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SELF-LEARNING MATERIAL

ENERGY AND ENVIRONMENT

DRE 101

SELF-LEARNING MATERIAL

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Course Title: ENERGY AND ENVIRONMENT

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DRE 101: ENERGY AND ENVIRONMENT

UNIT 1: ECOLOGICAL PRINCIPLES AND ENERGY FLOW

UNIT STRUCTURE

1.1 OBJECTIVES:

This unit is will acquaint you of the interaction of living organism among themselves and with their non-living environment in this thin, life supporting global skin of air, water, soil and organisms. After going through this unit, you will be able to explain how producers, consumers, and decomposers interact with the physical environment to accomplish energy flows and nutrient cycling.

1.1.1 ECOLOGICAL PRINCIPLE OF NATURE:

Life first appeared on Earth about 3 billion years ago. It started with a small living cell that fixes and uses energy in order to grow and reproduce. Subsequently life took part with many systems of energy management (or metabolism) to eventually evolve into more and more complex forms.

But how do we define life? Generally speaking, we may distinguish living from non-living things based on the following characteristics (Beeby and Brennan, 1997; Jones, 1997):

- Have a complex, organized structure based on organic (carbon) compounds;
- Acquire material and energy from their environment converting them to different forms;

- Actively maintain their complex structure;
- Respond to environmental stimuli;
- Grow and reproducing using a molecular blueprint (DNA); and
- Have the capacity to evolve.

We know that biologists normally study life and living things. At the same time, it is surprising to learn that biologists also study *non-living* things. Why should a biologist pay attention to things which are not alive? To answer this, it is pertinent to think for a moment about the basic principle of evolution through natural selection.

Natural selection is the result of interactions between living organisms and their environment. For selection to work, we need two things: **Genetic diversity** within a group of organisms, and an **environment** in which this diversity can be expressed. What is meant by the term *Environment*?

The environment is the world surrounding an organism. The environment can be divided into two basic parts:

- **Biotic factors**, which include any living organisms that directly or indirectly affect the subject of study; and
- **Abiotic factors**, which include any **non-living** phenomena which directly or indirectly affect the subject of study.

Biotic factors might include predators, competitors, parasites, food sources and so forth. Abiotic factors include things like soil composition, temperature and rainfall, sunlight and geological factors, among others. In the study of an organism, we thus need to pay attention to both living and non-living features of the environment to understand the way it fits into the surrounding world.

Fig 1: Biotic factors of the environment

1.1.2. ECOLOGY

When biologists study living things, one of the primary concerns is the study of how the biotic and abiotic factors in the environment affect the organism. The study of the interaction between living organisms and their surrounding environment is **ecology**. As ecologist C.J. Krebbs put it, ecology is the study of "**where** organisms are found, **how many** occur there, and **why**."

Ecology, or ecological science, is the scientific study of the distribution and abundance of living organisms and how the distribution and abundance are affected by interactions between the organisms and their environment. The environment of an organism includes physical components, which can be described as the sum of local abiotic factors such as solar insolation, climate and geology, as well as the other organisms that share its habitat. The term *Ökologie* was coined in 1866 by the German biologist Ernst Haeckel, which is derived from the Greek οικος (oikos, "household") and λόγος (logos, "study"). Therefore "ecology" means the "study of the household (of nature)".

1.1.2.1 ECOLOGICAL DISCIPLINES

Ecology is too broad a subject to discuss as a single line of scientific study. Just as biology can be broken into subdivisions such as botany, zoology, human medicine, and so forth, we can break ecology into separate disciplines, each of which focuses on one aspect of ecological study.

- **Behavioral ecology** examines the way in which the **behavior** of an organism helps it adapt to its environment.
- **Population ecology** studies the dynamics within a **group** of organisms: all its members are **of one species** and **live in the same place**.
- **Community ecology** is the study of interactions between **multiple populations** of **different species living together in one area**.
- **Ecosystem ecology** studies the **flow of energy and matter** within the biotic and abiotic elements of an area.
- **Landscape ecology** examines the way in which the surrounding **geological and geographical features** of multiple **adjacent ecosystems** affect the populations and communities within those areas. (Ref. 1)

1.1.3. ORGANISM AND ENVIRONMENT

Each and every living organism has its specific surrounding medium of environment with which it continuously interacts and remains fully adapted. The environment is the sum total of physical and biotic conditions influencing the responses of the organisms. The life supporting environment of the planet earth - the biosphere is composed of three chief media, the air, water and soil, which are the components of three major sub-divisions of the biosphere – the atmosphere, hydrosphere and lithosphere respectively.

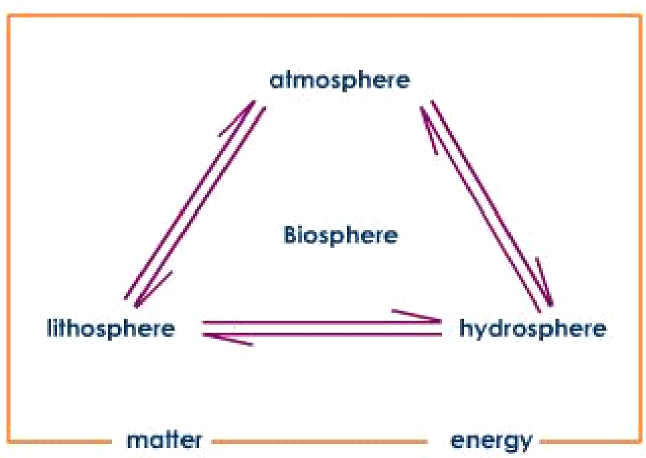

Fig 2: The Three Components of the Biosphere

These media are not completely isolated. In fact, some of the atmospheric gases are dissolved in natural water and some moisture is present almost all everywhere in the atmosphere.

