Complete Environmental Science Study Notes

PDF 1: Introduction to Environmental Science & Ecosystems

Course Structure

- **Evaluation:** Mid Term (20%), Assignments (15%), Quizzes (5%), Project Work (25%), Class Participation (5%), End Semester (30%)
- **Field Visit:** Possible visit in NCR or virtual visit depending on time and facilities

Introduction to Environmental Science

Definition of Environment (Environment Protection Act): Environment is defined as the sum of air, land, water and the inter-relationships among them and with human beings, other living organisms and materials.

What is Environmental Science: The study of how humans affect their environment. Our environment is everything that surrounds us, both natural and man-made.

Components of Environment:

- **Living things:** Animals, plants, forests
- **Non-living things:** Oceans, clouds, soil, rocks
- **Built environment:** Buildings, human-created centers
- **Social relationships and institutions**

Segments of Environment

1. **Atmosphere:** Composed of distinct layers - troposphere, stratosphere, mesosphere
2. **Hydrosphere:** Water component
3. **Lithosphere:** Solid part - the crust includes minerals; largest volume of Earth's interior
4. **Biosphere:** The part that includes Air, Land, Water where life occurs

Earth, Man & Environment

Earth's History:

- Age of earth: approximately 4.6 billion years
- Our ancestors depended on earth resources for survival
- Gave importance to natural elements like trees, plants, sun, water, air
- Plants and trees were exploited as ancient medicines (continuing as Ayurveda/Unani medicines)

Human Development Timeline:

- Agricultural practices started almost 10,000 years ago
- Industrial revolution: 1760-1840
- Currently in Industry 4.0/5th period
- Space and computer age began
- Mobile technology commercialized in 1983

Environmental Challenges from Human Activities:

1. Emission of greenhouse gases (CO_2, CH_4, NOx, water vapors, CFCs) causing ozone layer depletion
2. Hazardous chemicals (xenobiotics foreign to animal life) or anthropogenic compounds recalcitrant to biological degradation
3. Production of nuclear materials and wastes
4. Biological warfare
5. Drones and modern warfare technology

Ecology

Definition: Term described by Ernst Haeckel in 1869. Ecology deals with the study of interaction of organisms in their natural space with their environment.

Example: Interaction of tiny organisms in forest with other insects, animals, soil, water, air.

Ecosystem and Ecological Engineering

Ecosystem Definition (Tansley, 1935): Self-regulating group of biotic community interacting with each other and with the non-living environment, exchanging energy and matter.

Ecological Engineering: Design, restoration, or creation of ecosystems with strong emphasis on ecosystem self-design, self-organization and controlling the conditions in disturbed situations through self-regulations, interdependence, cooperative or antagonistic relationships.

Types of Ecosystems

Natural Ecosystems:

- **Aquatic:**
  - Marine
  - Fresh water
- **Terrestrial:**
  - Forest
  - Grassland
  - Desert
- **Lotic:** River, stream, or spring

Artificial Ecosystems: Human-made

Fundamental Characteristics of Ecosystems

Abiotic Components:

- Solar energy provides practically all energy for ecosystems
- Inorganic substances (sulfur, carbon, nitrogen, phosphorus) tend to cycle through ecosystems
- Organic compounds (carbohydrates, lipids, proteins) form links between biotic components

Biotic Components: Classified according to method of energy acquisition:

- **Autotrophs:** Produce their own food using energy sources like sun
- **Heterotrophs:** Consume other organisms as food source

Structure of Ecosystem

Trophic Levels (5 levels):

1. **Producers:** Primary producers using photosynthesis
2. **Herbivores:** Primary consumers
3. **Carnivores:** Secondary consumers
4. **Detrivores:** Feed on dead organic matter
5. **Decomposers:** Break down dead organisms

Examples of Interactions

Symbiosis Types:

- **Mutualism:** Both organisms benefit (e.g., sea anemones and clownfish, lichens = fungi + algae)
- **Commensalism:** One benefits, other unharmed (e.g., orchids on tree branches)
- **Antagonism:** One benefits at expense of other (e.g., mosquitoes and humans)

Physical and Chemical Factors in Environment

Physical Factors:

- Temperature, light, water availability
- Rainfall, soil moisture, flow rates
- Infrequent events: fires, floods, storms
- **Cloudbursts:** Occur when warm, moist air is pushed upward along mountain slopes

Chemical Factors:

- pH, electrochemical potential, transparency of air and water
- Critical nutrients, salinity, other chemical characteristics

Food Chains

Definition: Transfer of energy through eating and being eaten at each step (trophic level).

Types:

1. **Grazing Food Chain:** Starting with plants
    - Grass → Caterpillar/Grasshopper → Bird → Snake → Hawk
2. **Detritus Food Chain:** Starts with dead animals/plants
    - Leaf litter → Earthworms/insects → Sparrow/Blackbirds/Vultures → Hawk/Eagle

Food Webs

Most organisms feed on multiple species rather than single species. Individual food chains interconnect to form complex food webs. Example: Hawk eats both mouse and smaller birds.

Energy Flow in Ecosystems

Key Principles:

- All organisms must obtain energy and nutrients from environment
- Sun is ultimate source of energy
- **Primary Production:** Photosynthesis - chemical reaction using water and CO_2 to store energy in glucose
- Energy flows one-way through biotic community
- Only about 1% of solar energy is captured by plants
- Energy decreases at each trophic level
- Cannot occur in reverse

Nutrient Cycling

Biogeochemical Cycles: Cyclic movements of chemical elements between organisms and environment.

Major Cycles:

1. Hydrological Cycle:

- Steps: Evaporation → Condensation → Infiltration → Runoff → Precipitation → Cloud bursts

2. Carbon Cycle:

- Carbon enters plants as CO_2
- Photosynthesis removes carbon from atmosphere
- Carbon moves through food chains
- Cellular respiration, combustion return carbon to atmosphere
- Overall: $6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$

3. Nitrogen Cycle:

- 78% of atmosphere is nitrogen
- N_2 must be converted to usable forms by organisms
- **Nitrogen Fixation:** Conversion of $N_2 \rightarrow NH_3$
- **Symbiotic:** Rhizobium bacteria with legumes
- **Non-symbiotic:** Free-living bacteria and cyanobacteria
- **Natural:** Lightning storms convert atmospheric nitrogen

4. Phosphorous Cycle:

- Only cycle without atmospheric component
- Inorganic phosphate (PO4) released from rocks and sediments
- Absorbed by plants, incorporated into nucleic acids, phospholipids, ATP
- Returns to soil through decomposition

5. Oxygen Cycle:

- 21% of atmosphere is oxygen
- Plants and animals exchange O2 and CO2 through respiration

Types of Ecosystems (Detailed)

Terrestrial Ecosystems:

1. Forest Ecosystem:

- Occupies 40% of total earth surface
- India: 21% forest cover
- **Components:**
  - **Abiotic:** Organic debris, canopy layers, sun light penetration zones
  - **Biotic:** Trees, herbs, shrubs, climbers, epiphytes
- **Forest Types:**
  - **Boreal:** Farthest north, cold winters, short growing seasons
  - **Temperate:** Mid-latitudes, distinct seasons, mostly coniferous
  - **Tropical:** Along equator, high temperatures, long growing seasons, highest biodiversity

2. Grassland Ecosystem:

- 20-40% of earth surface
- Dominated by grass species with few trees and shrubs
- **Grass types:** Cynodon (Bermuda grass), Brachiaria, Dactyloctinium

3. Desert Ecosystem:

- 20-33% of earth surface (India: 12%)
- Extreme weather, less rainfall, high temperature
- **Plants:** Xerophytes (cactus, shrubs, bushes)
- **Animals:** Reptiles, insects, birds, rodents adapted to extreme conditions

Aquatic Ecosystems:

1. Freshwater:

- **Lotic (flowing):** Rivers, springs, streams
- **Lentic (still):** Ponds, lakes - stagnant water

2. Marine Ecosystem:

- 70% of earth covered with water
- **Abiotic:** Waves, tides, light, temperature, pressure, salinity
- **Producers:** Microalgae, dinoflagellates, diatoms, macroalgae
- **Consumers:** Fish larvae, molluscs, carnivorous fish

3. Estuary Ecosystem:

- Where river meets sea
- Variable salinity conditions
- **Producers:** Sea weeds, mangrove forests
- **Consumers:** Small fish, zooplankton, crustaceans, amphibians

Photosynthesis

Light Dependent Reactions:

- Occur in chloroplasts
- Light converted to chemical energy (ATP)
- Water split, oxygen evolved

Light Independent Reactions:

- Occur in stroma of chloroplast
- CO_2 fixed as glucose using ATP and NADPH
- Overall reaction: $6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$

Rubisco: Key enzyme in carbon fixation (described as "reversible" and "lethargic")

Respiration

External Respiration: Oxygen inhaled, CO_2 exhaled using gills/lungs

Internal (Cellular) Respiration:

- Chemical energy in organic molecules released as ATP
- **Aerobic:** Requires oxygen
- **Anaerobic:** Without oxygen
- Occurs in almost every cell

Photorespiration: Reaction in chlorophyll where chlorophyll-b absorbs light and passes to chlorophyll-a

Chronobiology - Circadian Rhythms

Definition: Physical, mental, and behavioral changes following 24-hour cycle responding to light and darkness in most living things including animals, plants, and microbes.

Function: Permits organisms to synchronize with daily/seasonal environmental changes including darkness and temperature.

PDF 2: Biodiversity and Conservation

Definition of Biodiversity

Convention of Biological Diversity (1992, Rio de Janeiro): "Variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part."

Types of Biodiversity

1. Species Diversity:

- Variability within populations or between species of a community
- Represents species richness and abundance
- **Measurement Indices:**
  - **Shannon-Wiener Index:** Measures richness and evenness (randomness index)
    - Formula: $H = -\Sigma Pi(\ln Pi)$ where Pi is proportion of each species
    - Good values: 1.5-3.5
    - Example calculation provided with 5 species sample
  - **Simpson's Index:** Measures dominance
    - Formula: $D = 1- [\Sigma n(n-1)/N(N-1)]$

2. Ecosystem Diversity:

- Diversity of ecological complexes showing variations in:
  - Ecological niches
  - Trophic structure
  - Food webs
  - Nutrient cycling
  - Physical parameters (moisture, temperature, altitude, precipitation)

Causes of Biodiversity Loss

1. Climate change (temperature, storms, earthquakes)
2. Pollution
3. Habitat destruction
4. Invasive alien species
5. Overexploitation of natural environment
6. Hunting
7. Habitat fragmentation
8. Collection for zoos and research
9. Control of pests and predators
10. Genetic mutations
11. Co-extinction (when related/dependent species vanishes)

Values of Biodiversity

1. Consumptive Use Value: Direct use where products can be harvested and consumed directly.

- **Food and Medicine:** 75% of world population depends on plant extracts for medicines
- **Important medicines:**
  - Penicillin from Penicillium fungus
  - Tetracycline from bacteria
  - Quinine from Cinchona bark (malaria cure)
  - Digitalin from foxglove (heart ailments)
  - Vinblastine and vincristine from Periwinkle (anti-cancer drugs)
- **Fuel:** Forests provide wood, fossil fuels (coal, petroleum, natural gas)

2. Productive Use Values: Commercially usable values that are marketed:

- Lumber, wild gene resources for crop improvement
- Animal products: elephant tusks, musk, silk, wool, fur, lac
- Industries dependent: Paper and pulp, plywood, railway sleeper, silk, ivory-works, leather
- **Illegal trade:** Despite international bans, smuggling of horns, tusks, live specimens worth millions continues

3. Social Value: Values associated with social life, customs, religion:

- **Holy plants in India:** Tulsi (holy basil), Peepal, Mango, Lotus, Bael
- Cultural significance in songs, dances, customs
- **Animals with social importance:** Cow, Snake, Bull, Peacock

4. Ethical Value (Existence Value): Based on "Live and Let Live" concept:

- Species should be preserved for ethical reasons
- Interdependence of all species
- Each species has role in maintaining natural balance
- People feel sorry when species like passenger pigeon or dodo become extinct

5. Aesthetic Value:

- **Ecotourism:** People spend money to visit wilderness areas
- **Economic impact:** Ecotourism generated Rs. 8.32 crores in India (2020-21)
- **Global market:** Valued at US$ 172.4 Bn (2021), estimated to reach US$ 355.8 Bn (2027)

6. Option Values: Potential values that are presently unknown:

- Possible cures for AIDS or cancer may exist in marine ecosystems or tropical rainforests
- Natural products research, bioinformatics, computational biology
- Value of visiting areas with endemic, rare, or endangered species

7. Ecosystem Service Value: Services provided by ecosystems:

- Prevention of soil erosion and floods
- Maintenance of soil fertility
- Nutrient cycling and nitrogen fixation
- Role as carbon sinks
- Pollutant absorption
- Reduction of global warming threat

Global Biodiversity

Current Status:

- Following 1992 Earth Summit, became evident that huge numbers of species remain unknown
- Roughly 1.7 million species known (only 1-2% of total estimated)
- Tropical deforestation reduces biodiversity by 0.5% annually

Terrestrial Biodiversity (Biomes):

- **Tropical Rainforests:** 50-80% of global biodiversity, 125,000 flowering plant species (only 1-3% known)
- **Temperate Forests:** Much less biodiversity but better documented
- **Global Statistics:** 170,000 flowering plants, 30,000 vertebrates

Marine Biodiversity:

- Much higher than terrestrial but less known
- 35 existing phyla of multicellular animals, 34 are marine, 15 exclusively marine

Indian Biodiversity

National Level:

- Ranks 10th among plant-rich countries
- 11th in endemic species of higher vertebrates
- Total identified living species: 150,000
- Ministry of Environment data (2000): 47,000 plant species, 81,000 animal species (7% and 6.5% of global flora and fauna)

Regional/Local Biodiversity Types:

- **Alpha (α) richness:** Number of species at single location
- **Beta (β) richness:** Rate of species change across habitats
- **Gamma (γ) richness:** Rate across large landscape gradients
- **Formula:** β diversity = γ/α

India as Mega-Diversity Nation:

- One of 12 mega-diversity countries
- About 62% of amphibians and 50% of lizards are endemic
- Western Ghats: site of maximum endemism

Center of Origin:

- 5000 species of flowering plants originated in India
- Center of origin for 167 species of crop plants
- 320 species of wild relatives of cultivated crops

Marine Diversity:

- 7500 km long coastline
- Rich mangrove forests, estuaries, coral reefs, backwaters
- More than 200 species of corals (global representation)
- Rich in molluscs and crustaceans

Hotspots of Biodiversity

Definition (Myers, 1988): Areas exhibiting high species richness and high species endemism.

