing only on marginal cost would not allow them to recover their large fixed costs. Once the investment is made, firms tend to treat the capital cost as a **sunk cost** and continue producing as much as possible, which may lead to **excess capacity and oversupply**.

4. Managing Indivisibility and Excess Capacity: The energy industry uses several strategies to manage indivisible capital and the problem of excess capacity:

- **Horizontal Integration:** This involves linking with other firms at the same stage of production through mergers, acquisitions, or even cartel formation. It has been widely used in the **oil industry**, allowing firms to share capacity and stabilize production.
- **Regulation:** In sectors like **electricity and other network industries**, government regulation plays a crucial role. Tariffs

are usually determined based on the **cost of providing energy**, including maintenance and operation of existing assets. Regulation helps ensure that firms cover their costs while preventing overproduction or price volatility.

Monopoly

The monopoly market structure often represents the **energy sector** more accurately than perfect competition. The energy industry tends to exhibit high entry barriers, significant fixed costs, and unique production characteristics that make it difficult for multiple firms to operate efficiently. A monopoly exists when a single firm dominates the market and controls the supply of a good or service. In such a case, the firm can charge a price higher than its marginal cost (P > MC). This situation is not unusual—for example:

- In the United States, the variable cost of making a medium pizza is about $1–$2, but the selling price is around $7.
- During the **1973 Oil Embargo**, the price of crude oil increased from $2 per barrel to nearly $12 as OPEC restricted supply.
- Similar pricing patterns are seen in copyright-based products like software or books, where producers have exclusive rights.

In India, **Coal India Limited** and **Indian Railways** have been classic examples of monopolies, as they were the sole suppliers in their respective industries for decades.

Causes of Monopoly

Monopoly power can emerge from several factors:

1. **Control over Key Resources :** When a firm owns a crucial resource, it can prevent others from entering the market. For example, in the late 19th century, the **De Beers** company in South Africa gained control over diamond mines and maintained dominance over the global diamond market for decades. Similarly, in India, **Coal India** controls most of the coal reserves, giving it monopoly power.
2. **Natural Monopoly and Production Process :** A natural monopoly arises when a single producer can supply the entire market at a lower cost than multiple producers could. This usually happens when **fixed costs are high** and **variable costs are low**, as seen in industries like power generation or pipelines.
   For instance, **Boeing** had a monopoly in the aircraft industry until the 1970s, when **Airbus** entered the market, creating a duopoly.

In energy sectors such as electricity, the large investment needed for generation, transmission, and distribution makes natural monopoly structures common.

Features of Monopoly

1. One Seller and Large Number of Buyers: The monopolist's firm is the only firm; it is an industry. But the number of buyers is assumed to be large.

2. No Close Substitutes: There shall not be any close substitutes for the product sold by the monopolist. The cross elasticity of demand between the product of the monopolist and others must be negligible or zero.

3. Difficulty of Entry of New Firms: There are either natural or artificial restrictions on the entry of firms into the industry, even when the firm is making abnormal profits.

4. Monopoly is also an Industry: Under monopoly there is only one firm which constitutes the industry. Difference between firm and industry comes to an end.

5. Price Maker: Under monopoly, monopolist has full control over the supply of the commodity. But due to large number of buyers, demand of any one buyer constitutes an infinitely small part of the total demand. Therefore, buyers have to pay the price fixed by the monopolist.

Price, Revenue, and Cost under Monopoly

In a monopoly situation, there is no difference between firm and industry. Therefore, under monopoly, firm's demand curve constitutes the industry's demand curve. Since the demand curve of the consumer slopes downward from left to right, the monopolist faces a downward sloping demand curve. It means, if the monopolist reduces the price of the product, demand of that product will increase and vice- versa.

So, for a monopolist

$\boldsymbol{TR = P\ Q * Q}$

$MR = dTR/\ dQ = P\ Q + P'\ Q * Q$

$AR = TR\ /\ Q = P\ Q$ = price charged by the monopolist

Thus, MR = AR + $P'\ Q * Q$

Since $P' Q < 0$, $MR < AR$

Similar to Perfect Competition, profit maximization implies:

• **Max π = TR - TC**

= [P Q ∗ Q] – C(Q)

FOC: $d\pi / dQ = 0$

$\Rightarrow [P\ Q + P'\ Q * Q]$ – MC =0

⇒ **MR =MC**

Also,

P(Q) –MC = $-P'\ Q * Q$

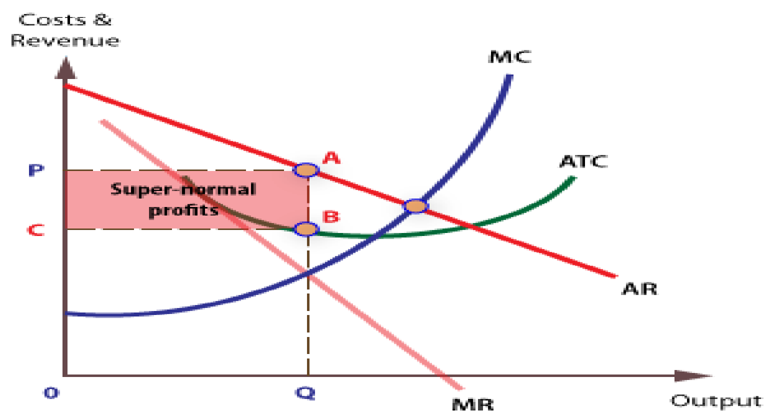
P(Q) – MC = - dP / dQ *Q

Dividing both sides by P, we get or mathematically, this condition leads to the relationship:

$$\frac{P - MC}{P} = \frac{1}{|\ e\ |}$$

where e is the price elasticity of demand, Therefore, lower the elasticity of demand, higher will be the power of the monopolist to charge more.

To represent it diagrammatically,



In the above diagram x- axis measures output and y axis measures cost and revenue. MC Curve cuts the MR curve at point E. AB is the profit from per unit of a commodity. The monopolist earns supernormal profit equal to the area CBAP. The Monopoly firm has come to equilibrium, and it is earning maximum profit. The monopoly price is higher than the marginal revenue and marginal cost. The equilibrium for the short period is also for the long period under monopoly as there will not be any competitor entering the field.

Profit and Loss under Monopoly

A monopolist does not always earn supernormal profits. If demand is weak or costs are high, the monopolist may incur losses even when it is the only seller. However, because entry barriers prevent new competitors, the monopolist can continue operating in the long run, often supported by regulation or government protection.