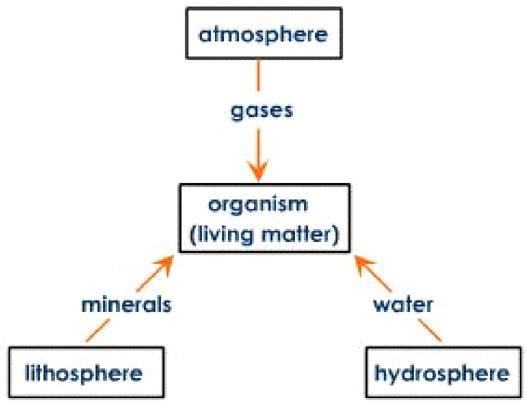

Fig 3: The material contribution of the three subdivisions of biosphere

1.1.3.1. PHYSICAL HIERARCHY

Every organism consists of parts that can be arranged in increasing levels of complexity. Each higher level is more complex than the one below it. The smallest structural unit of matter, both non-living and living are protons, neutrons and electrons. These particles combine in a specific manner to form the atom. The atoms in turn combine to form the next larger unit called as molecules or chemical compounds. The complexes of compounds combine to form the organelles, which are sub-microscopic bodies. Organelles by themselves do not qualify as living units. A specific combination of organelles forms a living unit called the cell.

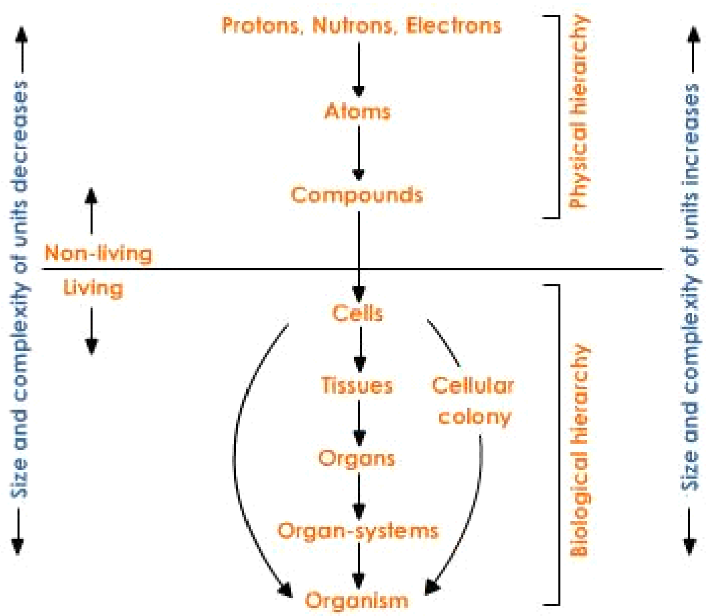

Fig 4: Hierarchy of levels in the organization of living organisms and nonliving matter

1.1.3.2. BIOLOGICAL HIERARCHY

A cell is regarded as the structural and functional unit of life. Thus a living organism must consist of at least one cell. Cells combine to form higher units, the tissues, which in turn come together and constitute the next higher unit, known as the organs. The organs occur in groups, to form organ systems. All the organ systems together form an organism.

The units at each level are specialised entities. They have their own structure and function, but no unit can exist in strict isolation in nature. They are mutually dependent on one another. Moreover, they derive energy and materials needed for their survival from their environment. Thus, at any level of organisation there exists an intimate relationship between a unit and its environment.

1.1.3.3. ECOLOGICAL HIERARCHY

Ecological hierarchy begins at the level of the organism and proceeds to levels of greater complexity.

