Subject Code:21EEO304T
Subject Name: Energy Efficient Practices

Course Offered To: B. Tech 6th Semester Students

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Course Code	21EEO304T	Course Name	ENERGY EFFICIENT PRACTICES	Course Category	O	OPEN ELECTIVE	L	T	P	C
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Pre-requisite Courses	Nil	Co- requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Electrical and Electronics Engineering	Data Book / Codes / Standards		Nil	

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	interpret present energy scenario and purpose of energy efficiency in engineering and its application
CLR-2:	comprehend the concept of energy efficiency in electrical supply system and machines
CLR-3:	describe energy efficiency practices in various basic electric utilities
CLR-4:	inspect problems on lighting and DG systems to provide efficient solutions
CLR-5:	analyze energy scenario and efficient solutions in industrial sector

Course Outcomes (CO):	At the end of this course, learners will be able to:	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	apprehend energy scenario and efficiency opportunities	3	-	-	-	-	-	-	2	-	-	-	-	-	-	-
CO-2:	analyze efficiency of electrical supply system and energy saving methodologies	3	-	-	-	-	-	-	2	-	-	-	-	-	-	-
CO-3:	perform energy efficiency practices in electric utility systems through new technologies	3	-	-	-	-	-	-	2	-	-	-	-	-	-	-
CO-4:	design the efficient lighting and DG system	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-5:	examine industrial system to determine energy efficient potential	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Unit-1 - Energy Scenario	**9 Hour**
Introduction: Commercial and Non-commercial energy, primary and secondary energy resources, energy needs of growing economy, energy pricing, Energy Conservation Act-2001, Bureau of Energy Efficiency.	
Unit-2 - Electrical Supply System	**9 Hour**
Electrical supply system, components of AC power, Concept of sanctioned load, maximum demand, contract demand, and AC machines.	
Unit-3 - Energy Efficient Practices	**9 Hour**
Energy efficiency in electrical utilities, tips for energy saving, compressed air system, Energy saving opportunities in HVAC and refrigeration system, impact of Power Electronics in energy efficiency	
Unit-4 - Lighting and Distributed Generation Systems	**9 Hour**
Introduction, Basic definitions, Types of different lamps, design and their features, energy efficiency opportunities in lighting and distributed generation systems	
Unit-5 - Industrial Sector	**9 Hour**
Energy efficiency in industrial sector, main challenges to improve energy efficiency in industry, Energy Efficient Technologies, Industrial Automation, Industrial Sensors	

Learning Resources

1. Bose, B. K., "Global energy scenario and impact of power electronics in 21st century", IEEE Transactions on Industrial Electronics, 60(7), 2638-2651, 2012.
2. Hegger, M., Fuchs, M., Stark, T., & Zeumer, M., "Energy manual: sustainable architecture", Walter de Gruyter, 2012.
3. El-Hawary, M. E., "Electrical energy systems", CRC Press, second edition, 2018.
4. Malinauskaite, J., Jouhara, H., Ahmad, L., Milani, M., Montorsi, L., & Venturelli, M., "Energy efficiency in industry: EU and national policies in Italy and the UK. Energy", 172, 255-269, 2019.
5. Dobrotkova, Z., Lukas, A., Singh, J., "Energy Efficiency in Industry", World Bank Group, 2018.

Unit-1
Energy Scenario

- Commercial and Non-Commercial Energy
- Primary and Secondary Energy Resources
- Energy Needs of a Growing Economy
- Energy Pricing
- Energy Conservation Act-2001
- Bureau of Energy Efficiency (BEE)

Energy is a key component for most of the consumption activities and production activities and hence plays a vital role in a country's economic growth and development.

- It is essential for industries and is now widely utilized in agriculture and related fields such as the manufacture and delivery of fertilizers, insecticides, and farm equipment. It is also required in homes for cooking, lighting, and warmth.

There are two sources of energy; viz., **Commercial Energy** and **Non-commercial Energy**.

What is Commercial Energy?

The sources of energy which command a price and their users have to pay a price for them, are known as Commercial Energy. This type of energy is usually consumed by commercial entities and industries rather than by individuals or families. It is a non-renewable source of energy. Commercial Sources such as coal, petroleum, and electricity are bought and traded to users. The utilization of a commercial source of energy can be taken as a sign of the development of an economy.

What is non commercial energy?

