



BHARATHIDASAN UNIVERSITY

Tiruchirappalli- 620024, Tamil Nadu, India

Programme: M.Sc., Environmental Science

Course Title : Energy and Environment

Course Code : NMEC2

Unit-I

Energy Availability and Usage

Dr. M.Govindaraju

Professor

Department of Environmental Biotechnology

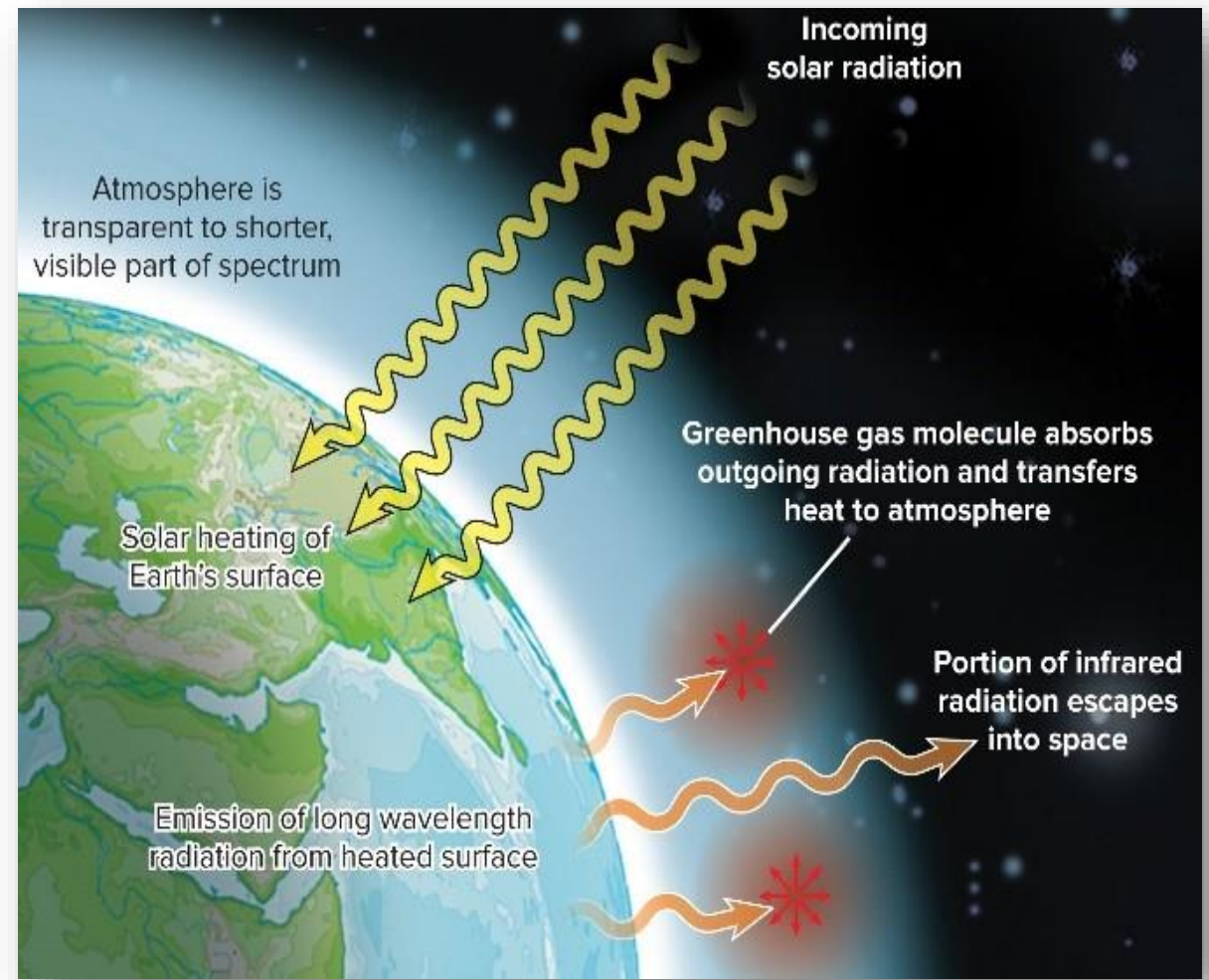
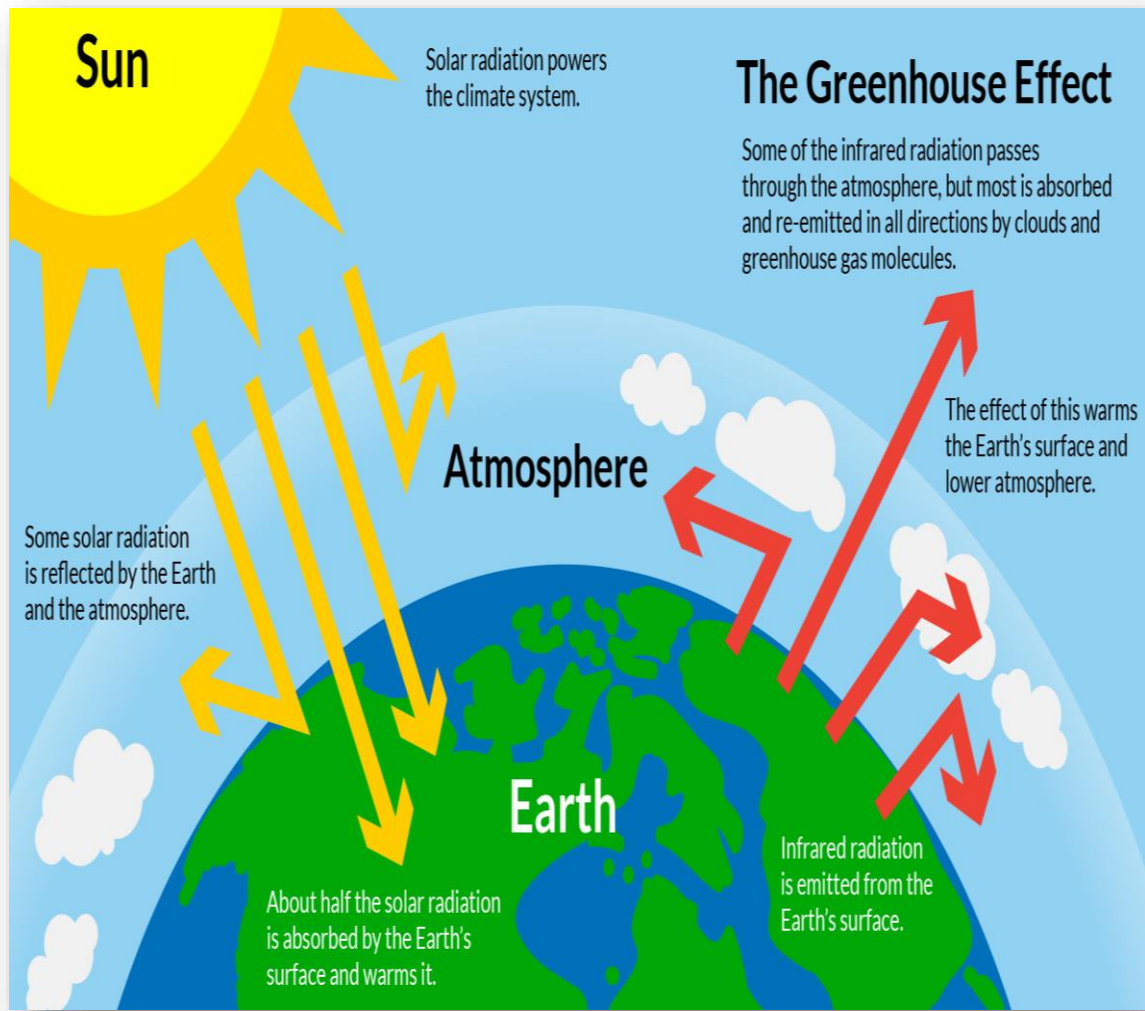
Earth's Energy Balance