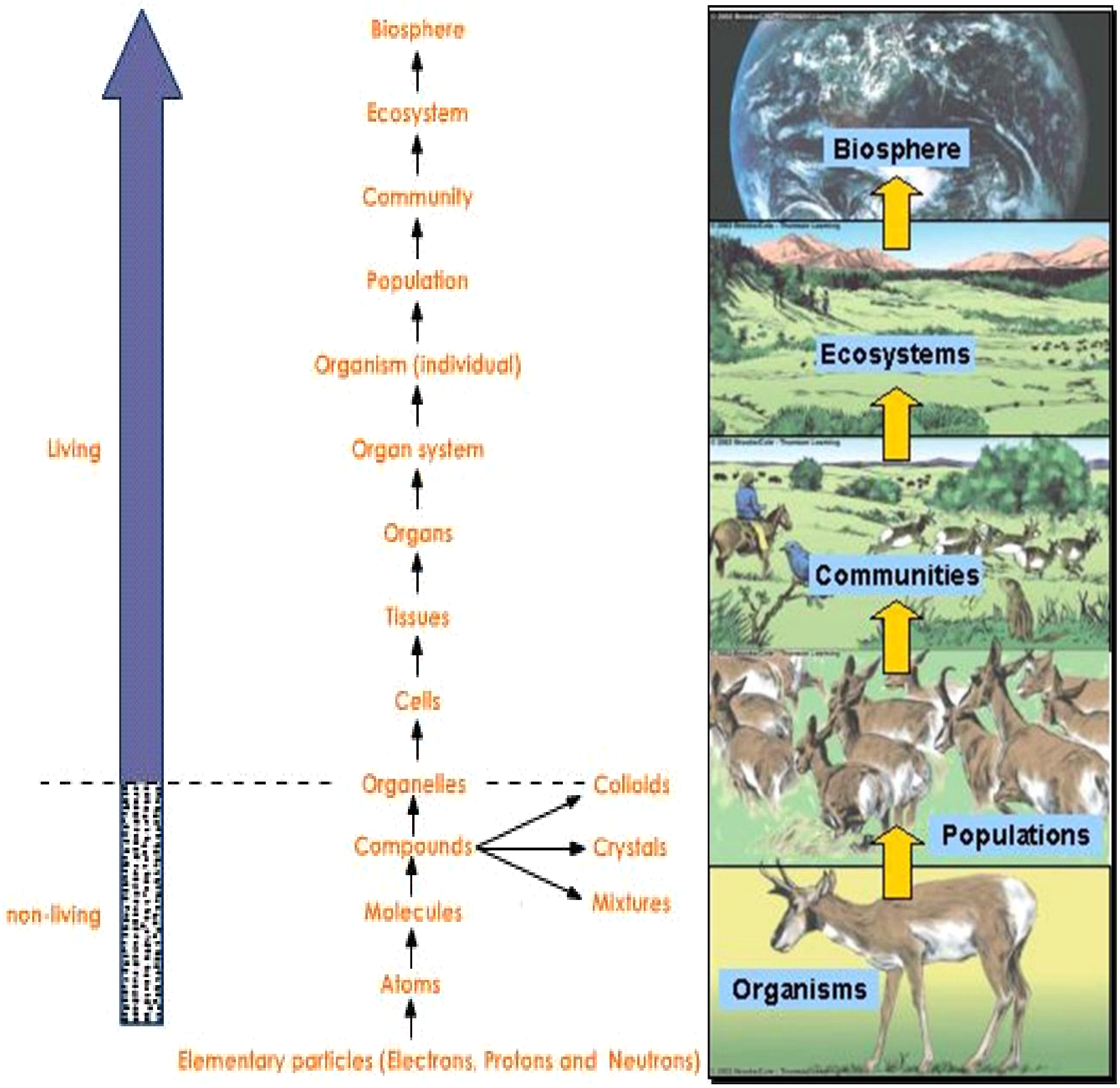

Fig 5: Ecological hierarchy

Organism

An organism may be small, unicellular or multicellular. Organisms have a fixed life span and organised life cycle comprising of birth, growth, maturity, old age and death. They are always derived from pre-existing ones through the mechanism of reproduction. The offspring resembles the parents very closely.

Population

A group of the same species inhabiting a specific geographical area at a particular time forms a population.

Biotic community

The organisms of all the populations that live in a defined area or habitat and interact in various ways with one another to form a self-sustained unit are collectively called a biotic community. Examples: Animal community, plant community or microbial community.

Table 1: Description of the Eight Ecological Principles and Associated Concepts

Principle	**Description**	**Associated Concepts**
Adaptation	The way a life system looks or behaves is not random or accidental; rather it is the result of changing to survive in a dynamic environment.	Evolution, Life History Patterns, Natural Selection, Survival, Predator-Prey Interactions
Behavior	Living systems evolve behavioral responses to stress and disturbances to enhance survival.	Reproduction, Predator-Prey interactions, Dispersal, Survival (humans and other animal species), Pest Control (exotics, nuisance animals) Harvesting
Diversity	Changes in environmental conditions over time have led to variety within each level of organization.	Competition, Land-Use Practices, Genetics, Survival, Fragmentation
Emergent Properties	When different levels of organization are functioning together, new properties are created that were not operational at lower levels	Complexity, Synthesis, Teamwork, Government
Energy Flow	Energy cannot be created nor destroyed but it can change form. Energy quality is always degraded through transformation.	Thermodynamics, Food Chains, Tropic Levels, Heat Exchange
Growth and Development	As organisms and systems increase in size, changes occur that allow survival. Growth rate slows as maximum capacity is met.	Succession, Reproduction, Population Dynamics, Competition
Limits	There are limits to how much stress can be tolerated by living systems.	Sustainability, Conservation, Disease, Natural Disaster, Agriculture, Pollution
Regulation	Energy is spent if a signal is sent to increase or decrease some function to maintain balance.	Feedback Loops, Organismal Systems, Cybernetics

1.2 CONCEPT OF ECOSYSTEMS

What is an ecosystem?

System : Regularly interacting and interdependent components forming a unified whole.

Ecosystem: An ecological system, *i.e.*, a community and its physical environment treated together as a functional system.

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Ecosystem is a basic functional unit that includes both organism and its environment, each influencing the properties of the other and both necessary for the survival and maintenance of life. The ecosystem comprises the biotic community and the non living environment.
Examples of natural ecosystem: ponds, lakes, oceans, grasslands, forests, deserts, tundra etc.

Ecosystem has the following four components:

1. **The non-living environment (abiotic)** such as the air, water, soil and the basic elements and compounds of the environment.

   The non-living environment consists of three types of components:

   - The climate regime and physical factors like temperature ,pH etc.
   - Inorganic substances such as water, carbon, nitrogen, sulphur, phosphorous and so on.
   - Organic substances like protein, carbohydrate, lipid, etc. which largely form the living body and link the abiotic and biotic components.

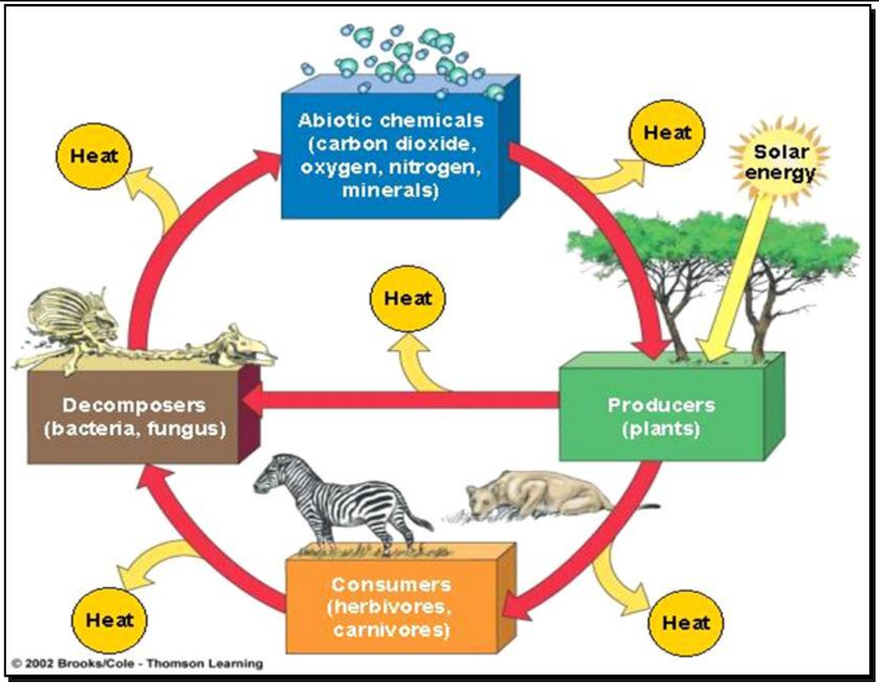

Fig 6: Four components of ecosystems.