The sources of energy which in general do not command a price, are known as Non-commercial Energy. People utilize this type of energy for domestic use. It shows a country's standard of living. Non-commercial energy is provided to users at no cost and is generally a renewable source of energy. For Example, Cow dung, firewood, agricultural waste, etc.

	Commercial energy	Non commercial energy
Meaning	The sources of energy which command a price and their users have to pay a price for them, are known as Commercial Energy.	The sources of energy which in general do not command a price, are known as Non-commercial Energy.
Utilization	The sources of energy that individuals utilize for commercial purposes.	The sources of energy that individuals utilize for domestic usage.
Indicator of	The utilization of commercial energy sources can be an excellent indicator of how well the economy of a country is doing.	The country's living standards can be determined by the usage of non-commercial energy sources.
Market	Commercial energy is traded in the market(domestic and international); i.e., a price is demanded for these goods.	Villagers often use non-commercial energy as free goods. At best, these goods have a local market. However, currently some of the non-commercial sources such as dried dung and firewood are charged a price in urban areas and are priced to some extent in rural areas as well.
Nature	It is generally an exhaustible source of energy (except hydropower).	It is generally a renewable source of energy.
Example	The main sources of commercial energy are coal, oil, natural gas, and hydroelectricity.	The main non-commercial energy sources include firewood, charcoal, cow dung, and agricultural waste.

Primary Energy Resources:

Primary energy resources are natural sources of energy that have not undergone any conversion or transformation process. They are extracted directly from nature and are used in their raw form. Examples include:

Fossil Fuels: Coal, crude oil, and natural gas.

Nuclear Energy: Energy released from nuclear reactions, usually from uranium or thorium.

Renewable Sources: Solar energy, wind energy, hydro energy, geothermal energy, and biomass.

Secondary Energy Resources:

Secondary energy resources are forms of energy that are derived from the transformation or conversion of primary energy sources. They are often more convenient for use, storage, and transportation. Examples include:

Electricity: Generated from primary sources like coal, natural gas, nuclear reactions, and renewables.

Refined Fuels: Products like gasoline, diesel, and kerosene, refined from crude oil.

Hydrogen: Produced from natural gas, water electrolysis, or other methods, used as a fuel or in fuel cells.

Key Differences

Source: Primary energy comes directly from natural sources, while secondary energy is derived from the conversion of primary energy.

Conversion Process: Primary energy doesn't require transformation, whereas secondary energy results from a conversion process.

End Use: Secondary energy is often more versatile and user-friendly compared to primary energy, which might need additional processing for practical applications.

Importance of energy for economic growth

Energy is absolutely essential for economic growth and development. Let's delve into why this is so important:

1. Industrial Production:

Energy powers factories, machinery, and production processes. Without a reliable energy supply, industrial activities would slow down or halt, affecting the production of goods and services.

2. Transportation:

Efficient transportation networks, which are vital for moving goods and people, rely heavily on energy sources like petroleum, electricity, and natural gas. This connectivity is critical for trade, commerce, and overall economic efficiency.

3. Infrastructure Development:

Building and maintaining infrastructure such as roads, bridges, airports, and buildings require significant energy input. A growing economy needs continuous infrastructure development to support its expansion.

4. Technological Advancements:

Innovation and technological progress often depend on energy availability. High-tech industries, research and development, and digital services all need substantial energy to operate and thrive.

6. Urbanization and Modernization:

As economies grow, urbanization increases, leading to higher energy consumption for residential, commercial, and public services. Modern amenities and improved living standards are closely tied to energy availability.

7. Agricultural Development:

Modern agriculture relies on energy for irrigation, machinery, processing, and transportation. Energy-intensive farming techniques can lead to increased agricultural productivity and food security.

Examples:

China: Its rapid economic growth has been closely linked to increased energy consumption, with significant investments in both traditional and renewable energy sources.

India: The country's economic development has been supported by expanding its energy infrastructure, including large-scale solar and wind energy projects.

Challenges faced by growing economies in meeting energy demands

Meeting the increasing energy demands of growing economies presents several challenges:

1. Energy Security:

Dependency on Imports: Many growing economies rely heavily on imported energy sources, making them vulnerable to global supply disruptions and price volatility.

Diversification of Sources: Finding a balanced mix of energy sources to reduce dependency on any single type or supplier can be difficult.