Global Status:

- 25 hotspots globally
- Cover less than 2% of world's land area
- Contain 50% of terrestrial biodiversity
- 40% of terrestrial plants and 25% of vertebrates are endemic to these hotspots

Indian Hotspots (2):

1. **Eastern Himalayas:** Numerous isolated valleys in Sikkim with 4250 plant species (60% endemic)
2. **Western Ghats:** 17,000 km strip through Maharashtra, Karnataka, Tamil Nadu, Kerala with 40% endemic plant species, 62% endemic amphibians

Threats to Biodiversity

Extinction Rates:

- E.O. Wilson estimates: 10,000 species per year (27 species per day)
- If current trend continues: 1/3 of current biodiversity lost by mid-21st century
- This could lead to ecosystem collapse and human extinction

Major Threats:

1. Habitat Loss:

- Billions of hectares of forests and grasslands cleared in past 10,000 years
- Conversion to agriculture, pastures, settlements, development projects
- Wetland destruction through filling and pollution
- **Habitat Fragmentation:** Division of habitat into small scattered patches

2. Poaching:

- Illegal trade despite international bans
- Products: furs, hides, horns, tusks, live specimens, herbal products
- Worth millions of dollars annually
- **Examples:** Elephant tusks ($5000/kg), leopard fur coat ($50,000 in Japan), hyacinth macaw ($10,000)

3. Man-Wildlife Conflict:

- Wildlife causing damage and danger to humans
- Creates difficulty for forest departments to gain public support
- Recent examples: Tiger/leopard attacks in Sitapur (2025)

Endangered and Endemic Species

IUCN Red Data Book: Lists endangered species of plants and animals.

India's Status:

- 450 plant species in endangered/threatened/rare categories
- 150 mammal species and 150 bird species threatened
- Unknown number of insect species endangered

Endemic Species:

- 7000 out of 47,000 plant species are endemic (about 62%)
- Restricted to Himalayas, Khasi hills, Western Ghats
- **Flora examples:** Orchids, Sapria himalayana, Uvaria lurida, Nepenthes khasiana
- **Fauna examples:** 62% amphibians, 50% lizards endemic to Western Ghats

Conservation of Biodiversity

Two Approaches:

1. In-situ Conservation (within habitat): Protection in natural environment through:

- **Biosphere Reserves (7 major):** Nanda Devi (UP), Nokrek (Meghalaya), Manas (Assam), Sunderbans (West Bengal), Gulf of Mannar (Tamil Nadu), Nilgiri (Karnataka-Kerala-Tamil Nadu), Nicobars and Similipal (Odisha)
- **National Parks (80):** Areas dedicated to wildlife conservation with tourism but no grazing/private rights
- **Wildlife Sanctuaries (420)**
- **Reserve Forests**
- **Botanical Gardens (120)**

Biosphere Reserve Structure:

- **Core Zone:** Strict protection
- **Buffer Zone:** Limited activities
- **Transition Zone:** Human settlements, research stations, monitoring, education, training, tourism

Special Projects:

- Project Tiger
- Gir Lion Project
- Crocodile Breeding Project
- Project Elephant
- Project Leopard

2. Ex-situ Conservation (outside habitat):

Gene Banks/Seed Banks:

- **National Bureau of Plant Genetic Resources (NBPGR), New Delhi:** Agricultural and horticultural crops preserved by cryo-preservation at -196°C
- **National Bureau of Animal Genetic Resources (NBAGR), Karnal:** Preserves semen of domesticated bovine animals
- **National Facility for Plant Tissue Culture Repository (NFPTCR):** Conservation through tissue culture

G-15 Countries Network: Gene bank network for aromatic and medicinal plants (India is coordinating country) Members: Argentina, Chile, Brazil, Mexico, Jamaica, Venezuela (Americas); Egypt, Algeria, Senegal, Nigeria, Zimbabwe (Africa); India, Malaysia, Indonesia (Asia)

PDF 3: Natural Resources

Introduction to Natural Resources

Definition: Life on earth depends on large number of things and services provided by nature, known as Natural Resources.

Examples: Water, air, soil, minerals, forests, crops, wildlife

Types of Natural Resources

1. Renewable Resources:

- Inexhaustible and can be regenerated within given time
- Examples: Forests, wildlife, wind energy, biomass energy, tidal energy, hydropower
- Solar energy is renewable as it's inexhaustible
- **Caution:** Even renewable resources can become non-renewable if exploitation rate exceeds regeneration rate

2. Non-Renewable Resources: Four major types: Oil, natural gas, coal, nuclear energy Also includes mineral resources

Sustainable Use of Resources

Importance of protecting and conserving natural resources for sustainable development.

Major Natural Resources

1. Forest resources
2. Water resources
3. Mineral resources
4. Food resources (not covered in syllabus)
5. Energy resources
6. Land resources

Forest Resources

Global Forest Distribution

World Statistics:

- About 1/3 of world's land area is forested
- **Major forest countries:**
  - Russia: 20% of world forests (55,992 sq m per capita)
  - Brazil: ~15% (23,652 sq m per capita)
  - Canada: 6-7% (94,461 sq m per capita)
  - USA: 6-7% (9,556 sq m per capita)
  - India: 2% (600 sq m per capita)

Forest Loss:

- Total world forest: 7,000 million hectares → 2,890 million ha (1975) → 2,300 million ha (1990)
- Greatest loss in tropical Africa (1/3 destroyed)
- At present rate: 40% of tropical forests will be lost in next 60 years

India's Forest Status

Current Status:

- **Total Recorded Forest Area:** 765,210 sq km (23.28% of geographical area)
- **Categories:**
  - Reserved Forests: 416,516 sq km
  - Protected Forests: 223,000 sq km
  - Unclassed Forests: 125,385 sq km
- **National Forest Policy target:** 33% (currently 19.27% based on satellite data, presently around 24%)

State-wise Largest Forests:

1. Madhya Pradesh (largest area)
2. Arunachal Pradesh
3. Chhattisgarh
4. Odisha
5. Maharashtra

Major Forests in India:

- **Abujmarh Forest:** Chhattisgarh (3,870 sq km)
- **Gir National Park:** Gujarat (1,412 sq km)
- **Jim Corbett National Park:** Uttarakhand (520.8 sq km)
- **Kanha National Park:** Madhya Pradesh (650 sq km)
- **Bandipur National Park:** Karnataka (874 sq km)

Uses of Forests

Commercial Uses (worth >$300 billion/year):

- Firewood, pulpwood, food items, gum, resins
- Non-edible oils, rubber, fibers, lac, canes, fodder
- Medicine, drugs, and many other items

Ecological Uses:

1. **Oxygen Production:** Essential for life
2. **Reducing Global Warming:** Carbon sequestration
3. **Wildlife Habitat:** Biodiversity conservation
4. **Hydrological Cycle Regulation:** Water cycle maintenance
5. **Soil Conservation:** Prevention of erosion
6. **Pollution Moderation:** Air purification

Over-Exploitation of Forests

International Timber Trade: Over US$40 billion per year

Causes of Deforestation:

1. **Shifting Cultivation:** Temporary farming, shifting when soil becomes infertile (practice in Northeast India, Andhra Pradesh, MP)
2. **Fuel Requirements:** Growing demand for fuelwood by increasing population
3. **Raw Materials for Industry:** Boxes, furniture, railway sleepers, plywood, matchboxes, pulp for paper
4. **Development Projects:** Hydroelectric projects, big dams, road construction
5. **Growing Food Needs:** Agricultural expansion, settlements
6. **Overgrazing:** Converting cleared forest land to grazing lands

Consequences of Deforestation:

1. Threatens existence of many species
2. Biodiversity loss and genetic diversity erosion
3. Hydrological cycle gets affected, influencing rainfall
4. Soil erosion and loss of soil fertility
5. Landslides in hilly areas

Major Forest Activities

Timber Extraction:

- Teak, Mahogany, Sandalwood removal
- Construction of approach roads

Mining:

- Coal mining: Jharia, Raniganj (Jharia fires ongoing)
- Mineral extraction in forests of Goa
- Magnesite and soapstone mining: Kosi valley, Almora
- Radioactive minerals: Kerala, Tamil Nadu, Karnataka
- Western Ghats mining: Copper, chromite, bauxite, magnetite

Dams and Their Effects

India's Dam Statistics:

- More than 1,550 large dams
- **Highest:** Tehri dam (river Bhagirathi, Uttarakhand)
- **Largest capacity:** Bhakra Nangal (river Satluj, Himachal Pradesh)

Environmental Activists:

- **Tehri Dam opposition:** Sunderlal Bahuguna (Chipko movement)
- **Sardar Sarovar issues:** Medha Patkar, Arundhati Roy, Baba Amte

Benefits of Dams:

1. Employment for tribals
2. Flood and famine control
3. Electricity generation
4. Irrigation water supply
5. Drinking water in remote areas
6. Navigation and fishery promotion

Environmental Problems:

Upstream Issues:

1. Displacement of tribal people
2. Loss of forests, flora, and fauna
3. Changes in fisheries and spawning grounds
4. Siltation and sedimentation
5. Loss of non-forest land
6. Stagnation and waterlogging near reservoir
7. Vector breeding and disease spread
8. Reservoir Induced Seismicity (earthquakes)
9. Growth of aquatic weeds
10. Microclimatic changes

Downstream Issues:

1. Waterlogging and salinity from over-irrigation
2. Microclimatic changes
3. Reduced water flow and silt deposition
4. Flash floods
5. Saltwater intrusion at river mouth
6. Loss of land fertility (nutrients deposited in reservoir)
7. Vector-borne diseases (malaria, dengue)

Water Resources

Global Water Distribution

India's Water Status:

- 18% of world population
- 4% of world's water resources

Water Characteristics:

- 97% of earth's surface covered with water
- Most animals and plants: 60-65% water in body

Unique Features of Water:

1. Liquid over wide temperature range
2. High specific heat - warms and cools slowly
3. High latent heat of vaporization - cooling effect
4. Excellent solvent including oxygen
5. High surface tension and cohesion - rises through tallest trees (Sequoia ~84m)
6. Anomalous expansion (expands when freezing 4°C to 0°C) - ice floats, aquatic life survives

Global Water Cycle:

- Total water resources: 1,404 million km³
- 1.4 inch thick layer evaporates from oceans annually
- Most returns to oceans through hydrological cycle

Water-Rich Countries: Brazil, Russia, Canada, Indonesia, China, Colombia account for half of Earth's freshwater

Water-Poor Countries: Bahrain, Jordan, Kuwait, Libya, Maldives, Malta, Qatar, Saudi Arabia, UAE, Yemen

Major River Systems in India

1. Indus River System
2. Brahmaputra River System
3. Ganga River System
4. Yamuna River System
5. Narmada River System
6. Tapti River System
7. Godavari River System
8. Krishna River System

Water Use and Over-Exploitation

Types of Water Use:

1. **Water Withdrawal:** Taking water from groundwater/surface water
2. **Water Consumption:** Water not returned for reuse (evaporated/absorbed)
3. **Hydrogen Generation:** New use category

Global Water Usage:

- **Agriculture:** 70% globally, 93% in India, 4% in Kuwait
- **Industry:** 25% globally (high 60% in European countries, low 5% in developing countries)
- **Domestic:** Remaining percentage

Water Footprint:

- USA: Average family of 4 consumes >1000 m^3/year
- India: Major wheat (4.1% global exports) and rice exporter (40% global trade)
- Water exported through crops (virtual water export)
- India's water availability declined 60% over recent decades

Water Scarcity Statistics:

- 2.2 billion people lack safely-managed drinking water
- 4.2 billion without adequate sanitation
- 3 billion lack basic handwashing facilities
- By 2024: 2/3 of world population may suffer acute water shortage

Rural India Water Access:

- Some people walk 5-20 km to fetch water
- Wells up to 78 meters deep

Groundwater

Characteristics:

- 9.86% of total freshwater resources
- 35-50 times more than surface water supplies
- Being polluted increasingly

Aquifer Types:

1. **Unconfined Aquifers:** Overlaid by permeable materials, recharged by rainfall/snowmelt
2. **Confined Aquifers:** Sandwiched between impermeable layers, recharged only where aquifer intersects surface

Effects of Groundwater Overuse:

Subsidence:

- Withdrawal > recharge leads to sediment compression
- Ground sinking, damage to buildings and pipelines

Water Table Lowering:

- Extensive mining in arid/semi-arid regions
- India: 5-10m decline due to increased tube wells and decreased rainfall
- NASA GRACE data: Northern India groundwater receding 10cm/year

Waterlogging:

- Excessive irrigation with brackish water
- Gradual rise in water table
- Salinity problems

Groundwater Contamination:

- Arsenic, fluorides, iron, nitrates
- Many aquifers unfit for use
- Population growth responsible for river pollution

Surface Water

Definition: Water from precipitation that doesn't penetrate ground or evaporate, forming streams, lakes, ponds, wetlands, artificial reservoirs.