Incoming Solar Radiation: The primary source of Earth's energy comes from the Sun. About 49% of the solar energy that reaches the Earth's atmosphere is absorbed by the Earth's surface.

Reflected Solar Radiation: Approximately 30% of incoming solar radiation is reflected back into space by clouds, atmospheric particles, and the Earth's surface.

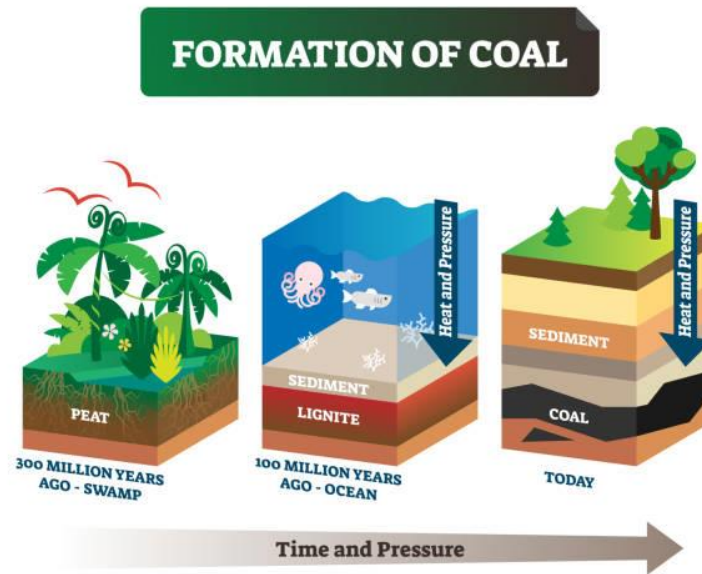
Outgoing Longwave Radiation: The Earth emits energy back into space in the form of infrared radiation. This process helps maintain the planet's energy balance.

Greenhouse Effect: Certain atmospheric gases (e.g., CO₂, methane) trap some of the outgoing infrared radiation, warming the Earth's surface and lower atmosphere.

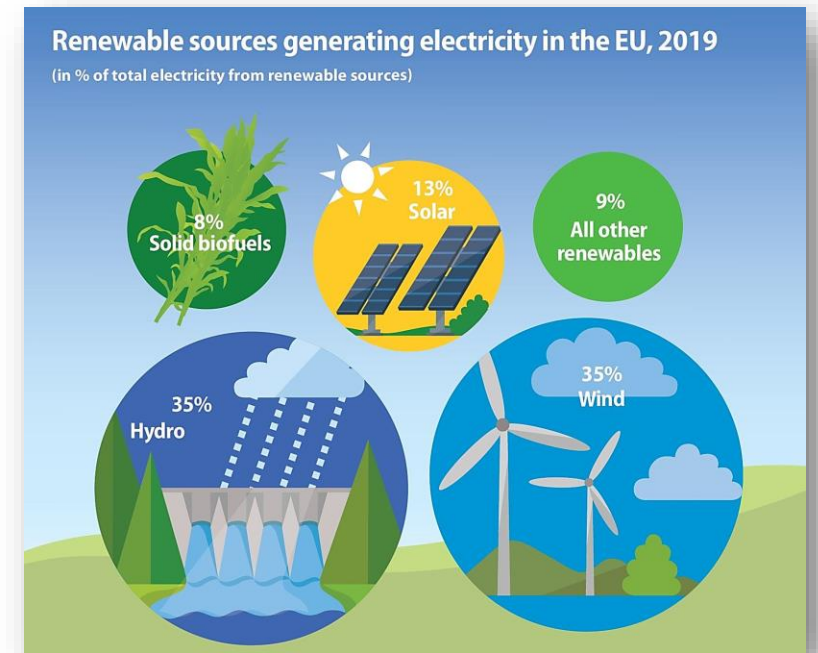


Energy Reserves and Usage

Fossil Fuels: Fossil fuels are made from decomposing plants and animals. These fuels are found in Earth's crust and contain carbon and hydrogen, which can be burned for energy. The major sources include coal, oil, and natural gas. These reserves are finite and are being depleted due to high usage.



Renewable Energy Sources: Renewable energy comes from unlimited, naturally replenished resources, such as the sun, tides, and wind. These include solar, wind, hydro, geothermal, and biomass.



Nuclear Energy: Uses uranium and thorium for energy production. It provides a significant portion of the world's electricity but comes with issues related to waste disposal and potential accidents.

Determinants of Growth in Energy Use

Economic Development: As economies grow, the demand for energy increases due to industrialization, infrastructure development, and higher living standards.