2. Infrastructure Development:

Aging Infrastructure: Existing energy infrastructure may be outdated and inefficient, requiring significant investment for upgrades and expansion.

Funding: Securing the necessary capital for developing and maintaining energy infrastructure can be a major hurdle.

3. Technological Constraints:

Access to Advanced Technology: Growing economies may lack access to the latest energy technologies, hindering their ability to improve efficiency and reduce emissions.

R&D Investment: Limited resources for research and development can slow down innovation and the adoption of new energy solutions i.e. advanced solar panels.

4. Environmental Impact:

Pollution and Emissions: Rapid industrialization often leads to increased pollution and greenhouse gas emissions, posing environmental and public health challenges.

Sustainable Practices: Balancing economic growth with sustainable energy practices is a complex task, requiring policies and incentives to promote clean energy.

5. Energy Pricing:

Affordability: Ensuring that energy remains affordable for all segments of the population while covering the costs of production and distribution is a significant challenge.

Subsidies: Balancing the need for energy subsidies to support vulnerable populations with the financial burden they place on government budgets.

6. Access and Equity:

Rural Electrification: Expanding energy access to remote and rural areas can be logistically and economically challenging.

Energy Poverty: Addressing energy poverty, where households lack access to reliable and modern energy services, is crucial for inclusive growth.

Examples:

- **India:** Balancing rapid economic growth with sustainable energy development, while addressing issues like energy access and pollution.
- **Brazil:** Expanding renewable energy capacity (e.g., hydropower) while dealing with infrastructure challenges and environmental concerns.
- **Nigeria:** Leveraging vast natural resources to meet energy demands while addressing issues of infrastructure, regulation, and security.

Addressing these challenges requires a comprehensive strategy that includes investment in infrastructure, technological innovation, sustainable practices, effective policies, and international cooperation.

Energy Pricing

Energy pricing is a critical aspect that influences both consumers and the economy. It reflects the cost of producing and delivering energy, as well as various external factors.

Components of Energy Pricing

Production Costs:

- **Extraction and Production:** Costs associated with extracting fossil fuels, generating electricity, or producing renewable energy.
- **Capital Investment:** Initial investments in infrastructure, technology, and facilities.
- **Operation and Maintenance:** Ongoing costs for running and maintaining energy plants and equipment.

Transportation and Distribution:

- **Infrastructure:** Costs for building and maintaining pipelines, transmission lines, and distribution networks.
- **Transmission Losses:** Energy lost during transportation from production sites to consumers.

Types of Energy Pricing

1. Fixed Pricing:

I. **Advantages:** Predictable and stable costs for consumers.

II. **Disadvantages:** May not reflect current market conditions, potentially leading to higher costs over time.

2. Variable Pricing:

I. **Advantages:** Reflects real-time market conditions, potentially lower costs when demand is low.

II. **Disadvantages:** Unpredictable and can lead to higher costs during peak demand periods.

3. Tiered Pricing:

I. **Advantages:** Encourages energy conservation by charging higher rates for higher usage levels.

II. **Disadvantages:** Can be complex and difficult for consumers to understand.

4. Time-of-Use Pricing:

•**Advantages:** Encourages consumers to use energy during off-peak hours, reducing strain on the grid.

•**Disadvantages:** Requires smart meters and can be challenging to implement.

Examples of Energy Pricing Strategies:

United States: Uses a mix of fixed, variable, and time-of-use pricing to reflect market conditions and encourage energy efficiency.

India: Implements subsidies to make energy affordable for low-income households while promoting solar energy through competitive bidding.

Example of Tiered Pricing

Imagine a residential electricity tariff with three tiers:

- **Tier 1**: 0-100 kWh at ₹3 per kWh
- **Tier 2**: 101-300 kWh at ₹5 per kWh
- **Tier 3**: Above 300 kWh at ₹7 per kWh

If a household consumes 350 kWh in a month, their bill would be calculated as follows:

- **Tier 1**: 100 kWh x ₹3 = ₹300
- **Tier 2**: 200 kWh x ₹5 = ₹1000
- **Tier 3**: 50 kWh x ₹7 = ₹350

Total bill = ₹300 + ₹1000 + ₹350 = ₹1650

Example

Let's say a household's TOU pricing scheme has the following rates:

- **Peak Hours (2 PM - 8 PM)**: ₹10 per kWh
- **Off-Peak Hours (10 PM - 6 AM)**: ₹2 per kWh
- **Mid-Peak Hours (6 AM - 2 PM & 8 PM - 10 PM)**: ₹5 per kWh