2. Producers or energy transducers: Solar energy to Chemical energy. For example, the autotrophs.

3. Consumers : heterotrophic (hetero= other, trophic= nourishing) organism chiefly animals.

Depending upon the food habit

Hervivores (plant eaters) lives on plant

carnivores (flesh eater) usually prey on hervivores & other carnivores

e.g., insects, zooplankton, deer, cattle, elephant etc.

e.g., insect →preying mantis, large animal→ tiger or lion.

4. Decomposers: heterotrophic organisms but depend upon dead organic matter for their food, *e.g.*, microorganism like bacteria, fungi etc.

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Fig 7: Ecosystem Boundaries.

1.2.1. FUNCTIONAL ATTRIBUTES OF AN ECOSYSTEM:

Ecosystems has some functional attributes which keep its components running together. The following seven aspects are considered as functional attributes of the ecosystems.

- Biodiesel diversity and maintenance of stability,
- Primary and secondary productivity,
- Food chain relationships,
- Energy flow,
- Material recycling,
- Homeostatics and feedback
- Developments & evaluation of ecosystems.

Homeostasis-The maintenance of constancy within a biological system, either in terms of interaction between the organisms of a community of the internal environment of an individual.

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Fig 8: Food chains and food webs of ecosystems

1.3 DIFFERENT TYPES OF ECOSYSTEMS; ECOSYSTEM THEORIES

1.3.1 THE RULES OF ECOLOGY

According to F.A. Bazzaz, the rules of ecology may be

a. Everything is connected to everything else.
b. Everything must go somewhere.
c. There is no such thing as a free lunch

According to American ecologist H.T. Odum, the rule of ecology is to understand any system you must understand the next larger system.

1.3.2. AN ECOSYSTEM HAS ABIOTIC AND BIOTIC COMPONENTS:

Abiotic components: Solar energy provides practically all the energy for ecosystems. Inorganic substances, *e.g.*, sulphur, boron etc. tend to cycle through ecosystems. Organic compounds, such as proteins, carbohydrates, lipids and other complex molecules, form a link between biotic and abiotic components of the system.

BIOTIC components: The biotic components of an ecosystem can be classified according to their mode of energy acquisition, as **Autotrophs and Heterotrophs**

Autotrophs (self-nourishing) are called primary producers**.**

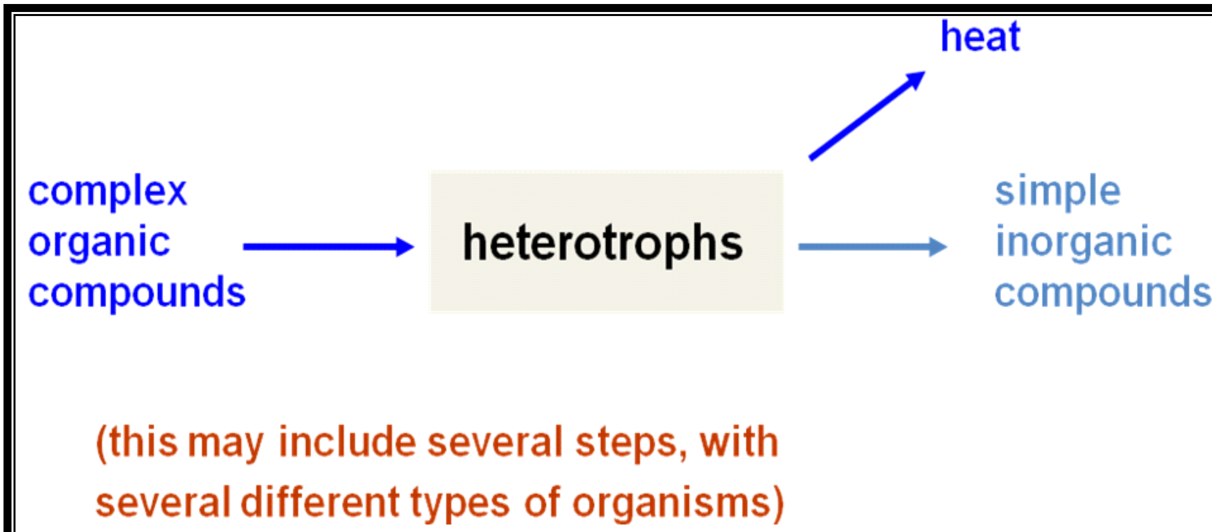
Photo-autotrophs fix energy from the sun and store it in complex organic compounds (*e.g.*, green plants, algae and some bacteria)

Chemoautotrophs (chemosynthesizers) are bacteria that oxidize reduced inorganic substances (typically sulphur and ammonia compounds) and produce complex organic compounds.

Fig 9. Chemoautotroph.

Heterotrophs

Heterotrophs (nourished from others) cannot produce their own food directly from sunlight and inorganic compounds. They require energy previously stored in complex molecules.



Heterotrophs can be grouped as **Consumers** and **Decomposers.** Consumers feed on organisms or particulate organic matter. Decomposers utilize complex compounds in dead protoplasm. Bacteria and fungi are the main groups of decomposers. Bacteria are the main feeders on animal material. Fungi feed primarily on plants, although bacteria also are important in some plant decomposition processes.

1.3.3. TYPES OF ECOSYSTEMS (REF 2)

As it is seen by now that in a marvelous way all the living, non living and climatic conditions of a place are interconnected and a geographical area along with this interconnected network is termed as an “Ecosystem”. Ecosystems differ in flora, fauna and weather but all of them support some kind of life. Therefore, it is very important to understand the features of the ecosystem before entering it and trying to make changes. It was lack of this understanding in early days that led to exploitation of the natural habitats and extinction of many rare species along with destruction of some beautiful landscapes. There are many important energy and matter transformation cycles that run through these ecosystems. Human beings are known to act in manners which disrupt these cycles and the natural flow of entities in an ecosystem. This leads to major problems in the ecosystems as links of cycles get detached and stability of the system is lost. To prevent this from happening we need to understand what kind of ecosystem we are dealing with. This is just a brief introduction to a subject which requires in depth study for its thorough understanding.