Case study: 4

Suppose the **demand function** for electricity in a regional market is given by: $Q = 150 - 2P$, where **Q** is the quantity of electricity (in megawatt-hours, MWh) and **P** is the price per MWh (in Rs.). The **cost function** of the firm is: $C(Q) = 200 + Q^2$. Find the price and quantity solution for perfect competition and monopoly.

Solution: For a Monopoly

From the demand equation, we can express price as a function of quantity:

$$P = 75 - 0.5Q$$

The **Total Revenue (TR)** is therefore:

$$TR = P \times Q = (75 - 0.5Q)Q = 75Q - 0.5Q^2$$

Differentiating TR with respect to Q gives the **Marginal Revenue (MR):**

$$MR = 75 - Q$$

Differentiating the cost function gives the **Marginal Cost (MC):**

$$MC = 2Q$$

At the profit-maximizing point, **MR = MC**, hence:

$$75 - Q = 2Q \Rightarrow 3Q = 75 \Rightarrow Q_m = 25$$

Substituting this back into the demand function gives the **monopoly price**:

$$P_m = 75 - 0.5(25) = 75 - 12.5 = 62.5$$

Thus, the **monopolist** produces **25 MWh of electricity** and charges **Rs. 62.50 per MWh**.

Total Revenue (TR) = 62.5 × 25 = Rs. 1,562.50

Total Cost (TC) = 200 + $(25)^2$ = 200 + 625 = Rs. 825

Profit = TR − TC = 1,562.50 − 825 = Rs. 737.50

The firm therefore earns a **supernormal profit of Rs. 737.50**.

For Perfect Competition

Under perfect competition, firms are price takers and must produce where

P = MC.

So,

$$75 - 0.5Q = 2Q \Rightarrow 2.5Q = 75 \Rightarrow Q_{pc} = 30$$

Substituting this into the demand function gives the market price:

$$P_{pc} = 75 - 0.5(30) = 75 - 15 = 60$$

Therefore, under perfect competition, firms will produce **30 MWh** and sell at **Rs. 60 per MWh**.

Total Revenue = 60 × 30 = Rs. 1,800

Total Cost = 200 + $(30)^2$ = 200 + 900 = Rs. 1,100

Profit = 1,800 − 1,100 = Rs. 700

Thus, under perfect competition, the firm earns a **normal profit of Rs. 700**, which is slightly lower than the monopoly profit.

Price Discirmination – Monopoly

Price discrimination in the energy sector refers to the practice of charging different prices for the same form of energy to different consumers, not because of cost differences but due to variations in their ability or willingness to pay. It is common in electricity, gas, and fuel markets and is used to recover high fixed costs, manage demand, and promote equity among users.

In **first-degree price discrimination**, an energy supplier charges each consumer the maximum price they are willing to pay. This form is rare in practice but is becoming possible with smart meters and data-based billing, where large industrial consumers often negotiate customized contracts.

Second-degree price discrimination occurs when energy companies offer different tariff options based on the quantity or timing of consumption. Examples include block tariffs in electricity pricing and time-of-use rates where prices are lower during off-peak hours and higher during peak periods.

Third-degree price discrimination involves dividing consumers into groups based on demand elasticity or social category and charging different prices. For instance, electricity boards charge lower rates for residential and agricultural users but higher rates for commercial and industrial consumers. This method is widely used to ensure fairness and financial sustainability in the energy market.

Natural Monopoly

A natural monopoly arises when a single firm can supply the entire market demand for a good or service at a lower cost than two or more competing firms could. This situation typically occurs when there are **strong economies of scale** that is, when the average cost of production continues to fall as output increases. In the context of energy economics, natural monopolies are common in industries such as **electricity transmission and distribution, natural gas pipelines, and water supply networks**. These sectors require very large, indivisible capital investments, and duplicating such infrastructure by multiple firms would be inefficient and wasteful.

The main features of a natural monopoly are:

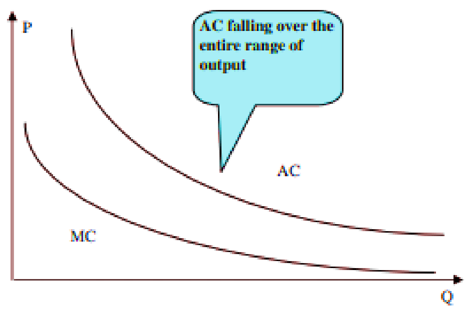
1. **High Fixed Costs and Low Marginal Costs:** The initial setup such as building power grids, pipelines, or refineries requires huge investment, but once the infrastructure exists, the cost of supplying an additional unit of energy is relatively low.
2. **Economies of Scale:** As production expands, the **average cost** of supplying energy continues to decline. Hence, one large producer can meet market demand at a lower cost than several smaller firms.
3. **Indivisibility of Infrastructure:** Energy networks and grids are **capital-intensive and technically indivisible**. Duplicating them for competition would lead to inefficient use of national resources.

4. **Barriers to Entry:** Because of the high capital and technical requirements, new firms find it difficult to enter the market, creating a situation where one firm dominates naturally.
5. **Public Interest Role:** Energy is an essential commodity. Hence, natural monopolies are often **publicly owned, regulated, or closely supervised** to prevent abuse of monopoly power and ensure universal service access.

Types of Natural Monopolies

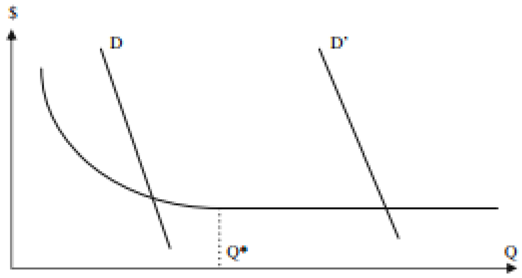
Natural Monopolies are of two types one is Permanent Natural Monopoly and Temporary Natural Monopoly

A **permanent natural monopoly** exists when a single firm can supply the entire market demand at a lower cost than two or more firms. In this case, the **long-run average cost (AC) declines continuously** over the full range of output, and the marginal cost (MC) also decreases. This means that, irrespective of the size of market demand, it is always least-cost for one firm to produce the good or service, making competition unnecessary. Permanent natural monopolies typically arise in industries with high fixed costs and significant economies of scale, where splitting production among multiple firms would increase overall costs. This is illustrated as



The average cost (AC) curve falls continuously over the entire range of output, indicating that a single firm can produce all output at the lowest possible cost. **The** marginal cost (MC) curve also declines, showing increasing efficiency with higher production. Multiple firms would face higher costs.