If the household uses 1 kWh of electricity at each period, the cost would be:

- **Peak Hours**: 1 kWh x ₹10 = ₹10
- **Off-Peak Hours**: 1 kWh x ₹2 = ₹2
- **Mid-Peak Hours**: 1 kWh x ₹5 = ₹5

Total cost for the day = ₹10 + ₹2 + ₹5 = ₹17

Types of energy pricing models

1. Cost-Based Pricing

Description: This model sets energy prices based on the costs incurred in producing and delivering energy. It includes the costs of raw materials, labor, capital, and operations.

Pros: Provides a stable and predictable pricing structure. Ensures that costs are covered, promoting financial sustainability for energy providers.

Cons: May not incentivize efficiency improvements or cost reductions. Can be inflexible in responding to market changes.

2. Market-Based Pricing

Description: Prices are determined by supply and demand dynamics in the energy market. This model reflects real-time market conditions, allowing prices to fluctuate based on availability and demand.

Pros: Promotes competition and efficiency. Encourages investment in energy production and infrastructure. Reflects true market value.

Cons: Can lead to price volatility, which may be challenging for consumers. Prices can spike during periods of high demand or supply shortages.

3. Time-of-Use Pricing

Description: Energy prices vary based on the time of day, encouraging consumers to use energy during off-peak hours when demand is lower.

Pros: Helps balance demand and reduce strain on the grid. Can lower overall energy costs for consumers who shift usage to off-peak times.

Cons: Requires smart meters and advanced metering infrastructure. Can be complex for consumers to understand and manage.

4. Tiered Pricing

Description: Energy usage is divided into tiers, with different price rates for each tier. Higher usage levels are charged at higher rates.

Pros: Encourages energy conservation by penalizing excessive use. Simple for consumers to understand.

Cons: Can be unfair to large households or businesses with inherently higher energy needs. May not reflect real-time market conditions.

Examples of Implementation:

Germany: Uses a combination of market-based pricing and feed-in tariffs to promote renewable energy.

United States: Employs time-of-use pricing in certain states to encourage energy efficiency and demand management.

India: Utilizes tiered pricing to make energy affordable for lower-income households while promoting conservation.

These models are often used in combination to balance the needs of energy providers, consumers, and regulatory bodies.

Factors influencing energy pricing (e.g., production costs, supply and demand, government policies

1. Production Costs

Extraction and Processing: The cost of extracting and processing fossil fuels (oil, natural gas, coal) and refining them into usable energy sources.

Capital Investment: Initial investments in infrastructure, such as power plants, refineries, and renewable energy installations.

Operational Costs: Ongoing expenses for labor, maintenance, and fuel.

Technological Advancements: Innovations can reduce production costs, while outdated technology can increase them.

2. Supply and Demand

Supply Side: Availability of energy resources, influenced by factors like natural resource abundance, geopolitical stability, and production capacity.

Demand Side: Consumption patterns driven by economic growth, industrial activity, population growth, and seasonal variations.

Market Equilibrium: Prices fluctuate to balance supply and demand. When demand exceeds supply, prices rise, and vice versa.

3. Government Policies and Regulations

Subsidies and Taxes: Governments may subsidize certain energy sources to make them more affordable or impose taxes to discourage the use of others.

Environmental Regulations: Compliance with regulations aimed at reducing emissions and promoting clean energy can increase production costs.

Tariffs and Trade Policies: Import and export tariffs on energy resources and technology can influence domestic energy prices.

4. Geopolitical Factors

International Relations: Political tensions and conflicts can disrupt energy supply chains, affecting prices.

Trade Agreements: Bilateral and multilateral agreements can facilitate or hinder energy trade, impacting availability and pricing.

The **Energy Conservation Act, 2001** is an important piece of legislation in India aimed at promoting efficient energy use and conservation. Here are some key aspects of the Act:

1. Objective:

The Act aims to provide for the efficient use of energy and its conservation, and for matters connected therewith or incidental thereto.

2. Establishment of the Bureau of Energy Efficiency (BEE):

The Act led to the creation of the Bureau of Energy Efficiency (BEE), which is responsible for promoting energy efficiency and conservation in various sectors.

3. Energy Audits:

The Act mandates energy audits for designated consumers to assess their energy consumption and identify areas for improvement.