Different Kinds of Ecosystem

There are basically two types of ecosystems; Terrestrial and Aquatic. All other sub-ecosystems fall under these two.

Terrestrial ecosystems

Terrestrial ecosystems are found everywhere excluding water bodies. They are broadly classified into:

The Forest Ecosystem

These are the ecosystems where abundance of flora (plants) is seen and have a large number of organisms living in relatively small areas. Therefore, the density of life in forest ecosystems is very high. Any small change in the ecosystem can affect the whole balance and even collapse the ecosystem. One can see wonderful diversity in the fauna of these ecosystems too. Forest Ecosystems are again divided into few types.

- **Tropical evergreen forest:** Tropical forests which receive an average rainfall of 80 to 400 inches a year. These forests are marked by dense vegetation comprising of tall trees with different level heights. Each level gives shelter to different kinds of animals.
- **Tropical deciduous forest:** Dense bushes and shrubs dominate these forests along with broad levels of trees. This type of forest is found in many parts of the world and large variety of flora and fauna are found here.
- **Temperate evergreen forest:** These have very few number of trees but ferns and mosses make up this kind of forest. Trees have spiked leaves to minimize transpiration.
- **Temperate deciduous forest:** This forest is found in the moist temperate regions with sufficient rainfall. Winters and summers are well defined with trees shedding their leaves during winter.
- **Taiga:** Situated just south of the arctic regions, Taiga is distinguished by evergreen conifers. While the temperature is subzero for almost six months, the rest of the year is marked by the buzzing of insects and migratory birds.

The Desert Ecosystem

Desert ecosystems are found in regions receiving an annual rainfall of less than 25cm. They occupy around 17 % of land on the planet. Due to very high temperature, intense sunlight and low water availability, flora and fauna are very poorly and scarcely developed. Vegetation consists of mainly bushes, shrubs, few grasses and rarely trees. Leaves and stems of these plants are modified so as to conserve water. The best known desert plants are the succulents like spiny leaved cacti. Animal life includes insects, reptiles, birds, camels all of whom are adapted to the xeric (desert) conditions.

The Grassland Ecosystem

Grasslands are found in both temperate and tropical regions of the world but the ecosystems are slightly different. This area comprises mainly of grasses with very less shrubs and trees. Main vegetation forms grasses, legumes and plants belonging to composite family. Many grazing animals, herbivores and insectivores are found in grasslands. Two main types of grasslands ecosystems are:

1. Savanna: These tropical grasslands are seasonally dry with few individual trees. They support large number of grazers and predators.

2. Prairies: This is temperate grassland. It is completely devoid of trees and large shrubs. Prairies can be categorized as tall grass, mixed grass and short grass prairie.

The Mountain Ecosystems

Mountain lands provide a scattered but diverse array of habitats in which a large range of plants and animals are found. At higher altitudes, harsh environmental conditions generally prevail and only treeless alpine vegetation is found. The animals living here have thick fur coats for preventing themselves from cold and they hibernate in winter months. Lower slopes commonly are covered by coniferous forests.

Aquatic Ecosystems

An aquatic ecosystem is an ecosystem located in a body of water. It comprises aquatic fauna, flora and the properties of water too. There are two types of aquatic ecosystems, Marine and freshwater.

The Marine Ecosystem

Marine ecosystems are the largest ecosystems with coverage of nearly 71% of the Earth's surface and containing 97% of the planet's water. The water in Marine ecosystems has salts and minerals dissolved in them in high amounts. Different divisions of marine ecosystems are:

- Oceanic: The relatively shallow part of the ocean that lies over the continental shelf.
- Profundal: Bottom or deep water.
- Benthic Bottom substrates.
- Inter-tidal: The area between high and low tides.
- Estuaries
- Salt marshes
- Coral reefs
- Hydrothermal vents-where chemosynthetic bacteria form the food base.

Many types of organisms are found in marine ecosystems including brown algae, dinoflagellates, corals, cephalopods, echinoderms, and sharks.

The Freshwater Ecosystem

In contrast to the Marine ecosystem, freshwater ecosystems only cover 0.8% of the Earth's surface and contain 0.009% of its total water. There are three basic types of freshwater ecosystems:

- **Lentic:** Still or slow-moving water like pools, ponds and lakes.
- **Lotic:** Fast-moving water like streams and rivers.
- **Wetlands:** Places where the soil is saturated or inundated for at least some time.

These ecosystems are home to amphibians, reptiles and almost 41% of world's fish species. Faster moving turbulent water typically contains greater concentrations of dissolved oxygen, which supports greater biodiversity than the slow moving water of pools.

1.3.4 ECOSYSTEMS THEORIES (REF 3)

A tentative ecosystem theory consisting of ten basic propositions

Jørgensen and Fath (2004) have previously presented a tentative ecosystem theory consisting of 8 basic laws, but it seems to be an advantage to split one of the laws into three to account for some recent results. Some comments based on various valuable inputs to the ecosystem theory by system ecologists during last 2-3 decades and on the paradigm shift which took place during the 20th century, are presented here together with the proposed laws to facilitate the understanding of how the laws are rooted in the general scientific development. The proposed laws 3-5 are based on the fundamental laws of Thermodynamics and the fundamental biochemical knowledge and observations.

1. *All ecosystems are open systems embedded in an environment from which they receive energy–matter input and discharge energy–matter output.* From a thermodynamic point of view, this principle is a prerequisite for the ecological processes. If ecosystems would be isolated, they would be at thermodynamic equilibrium without life and without gradients.
2. *Ecosystems have many levels of organization and operate hierarchically.* This principle is used again and again when ecosystems are described: atoms, molecules, cells, organs, organisms, populations, communities, ecosystems and the ecosphere. The law is based on the differences in the locality. The distance between components becomes essential because the

takes time for events and signals to disseminate. The complexity of biological systems therefore, makes it practical to distinguish between different levels with different locality.