- **Industrialization**
- **Higher Living Standards**

Industrialization:

- **Energy-Intensive Industries:** As countries industrialize, they develop energy-intensive industries such as manufacturing, mining, and chemical production. These sectors require large amounts of energy for machinery, transportation, and processing.
- **Infrastructure Development:** Economic growth often involves the construction of infrastructure such as roads, bridges, buildings, and transportation systems, all of which require substantial energy both during and after construction.
- **Service Sector Growth:** As economies mature, the service sector expands, leading to increased energy use in commercial buildings, IT services, healthcare, and retail.

Higher Living Standards:

- Household Appliances:** As income levels rise, households acquire more appliances (e.g., refrigerators, air conditioners, washing machines), increasing residential energy consumption.
- Mobility:** Increased ownership of vehicles and use of public transportation systems contribute to higher energy demand in the transportation sector.
- Leisure and Entertainment:** Economic development leads to more leisure activities and entertainment options, which require energy (e.g., cinemas, amusement parks, electronic devices)

Population Growth: More people lead to higher energy demand for residential, commercial, and industrial purposes.

- **Increased Residential Energy Demand**
- **Commercial and Industrial Energy Demand**

Increased Residential Energy Demand:

- **Housing Needs:** More people mean more homes are needed, leading to increased energy use for lighting, heating, cooling, and appliances.
- **Water and Sanitation:** Population growth drives up the demand for water supply and sanitation services, which are energy-intensive.

Commercial and Industrial Energy Demand:

- **Consumer Goods:** A growing population leads to a higher demand for consumer goods, necessitating more production and thus more energy.
- **Public Services:** More people require more schools, hospitals, and government services, all of which consume energy.

Technological Advancements: Innovations can lead to more efficient energy use, but they can also create new energy demands (e.g., data centres, electric vehicles).

- **Energy Efficiency Improvements**
- **New Energy Demands:**

Energy Efficiency Improvements

- **Efficient Appliances:** Advances in technology lead to the development of more energy-efficient appliances and equipment, reducing energy consumption per unit of output
- **Smart Grids:** Smart grid technology helps optimise energy distribution and reducing losses, leading to more efficient energy use.

New Energy Demands

- Data Centers:** The rise of the internet and cloud computing has led to the proliferation of data centres, which are major energy consumers due to their need for constant cooling and operation.
- Electric Vehicles:** While electric vehicles reduce dependency on fossil fuels, they increase electricity demand, impacting overall energy consumption patterns.

Urbanization: Urban areas tend to consume more energy due to higher concentration of people and activities.

- **Increased Energy Density**
- **Building and Infrastructure Energy Use**

Increased Energy Density

- **High Concentration of People and Activities:** Urban areas have a high concentration of people, businesses, and services, leading to higher per capita energy consumption compared to rural areas.

- **Public Transportation Systems:** Urban areas often develop extensive public transportation networks, which, while efficient, require significant energy.

Building and Infrastructure Energy Use

- **High-Rise Buildings:** Skyscrapers and high-rise buildings in cities require energy for elevators, lighting, heating, cooling, and other systems.
- **Infrastructure Maintenance:** The infrastructure in urban areas, such as roads, bridges, and tunnels, requires ongoing maintenance, contributing to energy use.

Policy and Regulation: Government policies on energy production, usage, and environmental protection can significantly influence energy consumption pattern

- **Government Policies**
- **Environmental Protection**
- **Energy Security**

Government Policies

•**Subsidies and Incentives:** Government subsidies for fossil fuels or renewable energy sources can significantly influence energy consumption patterns by making certain energy types more economically attractive.

•**Energy Efficiency Standards:** Regulations that set minimum efficiency standards for appliances, buildings, and vehicles can reduce energy use.

Environmental Protection

•**Emission Regulations:** Policies aimed at reducing greenhouse gas emissions can drive the adoption of cleaner energy sources and more efficient technologies.

•**Renewable Energy Mandates:** Requirements for a certain percentage of energy to come from renewable sources can accelerate the transition to sustainable energy systems.

Energy Security

- **Diversification of Energy Sources:** To enhance energy security, governments may promote a diverse mix of energy sources, reducing reliance on a single type of energy and encouraging the development of domestic energy resources.
- **Strategic Reserves:** Policies related to the maintenance of strategic petroleum reserves and other energy reserves can affect energy use patterns and market stability.