Uses: Irrigation, industrial use, public water supply, navigation

Water-Rich vs Water-Poor Countries:

Top 10 Water-Rich: Iceland, Surinam, Guyana, Papua New Guinea, Gabon, Solomon Islands, Canada, Norway, Panama, Colombia, Brazil

Water-Poor: Kuwait, UAE, Malta, Jordan, Saudi Arabia, Singapore, Moldova, Israel (Located in desert belt 15°-35° latitude, some densely populated)

Floods and Droughts

Floods:

- **Monsoon Pattern:** Concentrated rainfall (June-September) in India/Bangladesh
- **Contributing Factors:** Deforestation, overgrazing, mining, industrialization, global warming
- **Cloud Bursts:** Kedarnath 2013 (41 deaths, 4550 villagers affected)
- Excess rainfall in 2025

Droughts:

- **Affected Areas:** 80 countries in arid/semi-arid regions
- **Definition:** Annual rainfall below normal, less than evaporation
- **Anthropogenic Causes:**
  - Overgrazing, deforestation, mining → desertification
  - India: 70% area is drought-prone
  - Erroneous intensive cropping patterns
  - Increased exploitation of water resources through wells/canals
  - Maharashtra: 39 years with no record of adequate rainfall

Remedial Measures:

- Mixed cropping (wheat + gram, wheat + mustard)
- Social forestry and wasteland development
- Eucalyptus (lowers water table due to high transpiration, allelopathy)

Water Conflicts

Inter-State Disputes:

- 17 out of 18 major rivers are shared between states
- Intense conflicts over water resources

The Cauvery Water Dispute:

- Tamil Nadu (downstream) wants water regulation upstream
- Karnataka (upstream) refuses, claims rights as upstream user

Satluj-Yamuna Link (SYL) Dispute:

- Ravi-Beas water sharing between Punjab and Haryana
- Hathnikund barrage problem for Delhi

International Conflicts:

- **Middle East:** Jordan, Tigris-Euphrates, Nile river basins
- **Indus Water Treaty:** Three eastern rivers (Ravi, Sutlej, Beas) to India; three western rivers (Indus, Jhelum, Chenab) to Pakistan

Traditional Water Management:

- **Neerkatti:** South India traditional tank managers
- **Havaldars/Jaghyas:** Maharashtra water managers for canal distribution

Mineral Resources

Definition and Classification

Minerals: Naturally occurring, inorganic, crystalline solids with definite chemical composition and characteristic physical properties (silicates, carbonates, sulfides, halides, oxides).

Common Rock-Forming Minerals: Quartz, feldspar, biotite, dolomite, calcite, laterite

Composed of Elements: Oxygen, silicon, aluminum, iron, calcium, magnesium

Uses and Exploitation

1. **Industrial Development:** Plants and machinery
2. **Energy Generation:** Coal, lignite, uranium
3. **Construction:** Housing, settlements
4. **Defense:** Weapons, armaments
5. **Transportation:** Various means
6. **Communication:** Telephone wires, electronic devices
7. **Medicine:** Particularly Ayurvedic system
8. **Alloy Formation:** Various applications (phosphorite - calcium phosphate)
9. **Agriculture:** Fertilizers, seed dressing, fungicides (zineb-zinc, Maneb-manganese)
10. **Jewelry:** Gold, silver, platinum, diamond
11. **Permanent Magnets:** Rare earth elements for wind energy, semiconductors

Types of Minerals

Non-Metallic Minerals: Graphite, diamond, quartz, feldspar **Metallic Minerals:** Bauxite, laterite, hematite

Historical Significance: Human periods named after metals (Bronze Age, Iron Age)

Major Reserves and Uses

Aluminum:

- **Reserves:** Australia, Guinea, Jamaica
- **Uses:** Packaging, transportation, utensils, electronics

Chromium:

- **Reserves:** Kazakhstan, South Africa, India
- **Uses:** High-strength steel alloys, textile/tanning industries

Copper:

- **Reserves:** USA, Canada, Chile, Zambia
- **Uses:** Electrical/electronic goods, building, construction

Iron:

- **Reserves:** Australia, Brazil, Russia, China
- **Uses:** Heavy machinery, steel production, transportation

Lead:

- **Reserves:** Australia, China, Peru, Mexico, USA
- **Uses:** Car batteries, radiation protection, paints, ammunition

Manganese:

- **Reserves:** South Africa, Ukraine, Brazil
- **Uses:** High-strength, heat-resistant steel alloys

Platinum:

- **Reserves:** South Africa, Canada, USA, Zambia, Australia
- **Uses:** Automobiles, catalytic converters, electronics, medical

Gold:

- **Reserves:** Australia, Russia, South Africa, Indonesia
- **Uses:** Ornaments, medical, electronics, aerospace

Silver:

- **Reserves:** Peru, Australia, Poland
- **Uses:** Photography, electronics, jewelry

Cobalt:

- **Reserves:** DR Congo, Australia, Indonesia, Cuba, Philippines, Russia, Canada, Madagascar, USA
- **Uses:** Aircraft engines, gas turbines, magnets, super alloys, cemented carbides, catalysts

Nickel:

- **Reserves:** Indonesia, Australia, Brazil, Russia, Cuba, Philippines
- **Uses:** Chemical industry, steel alloys, catalysts, coins

Lithium:

- **Reserves:** Chile (8 million tons), Australia (2.7 million), Argentina, China (1 million)
- **Uses:** Storage batteries for solar/wind power, mobile phones, laptops, cameras, electric vehicles, catalysts

Rare Earth Metals

Global Deposits: China, United States, Australia, Russia; other viable ores in Canada, India, South Africa, Southeast Asia

Applications:

- **AI/ML Hardware:** Data centers, processors, learning algorithms
- **Renewable Energy:** Solar panels, electric vehicles, wind turbines, energy storage, catalytic converters, hydrogen production
- **Wind Turbines:** Neodymium, praseodymium, dysprosium, terbium for high-strength permanent magnets (300 kg neodymium per turbine)
- **Electronics:** Glass, lights, magnets, batteries
- **Robotics:** Dysprosium and terbium boost magnets in AI-powered robots

Non-Metallic Minerals

Silicate Minerals: Sand and gravel for construction, bricks, paving **Limestone:** Concrete, building stone, agriculture (neutralize acid soils), cement **Gypsum:** Plaster wall-board, agriculture, cement mixing **Potash, Phosphorite:** Fertilizers **Sulfur Pyrites:** Medicine, battery, metallurgical industries

Wealthy Nations and Mineral Resources

Resource-Rich Countries: Australia, South Africa, USA, Canada with most metallic mineral reserves

USA Resources: Abundant copper, lead, iron, natural gas, timber, bauxite, uranium **Japan:** Virtually no metal reserves, coal, oil but technologically advanced (world's third-largest economy)

Critical vs Strategic Minerals:

- **Critical:** Essential for economy (iron, aluminum, copper, gold)
- **Strategic:** Required for defense (manganese, cobalt, platinum, chromium)
- **Lithium:** Important for renewable energy
- **Rare Earth Elements:** Essential for renewable energy, digitalization, high-tech devices, medical equipment, military systems