Temporary natural monopoly occurs when average costs fall only over a limited range of output. Beyond a certain level of production, called Q^*, the AC becomes constant, allowing a competitive market to emerge if demand exceeds Q^*. This is illustrated as:



The graph shows a perfectly elastic supply curve (horizontal) and two demand curves, D and D'. The equilibrium quantity is Q*, determined where demand intersects supply. A shift from D to D' indicates increased demand, potentially raising equilibrium quantity while price remains constant due to the perfectly elastic supply.

Cost and Output Determination

In a natural monopoly, the **Average Cost (AC)** curve continuously falls over the relevant range of output due to increasing returns to scale. The **Marginal Cost (MC)** lies below the AC curve. If the monopolist is left unregulated, it will choose to produce the quantity where **Marginal Revenue (MR) = Marginal Cost (MC)** and set a price above that level, leading to **higher prices and**

restricted output. However, because energy is a **public good**, such outcomes are not socially desirable. Hence, **regulation** or **public ownership** is required to align the monopolist's output and pricing decisions with social welfare goals.

Regulation of Natural Monopolies

Bhattacharyya emphasizes that **government intervention** is essential in natural monopoly sectors to protect consumer interests and promote efficiency. Common methods of regulation include:

1. **Price Regulation (Rate of Return or Price Cap):** The government or regulatory authority sets a limit on the price or profit margin the monopolist can charge.
   - **Rate-of-return regulation** allows firms to earn a fair return on investment.
   - **Price-cap regulation (RPI – X)** sets an upper limit on price increases, encouraging cost reduction and efficiency.
2. **Public Ownership or State Control:** In many developing countries, electricity and gas networks are owned by the government to ensure equitable access and affordability.
3. **Unbundling and Competition in Segments:** Modern reforms often separate natural monopoly activities (like transmission and distribution) from competitive segments (like generation and retail) to increase efficiency. For example, in electricity markets, generation and retail may be open to competition, while transmission and distribution remain regulated monopolies.

4. **Independent Regulatory Bodies:** Establishing independent regulators, such as the Central Electricity Regulatory Commission (CERC) or Petroleum and Natural Gas Regulatory Board (PNGRB**)** in India, ensures transparency, fairness, and accountability in pricing and operations.

Two-Part Tariff Approach

In industries like electricity, marginal cost pricing can lead to financial losses because prices based solely on variable costs do not recover the large fixed costs. A **two-part tariff** system helps address this problem by charging:

1. A fixed fee to cover fixed or average costs, and
2. A variable charge per unit equal to the marginal cost.

For example, in **Chandigarh's electricity tariff (May 2019)**:

- 1–150 units: Rs. 2.75 per unit
- 151–400 units: Rs. 4.80 per unit
- 401 units and above: Rs. 5.20 per unit

This structure reflects both usage levels and cost recovery needs. In natural monopoly sectors, public ownership is often preferred to ensure fairness and prevent exploitation. For instance, until 2018, commercial coal mining in India was restricted to **Coal India Limited**, keeping the industry under government supervision.

Market Failure & Monopoly

Market failure refers to a situation in which the free market mechanism, i.e., the forces of demand and supply fails to allocate resources efficiently or does not lead to the best possible economic and social outcomes. In other words, market failure occurs when markets do not produce the quantity and type of goods and services that are most beneficial to society. Under perfect competition, it is assumed that markets operate efficiently and lead to maximum social welfare. However, in the real world, certain conditions such as monopoly power, externalities, lack of information, or public goods cause markets failures.

Causes of Market Failure

There are several key sources of market failure that are especially relevant in energy economics:

1. **Externalities**
    - **Negative externalities** occur when energy production or consumption imposes costs on others not reflected in market prices for example, air pollution, greenhouse gas emissions, or environmental degradation.
    - **Positive externalities** occur when benefits spill over to others — such as technological innovations in renewable energy that reduce overall carbon emissions.
    - Because markets ignore these effects, they tend to **overproduce goods with negative externalities** (like fossil fuels) and **underproduce goods with positive externalities** (like clean energy).
2. **Public Goods :** Energy-related goods like street lighting**,** national grids**,** and climate stability have public good characteristics they are non-rival and non-excludable. Private firms have little incentive to provide such goods since they cannot easily charge users, leading to under-provision.
3. **Imperfect Competition:** Energy markets often operate under monopoly or oligopoly conditions due to high entry barriers, economies of scale, or control over resources. When

firms have market power, they restrict output and charge higher prices than in competitive markets, causing inefficiency and welfare loss.

4. **Information Asymmetry:** Consumers and producers often have unequal information about energy products, prices, or technologies. For instance, consumers may not know the true efficiency of appliances or the long-term cost of energy use, leading to suboptimal choices.
5. **Natural Monopoly Conditions:** In sectors like electricity transmission or gas pipelines, it is technically efficient for only one firm to operate. However, without regulation, a natural monopoly can misuse its market power, resulting in excessive pricing and under-supply.

Policy Implications to Overcome Market Failures

To overcome market failures arising from monopoly power, externalities, and inefficiencies, there is need for effective policy interventions that promote efficiency, fairness, and sustainability in the energy sector. The key policy measures and their implications are explained below:

Regulated competition should be promoted wherever feasible. In segments such as electricity generation or retail supply, allowing multiple players encourages efficiency, innovation, and cost reduction. However, in network activities like transmission and distribution, where natural monopoly conditions exist, government regulation must continue to prevent exploitation and ensure reliable service.

Transparency in tariff design is essential. Energy prices should reflect the true cost of production, transmission, and environmental compliance, ensuring both producer viability and consumer protection. Tariff structures must be equitable, with cross-subsidies or targeted support for low-income consumers. Transparent pricing also builds trust and helps attract private investment.

Promotion of renewable energy is vital to correct environmental externalities and achieve sustainable development. Policy incentives such as subsidies, tax benefits, feed-in tariffs, and green financing mechanisms can encourage investment in clean energy technologies and reduce dependence on fossil fuels.

C**onsumer information and awareness** should be strengthened to reduce information asymmetry. Educating consumers about energy efficiency, technology choices, and conservation practices enables informed decision-making and supports demand-side management.

C**arbon pricing or emission taxes** should be implemented to internalize the social and environmental costs of pollution. Such mechanisms encourage industries to adopt cleaner technologies and promote low-carbon growth.

Together, these policy interventions help achieve a balanced energy system that promotes economic efficiency, environmental sustainability, and social equity**,** ensuring that the benefits of energy development are widely shared across society.