Energy Usage Pattern of the World and India

World

High Consumption Regions: North America, Europe, and parts of Asia (notably China and Japan) have high per capita energy consumption.

Energy Transition: There is a global shift towards renewable energy sources due to environmental concerns and sustainability goals.

Diverse Sources: The world uses a mix of fossil fuels, nuclear, and renewable energy. The transition varies significantly by region.

Case Study - Germany

Germany's Energiewende is a long-term strategy for transitioning to a sustainable energy system by increasing energy efficiency and expanding renewable energy. This strategy involves a significant shift away from fossil fuels and nuclear power towards renewable energy sources

1. Renewable Energy Expansion:

- **Wind Power:** Germany has invested heavily in both onshore and offshore wind farms. As of 2023, wind power is one of the largest contributors to Germany's electricity supply.
- **Solar Power:** Solar photovoltaic (PV) systems are widely used in Germany. The country has a significant number of residential, commercial, and utility-scale solar installations.
- **Biomass:** Biomass energy plays a role in Germany's renewable energy mix, particularly in rural areas where agricultural residues and waste can be used for energy production.
- **Hydropower and Geothermal:** While less prominent than wind and solar, hydropower and geothermal energy contribute to the overall renewable energy portfolio.

2. Energy Efficiency:

- **Building Standards:** Germany has stringent energy efficiency standards for buildings. The Energy Saving Ordinance (EnEV) and the Renewable Energies Heat Act (EEWärmeG) set requirements for new buildings and renovations to reduce energy consumption.
- **Appliance Efficiency:** Germany promotes the use of energy-efficient appliances and lighting. The Energy Labeling Ordinance requires appliances to display energy efficiency labels.
- **Industry Measures:** The German government encourages industries to adopt energy-saving technologies and practices through incentives and regulatory measures.

3. Grid and Storage Innovations:

- Smart Grids:** Germany is developing smart grid technologies to better manage electricity supply and demand, integrate renewable energy sources, and enhance grid stability.

- Energy Storage:** The country is investing in energy storage solutions, including battery storage systems, pumped hydro storage, and innovative technologies like power-to-gas.

4. Policy and Regulatory Framework:

- **Renewable Energy Act (EEG):** The EEG provides a framework for the expansion of renewable energy, including feed-in tariffs and market premiums for renewable energy producers.
- **Nuclear Phase-Out:** Germany decided to phase out nuclear power following the Fukushima disaster in 2011. The last nuclear plant is expected to close by the end of 2022.
- **Climate Action Plan 2050:** This plan outlines Germany's strategy to achieve carbon neutrality by 2050, with interim targets for reducing greenhouse gas emissions.

Impact and Achievements

1. Renewable Energy Penetration:

- By 2023, renewable energy sources accounted for approximately 46% of Germany's electricity consumption. Wind and solar power are the largest contributors to this share.

2. Emission Reductions:

- Germany has made significant progress in reducing greenhouse gas emissions. Between 1990 and 2020, emissions were reduced by more than 40%, largely due to the transition to renewable energy and energy efficiency measures.

3. Economic Benefits:

- The Energiewende has created jobs in the renewable energy sector, contributing to economic growth. The development of renewable energy technologies has also positioned Germany as a global leader in clean energy innovation.

4. Challenges and Solutions:

- **Grid Stability:** Integrating a high share of intermittent renewable energy sources has posed challenges for grid stability. Germany addresses this through grid upgrades, smart grid technologies, and energy storage solutions.
- **Public Acceptance:** The transition has faced opposition in some communities, particularly regarding wind farms and grid expansion. The government engages in public dialogue and provides incentives to address these concerns.

- **Energy Costs:** The costs of renewable energy subsidies have been passed on to consumers, leading to higher electricity prices. Germany is working to balance the costs and benefits of the energy transition.

Conclusion

Germany's energy usage pattern and its Energiewende strategy provide a comprehensive case study of how a country can transition to a sustainable energy system. The country's commitment to renewable energy, energy efficiency, and innovative technologies demonstrates the potential for other nations to adopt similar strategies to achieve energy sustainability and reduce greenhouse gas emissions.

India

Energy Mix: Predominantly relies on coal for electricity generation, but there is a growing emphasis on renewable energy (solar, wind, hydro).

Rising Demand: Rapid economic growth and urbanization are driving up energy demand.