Major Minerals of India

Energy Minerals:

- **Coal and Lignite:** West Bengal, Jharkhand, Odisha, MP, AP
- **Uranium:** Jharkhand, Andhra Pradesh (Nellore, Nalgonda), Meghalaya, Rajasthan (Ajmer)

Other Commercial Minerals:

- **Aluminum (Bauxite):** Jharkhand, West Bengal, Maharashtra, MP, Tamil Nadu
- **Iron:** Jharkhand, Odisha, MP, AP, Tamil Nadu, Karnataka, Maharashtra, Goa
- **Copper:** Rajasthan (Khetri), Jharkhand, Karnataka, MP, West Bengal, Andhra Pradesh, Uttarakhand

India's Mineral Ranking:

- **Coal:** Largest reserves globally
- **Iron Ore, Manganese, Bauxite:** 7th largest
- **Mica:** 8th largest
- **Other minerals:** Copper, natural gas, diamonds, limestone, thorium

India's Exports (April-January): USD 335.4 billion

- Refined Petroleum: $25.3B
- Packaged Medicaments: $17.8B
- Diamonds: $16B
- Rice: $8.21B
- Jewelry: $7.57B

Environmental Impact of Mineral Extraction

Indian Mining Problems: Annual value: Rs. 50,000 crores

Six Major Problematic Mines:

1. **Jaduguda Uranium Mine, Jharkhand:** Radioactive exposure
2. **Jharia Coal Mines, Jharkhand:** Underground fires, land subsidence, displacement
3. **Sukinda Chromite Mines, Odisha:** Hexavalent chromium (Cr6+) pollution - highly toxic and carcinogenic
4. **Kudremukh Iron Ore Mine, Karnataka:** River pollution, biodiversity threat
5. **East Coast Bauxite Mine, Odisha:** Encroachment, rehabilitation issues
6. **North-Eastern Coal Fields, Assam:** High sulfur contamination

Mining Methods and Impacts

Surface Mining Types:

1. **Open-Pit Mining:** Machines dig holes, remove ores (copper, iron, gravel, limestone, sandstone, marble, granite)
2. **Dredging:** Chained buckets/draglines scrape underwater minerals
3. **Strip Mining:** Ore stripped using bulldozers, power shovels, stripping wheels (phosphate rock, coal)

Environmental Damages:

1. **Devegetation and Landscape Defacing:** Topsoil and vegetation removal
2. **Land Subsidence:** Underground mining causes tilting buildings, cracks, road buckling
3. **Groundwater Contamination:** Disturbs hydrological processes; sulfur converts to sulfuric acid; heavy metals leach
4. **Surface Water Pollution:** Acid drainage contaminates streams/lakes
5. **Air Pollution:** Smelting emits pollutants, damages vegetation
6. **Occupational Health Hazards:** Respiratory and skin diseases from particulate matter
7. **Noise and Vibrations**

Remedial Measures:

- Environmental Impact Assessment (EIA)
- Mine worker safety priority
- Eco-friendly mining technology
- Microbial-leaching techniques (Acidithiobacillus ferrooxidans)
- Re-vegetation with appropriate plant species
- Land stabilization, flora restoration
- Prevention of toxic drainage discharge
- Air emission standards compliance

Land Resources

Land as a Resource

Characteristics:

- Finite and valuable resource for food, fiber, fuel, basic amenities
- Soil (especially topsoil) is renewable but regenerates slowly
- 200-1000 years needed for 1 inch (2.5 cm) soil formation

Countries with Most Arable Land:

1. **United States:** 389,767,633 acres (16.8% of land)
2. **India:** 385,641,557 acres (50.4% of land)
3. **Russia:** 300,594,679 acres (7.3% of land)
4. **China:** 295,220,748 acres (11.3% of land)

Green Revolution in India:

- High-Yielding Variety (HYV) seeds
- Mechanized tools, irrigation, pesticides, fertilizers
- Norman Borlaug: Dwarf wheat variety developer

Land Degradation

Causes:

- Population growth increases demand for arable land
- More population → more land degradation from overexploitation
- Average annual erosion rate: 10 times more than renewal rate

Types of Degradation:

- Soil erosion, waterlogging, salinization
- Contamination with industrial wastes (fly-ash, press-mud, heavy metals)

Soil Erosion

Types:

1. **Normal/Geologic Erosion:** Natural gradual removal, balanced with renewal
2. **Accelerated Erosion:** Human-caused, rate faster than formation

Agents:

- **Climatic:** Water (torrential rains, runoff, wave action, snow melting) and wind
- **Biotic:** Excessive grazing, mining, deforestation

Soil Conservation Practices

Seven Methods:

1. **Biodegradable Erosion Control Mats**
2. **Crop Rotation**
3. **Conservation Tillage:** No-till, strip-till, ridge-till systems maintaining crop residues
4. **Contour Farming:** Crops grown across slopes rather than up/down
5. **Strip Farming:** Alternating crop strips with soil-saving cover
6. **Terrace Farming:** Converting steep slopes to broad terraces
7. **Diversion Structures**

Additional Practices:

- **Alley Cropping:** Crops between tree/shrub rows (Agroforestry)
- **Fallow Land:** Land left without cropping to regain nutrients

Waterlogging

Cause: Heavy irrigation to provide moisture and leach salts deeper **Effect:** Soil becomes waterlogged with salinity issues

Landslides

Causes: Anthropogenic activities clearing forested areas:

- Hydroelectric projects, large dams, reservoirs
- Road and railway construction
- Building construction, mining **Effects:** Increased stream turbidity, reduced productivity

Desertification

Definition: Process where productive potential of arid/semi-arid lands falls by 10% or more **Severe desertification:** >50% productivity decline, huge sand dunes **India Status:** 29.32% land degradation and desertification

Characteristics:

- Devegetation and loss of vegetal cover
- Groundwater depletion
- Salinization
- Severe soil erosion

Causes:

1. **Natural:** Climate change
2. **Anthropogenic:**
    - Deforestation
    - Overgrazing
    - Mining and quarrying

Xenobiotics Definition: Chemical substances foreign to animal life including drugs, pesticides, cosmetics, flavors, fragrances, food additives, industrial chemicals, environmental pollutants

Individual Water Conservation Efforts

Daily Practices:

- Don't keep taps running while brushing, shaving, washing
- Fill washing machines only to required level
- Install water-saving toilets (≤6 liters per flush)
- Check and repair water leaks promptly (pin-hole leak = 640 liters/month waste)
- Reuse soapy water for washing courtyards/driveways
- Water plants/lawns in evening when evaporation losses minimum
- Use drip irrigation and sprinkling systems
- Install rainwater capture systems
- Build rainwater harvesting systems

Energy Resources

Introduction

Energy as Development Index: Energy consumption indicates nation's development level since almost all development activities depend on energy

Historical Energy Use:

- Early humans: cooking, heating
- Wind and hydropower: last 10,000 years
- Steam engines replaced wood burning with coal
- Coal largely replaced by oil
- Oil crises (Yom Kippur War, Iranian revolution) led to alternative energy exploration

Growing Energy Needs

Current Demand:

- Agriculture, industry, mining, transportation, cooling/heating all need energy
- World faces energy deficit with population increase
- Fossil fuels (oil, gas, coal) supply 80-90% of commercial energy
- These resources won't last many more years
- Lifestyle changing from simple to luxurious

Global Energy Inequality:

- **Developed countries (USA, Europe):** 5% population, consume 25% energy resources
- **Average consumption:** USA person = 230 GJ/year (60 barrels oil equivalent)
- **Developing countries:** Nepal, Bhutan, Ethiopia person <1 GJ/year

Current Energy Statistics (2023):

- **Global demand:** Rose 2.2%, reaching 650 EJ
- **India ranking:** 3rd largest primary energy consumer (35.26 EJ) behind China (170.74 EJ) and USA (94.28 EJ)
- **Per capita consumption:** India 27.3 GJ vs China 118.4 GJ vs USA 277.3 GJ
- **India's rural electrification:** 90% villages have electricity
- **India's power capacity:** 450 GW total (240 GW thermal, 110.9 GW solar, 89.6 GW wind)

Types of Energy Sources

Renewable (Non-conventional):

- Can be generated continuously, inexhaustible
- Examples: Wood, solar, wind, tidal, hydro, biomass, biofuels, geothermal, hydrogen
- Can be used repeatedly endlessly

Non-Renewable:

- Accumulated over long periods, cannot be quickly replenished
- Examples: Coal, petroleum, natural gas, nuclear fuels (uranium, thorium)
- Took millions of years to form

Renewable Energy Sources

Solar Energy

Source Characteristics:

- Sun is ultimate energy source (directly/indirectly for all others)
- Sun has ~5 billion years remaining life
- Solar constant: 1.4 kilojoules/sec received by near-earth space

Traditional Uses: Drying clothes, food-grains, food preservation, salt production

Solar Technologies:

1. Solar Heat Collectors:

- **Passive:** Natural materials (stones, bricks, glass) absorb heat during day, release at night
- **Active:** Pump heat-absorbing medium through collectors on building tops
- **Glauber's Salt:** Sodium sulfate decahydrate (melts at 32°C)
- **Solarimeter:** Pyranometer measuring solar radiation

2. Solar Cookers:

- Use mirrors to reflect solar radiation onto black insulated box containing food

3. Solar Water Heaters:

- Insulated black box with glass lid
- Black painted coils heat water flowing to storage tank
- Hot water supplied to buildings, hotels, hospitals

4. Solar Cells/Photovoltaic Cells:

- Thin wafers of semiconductor materials (silicon)
- Solar radiation creates potential difference, electron flow, electricity
- **Doping process:**
  - **N-type:** Silicon doped with phosphorus (increases electrons)
  - **P-type:** Silicon doped with boron/indium (increases positive holes)
  - **P-N junction:** Creates electric field for current flow

5. Solar Furnaces:

- Thousands of small plane mirrors arranged as concave reflectors
- Achieve temperatures up to 3000°C
- Concentrating lenses also used
- Applications: Solvent extractors, chemical reactions

6. Solar Power Plants:

- Large-scale solar energy harnessing
- Concave reflectors/solar concentrators boil water → steam → electricity
- **Gurugram Plant:** 50 kW capacity
- **Major Plants:** Karnataka, Telangana, Rajasthan, Andhra Pradesh, Gujarat

Major Solar Parks in India:

- **Bhadla Solar Park, Rajasthan:** 56 sq km, 2,245 MW capacity (largest in India, 11th globally)
- **NTPC Khavda Solar Park, Gujarat:** 4,750 MW proposed capacity (under construction)

Current Solar Capacity (July 2025): 119.02 GW total

- Ground-mounted: 90.09 GW
- Grid-connected rooftop: 19.88 GW
- Hybrid projects: 3.06 GW
- Off-grid: 5.09 GW

Wind Energy

Principle: High-speed winds have kinetic energy harnessed by windmills **Driving Force:** Solar energy creates winds **Optimal Locations:** Coastal regions, open grasslands, hilly regions, mountain passes, ridges **Minimum Wind Speed:** 15 km/hr for satisfactory operation **Height Range:** 10-200 meters

India's Wind Power Status:

- **Global Ranking:** 4th largest installed capacity, 3rd largest renewable producer
- **Growth:** 21.04 GW (2014) → 51.5 GW (May 2022)
- **Renewable Energy Contribution:** Second largest contributor after solar

Hydropower

Principle: Water flowing from height moves turbine blades → rotates generator → electricity (Faraday's law) **India's Potential:** 4×10^{11} kW-hours estimated **Current Utilization:** Little more than 25% of potential used

Tidal Energy

Source: Ocean tides from gravitational forces of sun and moon **Mechanism:** High and low tides cause water rise and fall **Limited Sites:** Few places worldwide suitable for tidal energy **Examples:**

- **Bay of Fundy, Canada:** 17-18m high tides, 5,000 MW potential
- **La Rance, France:** First modern tidal power mill
- **India:** Gulf of Cambay, Gulf of Kutch, Sunderbans deltas

Ocean Thermal Energy Conversion (OTEC)

Principle: Energy from temperature difference between surface and deep ocean water **Requirement:** 20°C+ difference between surface and deeper water **Process:**

- Warm surface water boils liquid (ammonia)
- High-pressure vapors drive turbine generator
- Cold deep water pumps up to cool and condense vapors
- **Rankine Cycle:** Continuous 24-hour operation

Geothermal Energy

Source: Hot rocks present inside earth **Natural Manifestations:** Steam/hot water comes through cracks as geysers **India Examples:** Manikaran (Kullu), Sohna (Haryana) **Successful Operations:** USA, New Zealand geothermal plants

Biomass Energy

1. Energy Plantations:

- **Fast-growing trees:** Cottonwood, poplar, Leucaena
- **Non-woody plants:** Sugarcane, sweet sorghum, sugar beet
- **Aquatic plants:** Water hyacinth, seaweeds
- **Carbohydrate-rich:** Cereal crops

2. Agricultural and Urban Waste:

- **Crop residues:** Bagasse, coconut shells, peanut hulls, cotton stalks
- **Animal waste:** Dung, fishery, poultry waste, human refuse
- **Brazil:** 30% electricity from burning bagasse
- **Rural India:** 80% heating from agricultural wastes, wood, animal dung

3. Biogas:

- **Composition:** Methane, carbon dioxide, hydrogen, hydrogen sulfide (methane major component)
- **Production:** Anaerobic digestion of animal waste (sometimes plant waste) with water
- **Plant Types:** Floating gas-holder type, Fixed dome type
- **Product:** Compressed Biogas (CBG)

Biofuels

Ethanol:

- Produced from carbohydrate-rich substances like sugarcane
- Burns clean, non-polluting
- Lower calorific value than petrol, produces less heat