Conclusion

Understanding market structures such as perfect competition, monopoly, oligopoly, and monopolistic competition is essential for analysing the functioning of energy markets. Unlike perfectly competitive markets, the energy sector faces unique challenges such as high capital intensity, indivisibility of infrastructure, and natural monopoly conditions. These characteristics make regulation crucial to ensure efficiency, affordability, and fairness. While monopolies and oligopolies dominate due to economies of scale and strategic behaviour, government intervention through price regulation, public ownership, and independent regulatory bodies ensures social welfare. Therefore, the study of energy market structures highlights the balance between economic efficiency and public interest.

Section – A

1. Define energy market and perfect competition.
2. Mention features and equilibrium of perfect competition.
3. Explain monopoly, price discrimination, and market failure.
4. Compare monopoly and perfect competition.
5. List causes of market failure and barriers to entry.
6. Define consumer welfare and inefficiency under monopoly.

Section – B

1. Explain short-run and long-run equilibrium under perfect competition.
2. Discuss non-competitive nature of energy markets.
3. Evaluate monopoly power and market failure.
4. Illustrate natural monopoly and competitive model in energy.
5. Explain government's role in correcting market failure.

Section – C

1. Examine firm behavior under perfect competition.
2. Analyze causes and consequences of market failure.

3. Discuss monopoly inefficiency and welfare loss.
4. Illustrate natural monopoly and equilibrium models.

UNIT – V
ENERGY PRICING

Energy pricing refers to the process of determining the monetary value of energy products and services such as electricity, petroleum, natural gas, coal, and renewable energy. Energy pricing plays a crucial role in balancing economic efficiency, social welfare, and environmental sustainability. It influences production, consumption, investment, and technological innovation in the energy sector.

Energy, being both a commodity and an essential service, requires pricing mechanisms that not only recover costs but also ensure affordability and encourage efficient use. Unlike ordinary goods, energy prices are shaped by multiple factors economic, political, environmental, and strategic. A well-designed energy pricing system promotes rational resource allocation, ensures financial viability of producers, and supports long-term energy security.

The objectives of energy pricing extend beyond profit-making. The key goals are as follows

1. **Economic Efficiency:** Prices should reflect the true cost of energy production and supply so that consumers make rational decisions and resources are not wasted.
2. **Cost Recovery and Financial Viability:** Energy prices must cover both operating and capital costs to ensure that producers and utilities remain financially sustainable.
3. **Equity and Social Welfare:** Affordable pricing ensures access to energy for all sections of society, especially low-income households, contributing to inclusive growth.

4. **Encouraging Energy Conservation:** Rational pricing discourages excessive energy use and promotes efficiency and environmental protection.
5. **Sustainability and Investment Promotion:** Prices should provide sufficient returns to attract investment in infrastructure, renewable energy, and technological improvements.

In short, energy pricing is not merely a financial decision it is a policy tool for achieving energy security, economic growth, and environmental balance.

Factors Influencing Energy Pricing

Energy prices are determined by a combination of **economic, technical, and policy-related factors**. Bhattacharyya identifies the following major influences:

1. **Cost of Production:** Includes exploration, generation, refining, and transportation costs. High capital intensity in energy industries significantly affects prices.
2. **Market Structure:** Competitive markets (like fuel retailing) behave differently from monopolistic ones (like electricity distribution).
3. **Government Policy and Regulation:** Taxes, subsidies, price controls, and environmental standards directly impact energy pricing decisions.
4. **International Energy Prices:** For traded fuels such as oil and gas, domestic prices are influenced by global market trends and exchange rates.
5. **Resource Availability:** The scarcity or abundance of domestic energy resources affects cost and pricing strategies.

6. **Environmental and Social Costs:** Pollution, carbon emissions, and land-use impacts must be reflected in prices through taxes or environmental charges.
7. **Demand and Seasonal Variation:** Fluctuations in energy demand during peak and off-peak periods influence short-term pricing decisions.

Together, these factors make energy pricing a complex process requiring careful policy coordination and continuous adjustment.

Methods of Energy Pricing

Various pricing methods are used in energy markets depending on the policy objectives, market structure, and cost conditions. The key types are described below.

Average Cost Pricing : Average cost pricing involves setting the price equal to the **average cost (AC)** of producing and supplying energy. Under this method, the price per unit of energy is determined by dividing total cost (fixed and variable) by total output.

Formula:

$$P = \frac{Total\ Cost}{Total\ Output}$$

Advantages

- **Ensures Full Cost Recovery:** The method allows energy producers and utilities to recover the total cost of production, including fixed infrastructure and operating expenses, ensuring financial stability.

- **Simplicity and Ease of Implementation:** It is easy to calculate and apply since it is based on observable cost data rather than complex demand or marginal cost estimates.
- **Price Stability:** Average cost pricing avoids frequent price fluctuations, providing predictable prices for consumers and stable revenue for producers.
- **Fair Return to Producers:** It guarantees a reasonable return on investment, which is especially important for public utilities and regulated energy companies.
- **Encourages Long-Term Investment:** Since prices cover all costs, investors and public agencies are encouraged to invest in new capacity and infrastructure projects.

Disadvantages:

- **Lack of Efficiency:** Prices set at average cost do not reflect the true marginal cost of production, leading to inefficient allocation of resources.
- **No Incentive for Cost Reduction:** Producers may become inefficient because higher costs can simply be passed on to consumers through higher average prices.
- **Discourages Demand Management:** Consumers do not face signals to reduce consumption during high-cost periods, leading to wastage and peak load problems.
- **Ignores Market Signals:** Average cost pricing may result in overproduction or underproduction since it does not respond to real-time changes in demand and supply.
- **May Burden Consumers:** In cases of high fixed or capital costs (e.g., nuclear or hydro power), the average cost per unit can be very high, making energy less affordable.

b) Marginal Cost Pricing : Marginal cost pricing sets the price equal to the additional cost of producing one more unit of energy**.** This pricing ensures **economic efficiency** because consumers pay a price equal to the cost of the last unit produced.

Formula:

$$P = MC = \frac{\Delta TC}{\Delta Q}$$

Advantages:

- **Promotes Economic Efficiency:** Since price equals marginal cost, resources are allocated optimally, ensuring that energy is produced and consumed where it is most valued.
- **Encourages Rational Consumption:** Consumers adjust their usage according to real production costs, helping manage demand and reduce unnecessary energy consumption.
- **Reflects True Cost of Supply:** Especially in electricity or gas sectors, marginal cost pricing signals the real cost of producing the next unit, aiding better planning and grid management.
- **Encourages Competition and Innovation:** Firms are motivated to reduce costs and improve efficiency since they cannot rely on guaranteed cost recovery as in average cost pricing.
- **Supports Demand-Side Management:** Marginal cost pricing, especially when combined with peak and off-peak

rates, encourages consumers to shift usage, reducing system congestion.