3. *Thermodynamically, carbon-based life has a viability domain determined between about 250-350 K.* It is within this temperature range that there is a good balance between the opposing ordering and disordering processes: decomposition of organic matter and building.
4. *Mass, including biomass, and energy are conserved.* This principle is recursively used in ecology, particularly in ecological modelling.
5. *The carbon based life on earth, has a characteristic basic biochemistry which all organisms share.* It implies that many biochemical compounds are shared by all living organisms.
6. *No ecological entity exists in isolation but is connected to others.* The theoretical minimum unit for any ecosystem is two populations, one that fixes energy and another decomposes and cycles waste. But in reality, viable ecosystems are complex networks of interacting populations. It can be shown by observations and ecological network calculations that the network has a synergistic effect on the components: the ecosystem is more than the sum of the components.
7. *All ecosystem processes are irreversible.* This is probably the most useful way to express the Second Law of Thermodynamics in ecology. It is widely used in ecology that living organisms need energy to cover the maintenance of the life processes. This energy is lost as heat to the environment which is in agreement with the Second Law of Thermodynamics. Time has an arrow. The evolution can only be understood in the light of the irreversibility principle rooted in the Second Law of Thermodynamics. The evolution is a step-wise development that is based on the previously achieved good solutions to survival in a changeable and very dynamic world.
8. *Biological processes use captured energy (input) to move further from thermodynamic equilibrium and maintain a state of low-entropy and high energy relative to its surrounding and to thermodynamic equilibrium.* This is just another way of expressing that ecosystems can grow. Svirezhev (1992) has shown that eco-energy of an ecosystem corresponds to the amount of energy that is needed to break down the system.
9. *After the initial capture of energy across a boundary, ecosystem growth and Development is possible by (a) an increase of the physical structure (biomass), (b) an increase of the network.* All growth forms imply that the system is moving away from thermodynamic equilibrium (Jørgensen *et al.*, 2000) and are associated with an increase of *i*) the eco-energy stored in the ecosystem and *ii*) the energy flow through in the system (power).

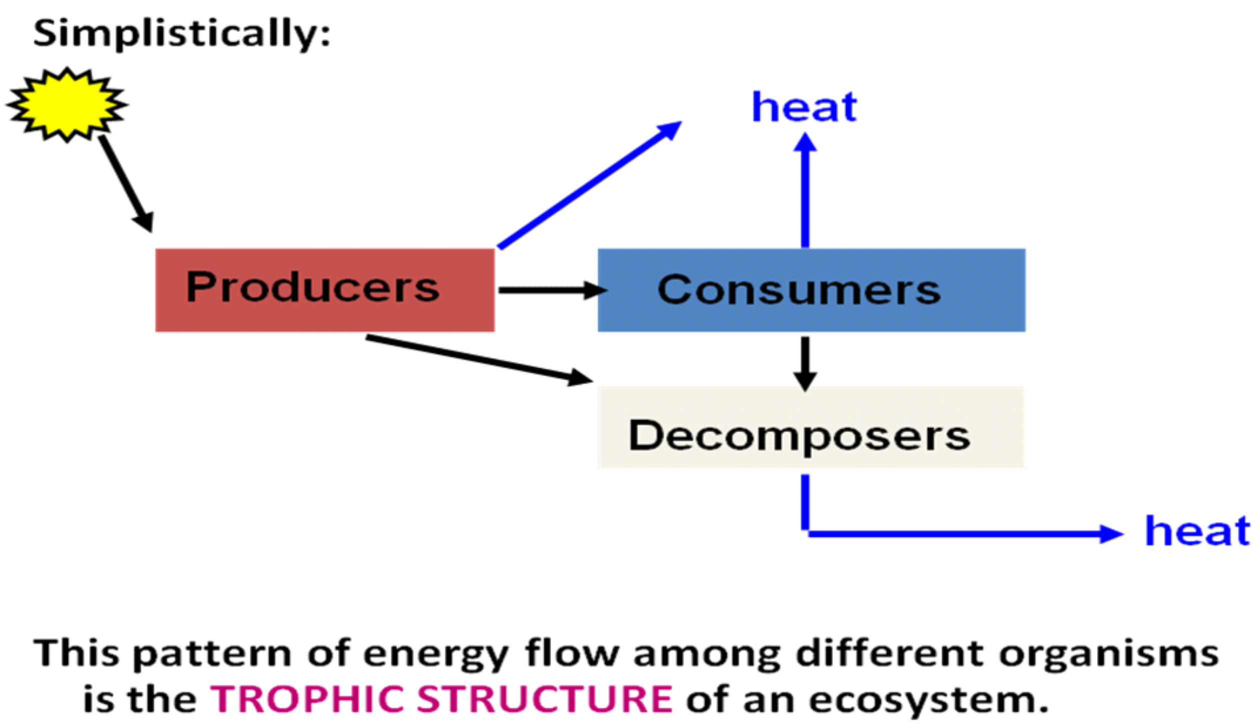
10. *An ecosystem receiving solar radiation will attempt to maximize eco-energy storage or maximize power such that if more than one possibility is offered, then in the long-run the one which moves the system furthest from thermodynamic equilibrium will be selected.*