Methanol:

- Burns at lower temperature than gasoline/diesel
- Very useful fuel

Biodiesel and Green Diesel:

- **Historical:** Rudolf Diesel tested peanut oil (August 10, 1893)
- **1930s-1940s:** Vegetable oils used as diesel
- **Sources:** Sunflower oil, soybean oil, palm oil, Jatropha oil, Pongamia oil, waste cooking oil

Hydrogen as Fuel:

- **Green Hydrogen:** Electrolysis using renewable energy
- **Blue Hydrogen, Brown Hydrogen, Pink Hydrogen:** Different production methods

Renewable Energy Global Status

Top Countries with Most Renewable Energy: Norway, Sweden, Brazil, New Zealand, Denmark, Switzerland, Finland, Colombia

India's Global Ranking:

- **Overall:** 3rd globally after China and USA for renewable power addition
- **Specific Rankings:** 4th in wind power, 3rd in solar power capacity
- **Growth:** 76.37 GW (March 2014) → 226.79 GW (2025) - nearly 3x increase

Non-Renewable Energy Sources

Coal

Formation: 255-350 million years ago in hot, damp regions during Carboniferous age

Types (in order of formation):

1. **Peat:** Lowest grade
2. **Lignite/Brown coal:** Low grade
3. **Bituminous coal:** Medium grade
4. **Anthracite:** Highest grade (only in J&K, India)

Reserves and Usage:

- **Current rate:** Coal reserves last ~200 years
- **With 2% annual increase:** Will last 65 years
- **India's production (2022-23):** 893 MT (8.67% growth)
- **Global reserves:** India has 9% (360 billion tons)

Major Indian Coalfields: Raniganj, Jharia, Bokaro, Singrauli, Godavari valley **Coal States:** Jharkhand, Odisha, West Bengal, Madhya Pradesh, Andhra Pradesh, Maharashtra **Coal Capital:** Dhanbad **Imports:** Coking coal mainly imported (~40 million tons annually)

Environmental Issues:

- Produces CO2 (greenhouse gas)
- Contains sulfur impurities → sulfur oxides, nitrogen oxides
- Fly ash production
- **Clean coal technologies** available

Petroleum

Global Importance: Lifeline of global economy **Major Reserves:** 67% in OPEC countries, 1/4 in Saudi Arabia **Current Estimates:** World reserves may be exhausted in 40-70 years

Crude Oil Processing:

- **Composition:** Complex mixture of alkanes and other hydrocarbons
- **Refining:** Fractional distillation process
- **Products:** Gasoline, kerosene, ATF, diesel, lubricating oil, paraffin wax, asphalt, petrochemicals
- **Advantages:** Cleaner than coal, burns completely, easier transport/use

Major Oil Companies: IOCL, HPC, BP

Liquefied Petroleum Gas (LPG)

Main Component: Butane, with propane and ethane **Storage:** Easily converted to liquid under pressure

Natural Gas

Composition: 95% methane, small amounts propane and ethane **Shale Gas:** 70-90% methane from shale formations **Formation:** Fossil fuel from decomposing remains of dead animals/plants

Advantages:

- Cleanest fossil fuel
- Easy pipeline transport
- High calorific value: 34 MJ/m^3
- Burns without smoke

Global Reserves:

- **Russia:** 40% maximum reserves
- **Iran:** 14%
- **USA:** 7%

India's Natural Gas:

- Found with oil fields
- **Major fields:** Tripura, Assam, off-shore Mumbai, Krishna-Godavari Delta
- **Companies:** ONGC, GAIL
- **Import:** LNG (Liquefied Natural Gas)

Nuclear Energy

Applications: High destructive power (weapons) and commercial energy generation

Two Types of Reactions:

1. Nuclear Fission:

- Heavy nucleus split into lighter nuclei on neutron bombardment
- Chain reaction releases large energy
- **Example:** $^{235}U + {}^{1}n \rightarrow {}^{92}Kr + {}^{141}Ba + \text{Energy}$
- **Also:** $^{238}U + {}^{1}n \rightarrow {}^{239}Pu + \text{Energy}$

Efficiency:

- 2 kg Uranium-235 generates 1000 MW electricity
- 5600 tons coal required for same electricity production

India's Nuclear Power:

- **Current:** 22 operating reactors
- **Capacity:** 6780 MWe installed

2. Nuclear Fusion:

- Light element isotopes fused at extremely high temperatures (>1 billion°C)
- Forms heavier nucleus, releases more energy than fission
- **Challenge:** Difficult to initiate, extreme heat containment
- **Examples:** Powers sun and stars
- **R&D Status:** ~20 fusion reactors worldwide in development

Fusion Reaction Principle:

- Two light nuclei merge → single heavier nucleus
- Total mass of result < original masses
- Leftover mass becomes energy

Present Energy Scenario and Future Trends

Current Trends:

- Move toward cleaner renewable energy sources (mainly solar)
- Electric vehicles encouragement (fuel cells, hydrogen)
- **COP 21 Paris:** Voluntary commitments for CO2 reduction

India's NDC (Nationally Determined Contributions) Targets by 2030:

1. **Emissions-intensity target:** 45% below 2005 levels
2. **Renewable energy target:** 50% cumulative electric power from non-fossil fuel sources
3. **Sustainable lifestyles:** Climate justice to protect poor/vulnerable from climate change impacts

Equitable Use of Resources and Sustainable Lifestyle

Global Divide

More Developed Countries (MDCs):

- 22% of world population
- Use 88% natural resources, 73% energy
- Command 85% global income
- Contribute major proportion to pollution
- **Countries:** USA, Canada, Japan, Australia, New Zealand, Western Europe

Less Developed Countries (LDCs):

- 78% of world population
- Use 12% natural resources, 27% energy
- Only 15% of global income
- Gap increasing due to sharp population increase in LDCs

Sustainability Challenges

Rich Nations' Growth:

- More development → more pollution
- Earth's life support system under threat
- 10% annual growth = 16x increase in 70 years
- **Question:** Is this level of growth sustainable?

Causes of Unsustainability:

1. **Poor countries:** Overpopulation, under-consumption of resources
2. **Rich countries:** Over-consumption, waste generation

Solution: More balanced and equitable global resource distribution to meet everyone's basic needs

Top 10 Sustainable Countries

1. Canada
2. Germany
3. Norway
4. Switzerland
5. Finland
6. Rural Sweden
7. Stockholm, Sweden
8. Denmark

Note: Individual efforts in natural resource conservation are essential for sustainability.

Assignment Information

Assignment 1 Topic: Rare earth metals - importance, uses, occurrence, production, and current demand for permanent magnets

Submission Details:

- **Due Date:** September 20, 2025
- **Length:** 5-6 pages (excluding figures)
- **Format:** Double-spaced, Font size 14
- **Sources:** Books, Encyclopedia, Wikipedia
- **Requirements:** Write in own words, references may be included within page limit
- **Evaluation:** Turnitin used for plagiarism checking, marks deducted for late submission and plagiarism