Disadvantages:

- **Difficulty in Cost Recovery:** In industries with high fixed costs—like power generation or pipelines—marginal cost pricing may not recover total costs, leading to financial losses unless supported by subsidies.
- **Measurement Challenges:** Determining the exact marginal cost can be technically complex, especially when production involves multiple plants or technologies.
- **Price Volatility:** Marginal cost can change frequently with variations in demand, input costs, or system load, leading to unstable prices for consumers.
- **Unsuitable for Natural Monopolies:** For sectors like electricity transmission and gas networks, pricing at marginal cost may not cover long-term investment needs, threatening system reliability.
- **Requires Government Intervention:** To balance efficiency with financial viability, governments may need to introduce two-part tariffs (fixed and variable charges) or provide targeted subsidies.

c) Long-Run Marginal Cost Pricing : Long-run marginal cost (LRMC) pricing considers the cost of expanding capacity to meet future demand over time. It includes not only short-run operational costs but also long-term capital and investment costs. LRMC pricing is especially useful for sectors like electricity and natural gas**,** where capacity planning and infrastructure investment are critical. It ensures financial sustainability and promotes efficient long-term expansion of the energy system.

d) Cost-Plus Pricing : Cost-plus pricing sets the energy price by adding a fixed profit margin or return to the total cost of production. It is commonly used by state-owned utilities and regulated industries and ensures guaranteed returns for producers.

Formula:

Price = Total Cost + Profit Margin

Limitations:

- Reduces efficiency incentives.
- Can encourage cost padding or over-investment since profits are assured.

e) Administered Pricing : Administered pricing refers to prices fixed or controlled by the government or regulatory authority**,** rather than by market forces. For example: Petroleum product prices and electricity tariffs in India are often administered to protect consumers and stabilize inflation.

- **Protect Consumers:** Ensures that households, especially low-income groups, have access to affordable energy.

- **Control Inflation:** By stabilizing energy prices, administered pricing helps prevent sudden increases in production costs and inflation in the broader economy.
- **Promote Equity:** Prevents energy costs from disproportionately affecting poorer sections of society.
- **Support Strategic Sectors:** Encourages the availability of energy for critical sectors such as agriculture, transport, and industry.
- **Stabilize the Energy Market:** Helps avoid extreme price fluctuations caused by international market volatility, speculative behavior, or supply shocks.

Advantages:

- Protects consumers from volatile global energy prices.
- Encourages equitable energy access and social welfare.
- Can support long-term energy planning and infrastructure investment.

Disadvantages:

- May lead to financial for energy producers if prices are kept below market levels. losses
- Encourages overconsumption due to artificially low prices.
- Can create fiscal burdens on the government through subsidies.
- Reduces incentives for efficiency and the adoption of alternative energy source

f) Import Parity Pricing (IPP) : Import parity pricing is the **price that would prevail if the product were imported**, including international price, freight, insurance, and customs duties. It is used to align domestic energy prices with global market trends and ensure competitiveness.

g) Export Parity Pricing (EPP) : Export parity pricing reflects the price domestic producers would receive if they exported their products, net of transport and export charges. EPP is applied when domestic producers also export energy products, ensuring fair domestic pricing relative to international markets.

h) Opportunity Cost Pricing: Opportunity cost pricing sets energy prices based on the value of the next best alternative use of the resource. If natural gas can be used for electricity generation or sold as LNG abroad, its domestic price should reflect its export value. It ensures rational resource allocation and efficient use of scarce energy sources.

i) Peak Load Pricing: Peak load pricing involves charging higher prices during periods of high demand (peak hours) and lower prices during low-demand (off-peak) periods. It encourages consumers to shift usage from peak to off-peak times, reducing strain on the energy system. For example: Electric utilities may charge higher tariffs during daytime hours and lower rates at night.

Principle of Peak Load Pricing

The principle of peak load pricing is used in energy economics to determine electricity prices based on the demand pattern during different periods of the year. The price is higher during peak demand periods and lower during off-peak periods. This approach ensures that consumers pay according to the actual cost of supplying electricity, thereby promoting efficient use of resources and preventing overinvestment in capacity.

Consider an electric utility where the annual electricity demand can be divided into two distinct periods: **off-peak** and **peak**.

Off-Peak Period: During off-peak hours, base load plants, such as coal or nuclear power plants, supply electricity. The fixed cost per kilowatt of capacity for these plants is denoted by a, and the variable running cost per hour is denoted by f. Let the base load capacity be Xkilowatts. The cost of supplying 1 kW of base load capacity for $h$hours is given by the formula:

$$\boldsymbol{y = a + f \cdot h}$$

Peak Period: During peak hours, additional peaking plants are used to supplement the electricity supply. These plants have a fixed cost per kilowatt of capacity $b$and a running cost per hour g. The total load during peak periods is Ykilowatts, which means the peak load capacity is $Y - X$kilowatts. The cost of supplying 1 kW of peak capacity for $h$hours is:

$$\boldsymbol{z = b + g \cdot h}$$

It is usually assumed that $a > b$and $f < g$, reflecting the higher fixed cost but lower running cost of base load plants compared to peaking plants.

The number of hours during which the peaking plant operates can be determined by equating the cost of base load and peak plants:

$$\boldsymbol{y = z \implies H = \frac{a - b}{g - f}}$$

This calculation identifies the duration $H$for which peaking plants are economically justified.

The total annual cost of electricity supply, including both base load and peaking plants, is given by:

$$\boldsymbol{C = X \cdot a + f \cdot X \cdot T + (Y - X) \cdot (b + g \cdot H)}$$

where T is the total number of hours in a year, typically 8760 hours.

j) Off-Peak Pricing: Off-peak pricing refers to lower tariffs charged during periods of low energy demand**.** It helps in better utilization of existing capacity and promotes load balancing across the energy system.

Pricing under Supply Constrained Framework

When energy supply is constrained, prices are influenced by multiple interrelated factors. Understanding these determinants is crucial for policymakers, energy companies, and consumers.

1. Resource Availability: The most fundamental factor is the physical availability of energy resources. Non-renewable sources such as coal, oil, and natural gas have limited reserves, and extraction capacity cannot always meet demand. Renewable sources may also face supply constraints due to geographic or technological limitations. Scarcity directly increases prices.

2. Demand Levels: Energy prices rise when demand exceeds supply. Seasonal variations, economic growth, population changes, and industrial activity influence energy demand. Peak periods, such as winters for heating or summers for electricity, see higher prices due to constrained supply.