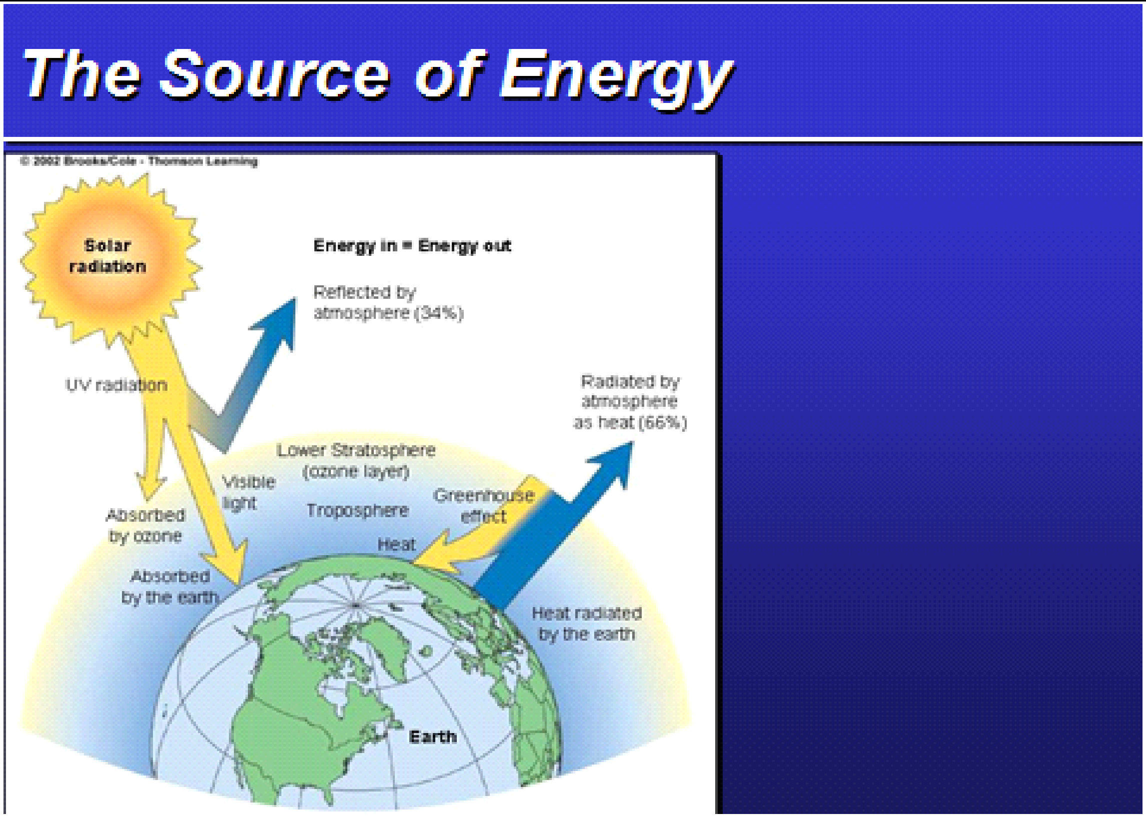
1.4 ENERGY FLOW IN ECOSYSTEMS; BIODIVERSITY

1.4.1. THE TRANSFORMATION OF ENERGY (REF. 7)

The transformations of energy in an ecosystem begin first with the input of energy from the sun. Energy from the sun is captured by the process of photosynthesis. Carbon dioxide is combined with hydrogen (derived from the splitting of water molecules) to produce carbohydrates (CHO). Energy is stored in the high energy bonds of adenosine triphosphate, or ATP

Energy flow





The amount of energy received differs in amount as it depends upon the slope, cloud, latitude and pollutants present in the atmosphere. The energy received in the Varanasi of India is three times more than the energy received in the Britain. Some part of the energy is used by the producers. The rest is dissipated. The efficiency to convert energy is around 1% in the grasslands and savannas. It is also similar in the mixed forests. It is higher in the modern crops and sugarcane field. It ranges in 5-10%. The autotrophs are also known as the producers. They make the food by the process of photosynthesis from the inorganic materials. They not only make their food but also for the other organisms. They absorb the energy from sun and convert into the chemical energy and release oxygen. The organic compounds thus formed, play an important role in the build up of bodies and help in the release of energy which helps to overcome the entropy. The energy is dissipated as a heat. There are herbivorous which feed on the plants. As they are not able to eat the whole of plant, the left-over of food passes into the decomposers. The phytoplankton in the aquatic food chain is mainly eaten by the herbivore. The herbivores act on the ingested food which gets accumulated. It releases the energy thereon and helps in the respiration. The energy lost in this case is not much and the remaining is used to overcome the entropy. The fraction of assimilated food is used for the growth of the body. The primary carnivores feed on the herbivores on which the secondary carnivores feed. In the food chain when the food is broken energy is released. The small part of energy is utilized and so the rest of energy is dissipated. The energy transferred from one trophic level to the other decreases in amount.

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1.4.2 LAWS GOVERNING ENERGY TRANSFORMATION

Energy transformation in ecosystems can also be explained in relation to the laws of thermodynamics, which are usually applied to closed systems. The first law of thermodynamics is the law of conservation of energy, which says that energy may be converted from one form to another but is neither created nor destroyed.

If an increase or decrease occurs in the internal energy(E)of the system itself ,work (W) is done and heat (Q) is either evolved or absorbed. Thus

$$\Delta E \quad = \quad \Delta W \quad + \quad \Delta Q$$

The decrease in the internal energy of the system	*work done by the system*	*heat given off by the system*

This law recognizes the interconvertibility of all forms of energy but does not refer to the efficiency of transformation or conversion.

The second law of thermodynamics states that processes involving energy transformation will not occur spontaneously, rather there is degradation of energy from a non-random to a random form.

The transformation of solar radiation into the chemical energy of tissues confirms the laws of thermodynamics.

1. Solar energy assimilated by Photoautotrophs (GPP)	=	NPP(chemical energy)	+	R(heat energy of respiration)
2. NPP eaten by heterotrophs produced by (herbivores)	=	Chemical energy of assimilation by hervivores	+	Chemical energy of faeces herbivores
i.e., Consumption	=	*Assimilation*	+	*egestion*
3. Chemical energy by herbivores assimilated	=	Chemical energy of secondary production (growth and reproduction) of herbivores	+	Metabolic energy loss by herbivores
4. Chemical energy of secondary production of herbivores consumed by carnivores	=	Chemical energy assimilated by carnivores	+	Chemical energy of faeces of carnivores
5. Chemical energy assimilated by carnivores	=	Chemical energy of secondary production(growth and reproduction) of carnivores	+	Metabolic energy loss by carnivores

This flow diagram shows that at each transfer heat energy (random form) dissipates. Hence the energy transfer is not 100% efficient and there is degradation of energy from a non-random to a random form (second law of thermodynamics).