4. Energy Conservation Building Codes:

The Act provides for the development and implementation of energy conservation building codes to ensure that new buildings are designed and constructed to be energy-efficient.

5. Energy Consumption Standards:

The Act empowers the Central Government to specify energy consumption standards for various equipment and appliances to promote energy efficiency.

6. Penalties:

The Act includes provisions for penalties for non-compliance with its provisions, including fines and other measures to enforce energy conservation.

7. State and Central Government Roles:

Both the Central and State Governments have roles in enforcing the Act and promoting energy conservation measures.

8. Energy Savings Certificates:

The Act allows for the issuance of energy savings certificates to entities that achieve energy savings beyond their targets, which can be traded or sold.

9. Carbon Credit Certificates:

The Act also provides for the issuance of carbon credit certificates to entities that reduce their greenhouse gas emissions.

The Energy Conservation Act, 2001 is a comprehensive framework designed to enhance energy efficiency and promote sustainable energy practices in India. It aims to create a more sustainable and energy-efficient economy while addressing environmental and economic challenges.

Bureau of Energy Efficiency (BEE)

The **Bureau of Energy Efficiency (BEE)** is an agency under the **Ministry of Power, Government of India**. It was established on **March 1, 2002**, under the provisions of the **Energy Conservation Act, 2001**. The primary mission of BEE is to **reduce energy intensity** of the Indian economy by promoting **energy efficiency and conservation**.

Roles of BEE:

1. **Policy Development**: Formulating and implementing energy conservation policies and programs.
2. **Setting Standards**: Establishing minimum energy performance standards for appliances and equipment.
3. **Certification & Labeling**: Providing energy efficiency labels to products, which help consumers make informed decisions.
4. **Industry Collaboration**: Working with industries to adopt best practices for energy conservation.
5. **Awareness Campaigns**: Conducting campaigns to educate the public about the importance of energy conservation.

Gross Domestic Product (GDP), measures the total value of all goods and services produced within a country over a specific period, usually a year. It's a key indicator of a country's economic performance and is composed of four main components:

Consumption (C): This includes all private expenditures by households on goods and services, such as food, clothing, healthcare, and entertainment. It's typically the largest component of GDP.

Investment (I): This consists of spending on capital goods that will be used for future production, such as buildings, machinery, and technology. It also includes investments in inventories and residential construction.

Government Spending (G): This covers all government expenditures on goods and services, including salaries of public servants, defense spending, infrastructure projects, and public healthcare and education.

Net Exports (NX): This is the value of a country's exports minus its imports. It can be positive or negative, depending on whether a country exports more than it imports (trade surplus) or imports more than it exports (trade deficit).

In a formula, GDP is expressed as:

$$GDP = C+I+G+(X-M)$$

Where: C = Consumption, I = Investment, G = Government Spending, X = Exports, M = Imports. Understanding these components helps economists and policymakers analyze the economic health of a country, make comparisons between different economies, and design policies to promote growth and stability.

- GDP shows the productivity rate of a nation.
- If GDP is higher, the capacity of production of goods and services of a country is higher.
- The Gross Domestic Product (GDP) in India was worth 3889.13 billion US dollars in 2024.

Energy Intensity

- Energy intensity is a measure of the energy efficiency of a particular economy.
- The numeral value is calculated by taking the ratio of energy use (or energy supply) to the GDP.
- Unit of energy intensity- Joule (or Btu) per dollar.
- It is calculated as units of energy per unit of GDP.
- High energy intensities indicate a high price or cost of converting energy into GDP.

- Low energy intensity indicates a lower price or cost of converting energy into GDP.
- Low energy intensity is the desired goal of every nation using less energy to produce a product or provide a service results into a reduced energy intensity.

Functions of BEE:

1. **Energy Audit**: Conducting energy audits to identify potential savings in energy consumption.
2. **Research & Development**: Supporting R&D activities to innovate new energy-efficient technologies.
3. **Financial Assistance**: Providing financial incentives for energy efficiency projects.
4. **Monitoring & Verification**: Ensuring compliance with energy efficiency standards and regulations.
5. **Developing Protocols**: Creating guidelines and protocols for energy conservation activities.
6. **Advisory Role**: Advising the government on energy conservation policies and strategies.
7. **Collaboration**: Working with international agencies to adopt global best practices in energy conservation.

Thank You