3. Price Elasticity of Demand: Consumer responsiveness to price changes affects how prices adjust under scarcity. Inelastic demand, where consumers cannot easily reduce consumption, leads to sharp price increases. Energy products with elastic demand allow consumers to switch to alternatives, moderating price rises.

4. Production and Extraction Costs: Marginal costs of extraction, refining, and distribution determine the minimum price suppliers can accept. Under constraints, reliance on costlier sources raises the effective price.

5. Availability of Substitutes: Access to alternative energy sources, like renewable electricity or imported fuels, can reduce price pressure during scarcity.

6. Government Policies: Subsidies, taxes, price caps, and administered pricing can influence prices. Policies may moderate market effects but can also distort incentives for conservation.

7. Market Structure and External Factors: Monopoly or oligopoly markets can exploit scarcity for higher prices. External shocks such as natural disasters, geopolitical tensions, or infrastructure failures may temporarily reduce supply, increasing prices.

8. Expectations and Technology: Strategic stockpiling and expectations of future scarcity influence current pricing. Technological and infrastructure limitations in production, storage, and transmission also affect supply and pricing.

Challenges in Pricing of Energy Products

Pricing energy products is a complex task due to the interplay of economic, social, and technical factors. Energy markets face several challenges that make setting appropriate prices difficult.

1. Supply Constraints and Scarcity: Many energy resources, especially non-renewables like coal, oil, and natural gas, are limited. Extraction, transportation, and refining capacities are often insufficient to meet peak demand, leading to scarcity-driven price volatility.

2. Demand Fluctuations: Energy demand varies seasonally, daily, and with economic cycles. Sudden surges in demand during extreme weather, industrial growth, or population increases make it difficult to maintain stable prices.

3. Market Volatility: Global energy markets are highly volatile due to geopolitical tensions, natural disasters, international trade disruptions, and fluctuations in foreign exchange rates. These external shocks can lead to sudden and unpredictable price changes.

4. Price Elasticity of Demand: Energy products often have inelastic demand, especially for households and critical industries. Consumers cannot easily reduce usage in the short term, which amplifies price spikes when supply is constrained.

5. Government Policies and Subsidies: Administered pricing, price caps, and subsidies can distort market signals. While intended to ensure affordability and equity, they often create fiscal burdens, encourage overconsumption, and reduce incentives for efficiency.

6. Environmental and Social Considerations: Incorporating environmental costs, carbon taxes, or sustainability objectives complicates pricing. Balancing economic efficiency with social welfare and climate goals is challenging.

7. Infrastructure and Technology Limitations: Constraints in generation, storage, and transmission infrastructure limit the ability to respond to demand changes, affecting price stability.

8. Equity and Affordability Issues: Policymakers must ensure that prices are fair and affordable, especially for low-income households. Balancing equity with cost-reflective pricing remains a persistent challenge.

Role of Subsidies in Energy Pricing

Subsidies play a vital role in the energy sector, particularly in developing economies, where ensuring universal access to affordable energy is a key policy objective. A subsidy refers to a financial assistance or price support provided by the government to producers or consumers to make energy more accessible, affordable, and socially equitable. Subsidies are an important policy instrument used to correct market imperfections, promote renewable energy, and protect vulnerable groups from high energy prices. The Purpose of Energy Subsidies

a) Promoting Access to Basic Energy Services: In many countries, especially in rural and low-income regions, market-determined energy prices may be too high for poor households. Subsidies help reduce the cost of electricity, LPG, kerosene, and other fuels, enabling wider access to essential energy services such as lighting, cooking, and heating. This contributes to improved living standards and supports inclusive economic growth.

b) Encouraging Renewable Energy Development: Subsidies are also used to promote cleaner energy sources like solar, wind, and bioenergy, which may initially be more expensive than fossil fuels. By offering tax incentives, feed-in tariffs, or capital grants, governments can attract investment in renewable energy technologies, helping to diversify the energy mix and reduce greenhouse gas emissions.

c) Supporting Low-Income Consumers and Small Industries: Energy subsidies provide relief to economically weaker sections and small-scale industries that depend on affordable energy for their livelihood. Lower energy costs help sustain employment, enhance productivity, and reduce income inequality.

To ensure that subsidies achieve their intended outcomes without harming market efficiency, Bhattacharyya (2011) recommends that energy subsidies should be:

1. **Transparent:** The amount, beneficiaries, and duration of subsidies must be clearly stated in government budgets to promote accountability and reduce misuse.
2. **Targeted:** Subsidies should be directed only toward deserving consumers or sectors, such as rural households or renewable energy projects, rather than across-the-board price reductions.
3. **Temporary:** Subsidies should be time-bound, with a clear phase-out plan once their objectives such as technology adoption or social protection are achieved.
4. **Complemented by Structural Reforms:** In parallel, governments should focus on improving energy efficiency, expanding infrastructure, and developing competitive markets to gradually reduce dependence on subsidies.

<u>Types of Energy Subsidies</u>: Several forms of subsidies used in the energy sector:

- **Price Subsidies:** Direct reduction in consumer prices by setting tariffs below cost.
- **Production Subsidies:** Financial incentives to producers for generating or refining energy.
- **Tax Exemptions and Concessions:** Reduced taxes or duties on renewable energy equipment or fuels.

- **Capital Grants and Soft Loans:** Financial support for installing renewable or efficient technologies.

Each type of subsidy influences the cost structure, competitiveness, and investment decisions in the energy market.

Subsidies are a powerful policy tool in energy pricing, designed to promote social equity**,** economic development**,** and sustainability. However, if poorly designed, they can undermine efficiency, strain public finances, and distort markets. Therefore, as Bhattacharyya emphasizes, the challenge lies in balancing affordability with efficiency using transparent, well-targeted, and time-limited subsidies that support long-term energy security and environmental goals.

Tradability of Energy Products

Energy products can be traded both internationally and regionally. The tradable nature of these products affects the supply and demand curves of countries and influences pricing outcomes. Four specific scenarios arise depending on a country's energy situation:

1. **Self-Sufficient Country:** A self-sufficient country can meet its energy demand entirely from domestic sources without relying on imports or exports. In such cases, the relevant domestic price lies between the international **import parity price (Pm)** and **export parity price (Px)**.
2. **Importing Country:** An importing country supplements its domestic production with imports. For such a country, the **import parity price** determines the effective domestic price. Domestic production meets part of the demand (Qp), and the remaining demand ($Qc - Qp$) is met through imports.