Rural Electrification: Efforts are ongoing to provide electricity to rural areas, increasing overall energy consumption.

Government Initiatives: Programs like the National Solar Mission aim to increase the share of renewable energy in the energy mix.

Tamil Nadu is one of the leading states in India in terms of renewable energy capacity, particularly wind energy. The state's strategic focus on harnessing wind power provides an excellent case study for understanding its energy usage pattern.

1. Wind Power Expansion

•Wind Farms:

- Tamil Nadu has some of the largest wind farms in India, with major installations in districts like Coimbatore, Tirunelveli, and Kanyakumari.
- The Muppandal Wind Farm in Kanyakumari is one of the largest onshore wind farms in the world, with a capacity of over 1,500 MW.

- **Installed Capacity:**

- As of 2023, Tamil Nadu's installed wind power capacity exceeded 9,000 MW, making it the state with the highest wind energy capacity in India.

2. Policy and Regulatory Framework:

- **Tamil Nadu Energy Development Agency (TEDA):**

- TEDA plays a crucial role in promoting and facilitating renewable energy projects in the state. It provides incentives, subsidies, and technical support to wind energy developers.

•**Wind Power Policies:**

- The state has implemented favorable policies, such as feed-in tariffs and concessional grid connectivity charges, to attract investment in wind energy.
- Policies also include mandates for renewable purchase obligations (RPOs), requiring utilities to purchase a certain percentage of power from renewable sources.

3. Public-Private Partnerships:

•**Investment and Collaboration:**

- Tamil Nadu has encouraged public-private partnerships to develop wind energy projects, involving both domestic and international investors.
- Collaborations with technology providers and financial institutions have facilitated the growth of the wind energy sector.

4. Grid Integration and Storage:

- **Grid Infrastructure:**

- The state has invested in upgrading its transmission and distribution network to accommodate the variable nature of wind energy.
- Efforts include implementing smart grid technologies and real-time monitoring systems to ensure efficient grid management.

- **Energy Storage and Hybrid Systems:**

Tamil Nadu is exploring energy storage solutions and hybrid systems (combining wind with solar) to address intermittency and enhance grid stability.

Pilot projects for battery storage and pumped hydro storage are underway to complement wind energy generation.

Impact and Achievements

1. Renewable Energy Capacity:

- **Leading Wind Energy Producer:**

- Tamil Nadu's focus on wind energy has positioned it as a leading wind energy producer in India, contributing significantly to the national renewable energy targets.

- **Diversified Energy Mix:**

- The state's energy mix includes a substantial share of renewable energy, reducing dependency on coal and natural gas.

2. Economic and Social Benefits:

- **Job Creation:**

- The wind energy sector has created numerous jobs in the manufacturing, installation, operation, and maintenance of wind turbines.
- Local communities have benefited from employment opportunities and economic development associated with wind projects.

- **Rural Development:**

- Wind farms in rural areas have spurred infrastructure development, including roads, schools, and healthcare facilities.

3. Environmental Impact:

- **Reduction in Carbon Emissions:**

- The shift to wind energy has significantly reduced greenhouse gas emissions and air pollution in Tamil Nadu.
- The state's renewable energy initiatives contribute to India's climate change mitigation efforts and global environmental goals.

4. Challenges and Solutions:

- **Grid Stability:**

- Integrating a high share of wind energy into the grid poses challenges for grid stability and reliability.
- Tamil Nadu addresses this by upgrading grid infrastructure, implementing energy management systems, and developing storage solutions.

- **Land and Community Issues:**

- Land acquisition for wind projects can lead to conflicts with local communities and landowners.
- The state government engages in stakeholder consultations and provides compensation and benefits to affected communities.

- **Seasonal Variability:**

- Wind energy generation is subject to seasonal variability, with peak production during the monsoon season.
- Tamil Nadu mitigates this by diversifying its renewable energy portfolio with solar and other renewable sources.

Conclusion

Tamil Nadu's wind energy initiatives provide a comprehensive case study of how a state can effectively harness renewable energy to meet its energy needs. The state's proactive policies, investment in infrastructure, and focus on public-private partnerships have driven significant growth in wind energy capacity. Tamil Nadu's experience offers valuable insights for other regions aiming to develop sustainable energy systems and reduce their carbon footprint.