3. **Exporting Country:** A net exporter sets the domestic price equal to the **export parity price (Px)**. The country produces Qpunits, consumes Qcunits domestically, and exports the remaining $Qp - Qc$.
4. **Importer without Domestic Resources:** A country with no indigenous energy resources relies entirely on imports. Its energy price is determined by the import parity price.

The underlying logic is that the price of a tradable energy good should reflect its opportunity cost, which is the value the good could fetch in the international market. The difference between import and export prices generally represents transport and handling costs. For globally traded products like oil, this difference is small. However, for products like coal or gas, transport costs can be significant, reducing tradability.

Economic Efficiency and Equity Considerations

Energy pricing and taxation are complex issues, especially when equity and efficiency need to be balanced. Some policymakers support subsidies for fuels used directly by poorer households to address equity concerns. However, implementing such subsidies is challenging. Three main issues arise: accurately targeting poorer sections of the population, delivering subsidies effectively without unintended consequences, and doing so at a low administrative cost. Because it is difficult to meet all these criteria simultaneously, many subsidy policies are criticized or avoided.

The theory of optimal commodity taxation initially focused only on efficiency, ignoring distribution. Early work by Ramsey considered only a single individual, aiming to minimize welfare loss from taxation. Later, Diamond and Mirrlees (1971) and Feldstein (1972) explicitly incorporated distributional equity into the analysis. Feldstein proposed a formula for determining optimal taxes, which depends on three factors: the own and cross price elasticities of goods, the distributional characteristics of the commodity (denoted by R), and the shadow price of the budget constraint (L). Necessities have higher R values than luxuries, implying lower mark-ups over marginal costs. When distributional characteristics are ignored, the formula reduces to the traditional Ramsey rule. When cross elasticities are zero, the optimal tax ratio is a product of an efficiency factor and a distributional equity factor. Computationally, this requires detailed information on each product's distributional attributes and the budget constraint's shadow price, making practical application challenging.

Energy Taxes and Subsidies

Subsidies can be defined as the difference between the price that would exist in a market in the absence of any distortion or market failures and the price actually faced by consumers at a given time. When market distortions or failures are present, a reference price is used instead of the market price to correct the problem. For traded goods, relevant border prices are considered appropriate reference prices in the absence of externalities. Subsidies often lead to several perverse consequences. They send incorrect price signals to consumers, encouraging over-consumption, which may be economically inefficient. Subsidies also divert scarce financial resources from other essential needs. They can hinder the development of alternative energy sources and may act as trade barriers.

Forms of Subsidies: Subsidies are provided in various forms. **Producer subsidies** reduce the cost of production, while **consumer subsidies** lower the price paid by end-users. In developed countries, fossil fuel subsidies often support specific indigenous fuels, such as coal in Germany and the UK, mainly to protect employment. Nuclear energy also receives substantial subsidies in many nations. Consumer subsidies are typically aimed at lower-income groups, but the revenue loss is often offset by higher taxes on other consumers. Developing countries, however, tend to provide subsidies more extensively, often across all income groups. Price controls remain the most commonly used method of intervention, but their effectiveness is limited because the benefits may not reach the intended groups.

Global Energy Subsidies: Fossil fuel subsidies are widespread in both developed and developing countries and have become a key topic in international discussions on sustainable development. According to Morgan (2007), global energy subsidies cost between USD 250 to 300 billion per year, net of taxes, which is equivalent to 0.6–0.7% of the world GDP. In developing countries, subsidies primarily aim to lower consumer prices, whereas in developed countries, subsidies are often directed toward producers. The total subsidies provided in developing nations dominate the global subsidy scenario.

Positive Role of Subsidies: Not all subsidies are harmful. When the social or environmental benefits of a subsidy exceed its cost, the subsidy can produce positive effects. For example, subsidies promoting renewable energy can encourage environmental sustainability and reduce dependency on fossil fuels.

Global Energy Market

The global energy market is undergoing a significant transformation driven by rising demand, geopolitical tensions, and the urgent need to transition to cleaner energy sources. Energy security has become a central concern, especially in the wake of conflicts such as the war in Ukraine, which have exposed vulnerabilities in global supply chains. Electricity demand is increasing rapidly due to economic growth, industrialization, and greater electrification across sectors. Renewable energy capacity is expanding at an unprecedented pace, but current growth rates are still insufficient to meet international climate targets. While global CO_2 emissions are expected to peak soon, a rapid decline is necessary to limit climate change impacts. Investment in clean energy technologies, including renewables, energy storage, and low-carbon fuels, is essential to ensure both sustainability and security. Policymakers worldwide face the challenge of balancing energy affordability, reliability, and environmental responsibility. Coordinated and ambitious policies are required to align energy security with climate objectives, promote the adoption of clean technologies, and strengthen resilience against supply disruptions. Overall, the global energy market is moving toward a more diversified and low-carbon future, but significant efforts are needed to accelerate the energy transition and achieve sustainable growth.

Energy Market in India

India's energy market has undergone significant transformation over the past decade, driven by robust policy support, infrastructure development, and a commitment to sustainability.

Here's an overview of the current landscape, key challenges, and government policies shaping the sector:

- **Installed Capacity**: As of June 2025, India's total installed power capacity reached 476 GW, with thermal power contributing 240 GW, solar 110.9 GW, and wind 51.3 GW.
- **Renewable Energy Growth**: Non-fossil fuel sources now account for 49% of the total capacity, comprising 226.9 GW of renewable energy and 8.8 GW of nuclear power.
- **Electrification Milestones**: India achieved 100% village electrification by April 2018 and has since connected over 2.8 crore households to the grid.

Key Challenges

1. **Infrastructure Constraints**: Despite significant capacity additions, transmission and distribution infrastructure in certain regions remain inadequate, leading to inefficiencies and power losses.
2. **Fuel Supply Dependencies**: The energy sector's heavy reliance on coal and natural gas imports makes it vulnerable to global market fluctuations and supply disruptions.
3. **Financing Renewable Projects**: While renewable energy investments have increased, securing financing for large-scale projects, especially in emerging technologies like offshore wind and green hydrogen, remains a challenge.
4. **Policy Implementation Gaps**: Despite ambitious targets, the pace of policy implementation varies across states, leading to disparities in renewable energy adoption and energy access.

Government Policies

- **National Green Hydrogen Mission (NGHM)**: Launched in January 2023 with a financial outlay of ₹19,744 crore, the NGHM aims to position India as a global leader in green hydrogen production, targeting 5 million metric tonnes per annum by 2030.
- **Pradhan Mantri Ujjwala Yojana (PMUY)**: This initiative has provided over 10 crore LPG connections to women from poor households, promoting health and environmental sustainability.
- **Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY)**: Focused on rural electrification, this scheme has been instrumental in achieving 100% village electrification and connecting millions of households to the grid.
- **Commercial Mining Policy**: Introduced in 2020, this policy has led to the allocation of 124 coal blocks, with 17 already operational, aiming to increase domestic coal production and reduce import dependency.

Regulations

India's energy market is governed by a comprehensive regulatory framework aimed at ensuring sustainable, affordable, and secure energy access. Below is an overview of the key regulations and policies shaping the sector:

- **Central Electricity Regulatory Commission (CERC)**: Regulates interstate electricity transmission, electricity trading, and determines tariff structures. It also oversees the implementation of market reforms and the introduction of new market products.

- **State Electricity Regulatory Commissions (SERCs)**: Function at the state level, regulating electricity distribution, retail tariffs, and ensuring compliance with national policies.
- **Bureau of Energy Efficiency (BEE)**: Under the Ministry of Power, BEE promotes energy efficiency and conservation across various sectors, implementing programs like the Perform, Achieve, and Trade (PAT) scheme.
- **Power Market Regulations, 2020**: These regulations govern the operation of power exchanges and over-the-counter markets, promoting transparency and efficiency in electricity trading.
- **Virtual Power Purchase Agreements (VPPAs)**: Introduced to facilitate renewable energy trading, allowing consumers to support renewable projects financially without physical delivery of power.
- **Cost-Reflective Tariffs**: The Power Ministry has proposed amendments to the Electricity Act to ensure that electricity pricing aligns with actual supply costs, aiming to reduce financial stress on distribution companies.

Legal Framework

- **The Electricity Act, 2003**: Serves as the cornerstone of India's electricity sector, promoting competition, protecting consumer interests, and ensuring the supply of electricity to all areas. It also facilitates the establishment of regulatory commissions and the rationalization of electricity tariffs.

- **Energy Conservation Act, 2001**: Empowers the BEE to implement energy conservation measures and sets standards for energy performance in various sectors.
- **National Action Plan for Climate Change (NAPCC)**: Outlines India's strategy to address climate change, including initiatives like the National Mission for Enhanced Energy Efficiency (NMEEE) and the National Solar Mission.

Conclusion

Energy pricing plays a vital role in ensuring economic efficiency, social equity, and environmental sustainability. It influences production, consumption, investment, and energy security across all sectors. A balanced pricing framework should reflect true production costs, encourage conservation, and promote renewable energy adoption while maintaining affordability for all. In India, effective regulation, transparent subsidies, and innovative policies such as the National Green Hydrogen Mission are driving the energy transition. However, challenges such as infrastructure limitations, price volatility, and financing gaps remain. Achieving a sustainable and equitable energy future requires coordinated policies, technological innovation, and continuous investment in clean energy systems.

Questions for Practice

Section – A

1. Define energy pricing, average and marginal cost pricing.
2. Explain import parity, cost-plus, and opportunity cost pricing.
3. Define peak load, off-peak, and administered pricing.

4. Mention reasons pricing is complex.
5. Differentiate between cost pricing methods.

Section – B

1. Explain pricing methods: average cost, marginal cost, import parity.
2. Discuss principles of peak load and long-run marginal cost pricing.
3. Analyze challenges in energy market and government regulation.
4. Evaluate energy product pricing and subsidies.

Section – C

1. Examine pricing methods and their pros/cons.
2. Discuss tradability, opportunity cost, and regulations in pricing.
3. Evaluate issues and challenges of Indian energy market.
4. Explain importance and challenges of energy pricing.

Case Studies for Practice

1.A ceiling fan of **75 W** runs for **4 hours**.

(a) Calculate the energy consumed in **Wh**.

(b) Convert the result into **kWh**

2. A refrigerator of **200 W** runs for **10 hours** per day.

(a) Find the total energy consumed in **Wh**.

(b) Convert it into **kWh**

3. A household uses the following electrical appliances in one day:

a. 2 LED bulbs (10 watts each) used for 5 hours
b. 1 fan (60 watts) used for 8 hours
c. 1 refrigerator (150 watts) running for 24 hours

Calculate the total energy consumed in kilowatt-hours (kWh) for that day.

4. A household consumes **200 units of electricity** per month when the price is ₹5 per unit.

- When the price rises to ₹6 per unit, their consumption falls to 180 units.
- At the same time, their monthly income increases from ₹30,000 to ₹33,000, and electricity use increases further to 190 units.

(a) Calculate the **Price Elasticity of Demand** for electricity.

(b) Calculate the **Income Elasticity of Demand** for electricity.

5. A family consumes **40 litres of petrol** per month when the price is ₹100 per litre.

- When the price decreases to ₹90 per litre, their petrol consumption rises to 44 litres.
- In the same period, their monthly income rises from ₹50,000 to ₹55,000, and petrol use increases to 46 litres.

(a) Find the Price Elasticity of Demand for petrol.
(b) Find the Price Elasticity of Demand for petrol.

6. A student hostel has the following daily electricity usage:

i.20 tube lights (40 watts each) used for 7 hours

ii. 15 ceiling fans (60 watts each) used for 12 hours

iii. 2 water heaters (2000 watts each) used for 2 hours

iv. 1 refrigerator (250 watts) used for 24 hours

(a) Calculate total daily energy consumption in kWh.

(b) Calculate the total energy consumption in a 30-day month.

(c) If the electricity cost is ₹5.50 per kWh, find the monthly electricity bill.

7. An industry uses 10 machines of 2 kW each for 8 hours daily. Calculate daily and monthly (30 days) energy consumption in kWh. Suggest one method of saving energy.

8. A case study: *In a developing country, energy demand is increasing rapidly. Discuss how renewable energy can be promoted to balance growth and environment.*

9. Suppose that Household energy demand is shifting from kerosene to LPG and electricity. Analyze the factors influencing this change.

10. A small hydro power plant has a **Total Fixed Cost (TFC) of ₹5,000 per month** for salaries, rent, and maintenance. The **Variable Cost per unit of electricity is ₹25 per unit** (mainly operation and water regulation expenses).

You are asked to calculate the following for output levels of **1, 2, 3, 4, and 5 units**:

1. **Total Variable Cost (TVC)** at each output.

- **Total Cost (TC)** at each output.

2. **Average Fixed Cost (AFC)**, **Average Variable Cost (AVC)**, and **Average Cost (AC)** at each output.
3. **Marginal Cost (MC)** between successive levels of output

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