Table 2: Classification of ecosystems on basis of energy flow

Ecosystem types	Annual energy flow in kj/m^2 (Odum,1975)
• Unsubstituted natural solar powered ecosystems like forests, grasslands, oceans, lakes etc. These systems form the main life-supporting system on the planet since they provide food, fodder, fuel, fibre, medicine etc. Sun natural ecosystem (unsubsidised)	$(4.18 - 41.8)\times10^3$ (1000 - 10000 kcal)
• Nature subsidized, solar-powered ecosystems, such as tropical rain forests, tidal estuaries, coral reef ecosystems etc. The interaction of wind, rain and evaporation in a tropical rain forest as an energy subsidy. NAE (Natural Auxiliary Energy) Sun natural ecosystem (Nature subsidized)	$(4.18 - 16.72)\times10^4$ (10,000- 40,000 kcal)
• Man subsidized or man made (auxiliary energy). Solar powered ecosystems like agriculture and aquaculture. Man puts in a lot of auxillary energy in the form of fertilizers, pesticides, human and animal labour, and fossil fuels into these systems to increase productivity (edible energy). FF (Fossil Fuel) Sun Agriculture based rural ecosystem (fuel subsidized).	$(4.18 - 16.72)\times10^4$ (10,000- 40,000 kcal)
• Man made fossil fuels (petrol,coal etc) powered urban industrial systems such as towns, cities, industries etc. These systems do generate jobs, but cause pollution and consume natural resources. Sun NAE FF Urban ecosystem	$(4.18 - 167.2)\times10^5$ (1,00,000-3,00,000 kcal)

1.4.3. BIODIVERSITY: Biological diversity or biodiversity is one of the important renewable resources, which consists of the different life forms (species) that can best survive on the variety of conditions existing on the surface of the earth. Biodiversity includes

(i) Genetic diversity **:** Variety in the genetic makeup among individual within a single species.

(ii) Species diversity **:** Variety among the species or distinct types of organism

(iii) Ecological diversity: Variety of forest, desert, ocean, lake ,wetland etc.

References:

- **https://www.msu.edu/~nixonjos/teaching/bio/ecology/ecology01.html**
- **http://lifestyle.iloveindia.com/lounge/types-of-ecosystem-10697.html**
- **http://www.eurasc.org/annals**
- Jørgensen, S.E. and Fath, B., Application of thermodynamic principles in ecology, *Ecological Complexity* **1** (2004), 267-280.
- Svirezhev, Y.M., Thermodynamic Ideas in Ecology, Lecture on the School of Mathematical Ecology, ICTP, Trieste, 1992.
- Jørgensen, S.E., Patten, B.C. and Strakraba, M., Ecosystems emerging: 4. Growth, *Ecological Modelling* **126** (2000), 249-284
- http://www.globalchange.umich.edu/globalchange1/current/lectures/kling/ecosystem/ecosystem.html
- Beeby, A. and Brennan, A. (1997), First Ecology, Chapman & Hall, New York, p.23, 26, 86-95.
- Buell, P. and Girard, J. (1994), Chemistry: An Environmental Perspective, Prentice Hall,
- Bunce, N.J. (1993), Introduction to Environmental Chemistry, Wuerz Publishing Ltd., Winnipeg, Canada.
- Dickinson, G. & Murphy K.(1998), Ecosystems: A Functional Approach, Routledge, London, p.2, 12,71.
- Hanks S. (1996), Ecology and the Biosphere: Principles and Problems, St. Lucie Press, Delray Beach, p.63-68, 85.
- Jarvis, P.J. (2000), Ecological Principles and Environmental Issues, Pearson Education Ltd., Harlow, England, p.35-122.
- Jeffries, M. (1997), Biodiversity and Conservation, Routledge, London, p.59.
- Jones, A. (1997), Environmental Biology, Routledge, London, p.3, 58, 163, 169.
- Reiss, M. and Chapman, J. (2000), Environmental Biology, Cambridge University Press, p. 1-4.

- Townsend, C, Begon, M. and Harper, J. (2003), Essentials of Ecology, Blackwell Pub., Maiden, MA, p.8, 55, 96, 317.

SUGGESTED READING

- Borman, F.H. and G.E. Likens. 1970. "The nutrient cycles of an ecosystem." *Scientific American*, October 1970, pp 92-101.
- Wessells, N.K. and J.L. Hopson. 1988. *Biology*. New York: Random House. Ch. 44.

UNIT 2: ENERGY SCENARIO AND DEVELOPMENT

UNIT STRUCTURE

2.1 OVERVIEW OF WORLD ENERGY SCENARIO

2.1.1 INTRODUCTION

Energy is the key mover of economic growth and is vital to the sustenance of modern economy. Energy sources that are affordable, accessible and environmentally friendly are crucial for long-term availability of energy and future economic growth of any country on a sustainable pace crucially depends on it.

Energy scenarios provide a framework for exploring future energy perspectives, including various combinations of technology options and their implications. Many scenarios in the literature illustrate how energy system developments will affect the global issues. Some describe energy futures that are compatible with sustainable development goals, such as improved energy efficiencies and the adoption of advanced energy supply technologies. Sustainable development scenarios are also characterized by low environmental impacts (local, regional, global) and equitable allocation of resources and wealth.

Energy has been universally recognized as one of the most important inputs for economic growth and human development. There is a strong two-way relationship between economic development and energy consumption. On one hand, growth of an economy, with its global competitiveness, hinges on the availability of cost-effective and environmentally benign energy sources, and on the other hand, the level of economic development has been observed to be reliant on the energy demand.

2.1.2 WORLD ENERGY SCENARIO

According to conventional wisdom, the world is unlikely to run out of energy in the near future. However, current patterns of energy production and use have destructive impacts on the environment and, in recent years, environmental issues such as possible climate change resulting from greenhouse gas emissions have thrown the spotlight onto the links between energy and the global environment. At the same time, there is a need, especially in developing countries, for higher levels of energy supply and use to fuel economic development. At present, 'energy poverty' hinders the economic and social development of very large number of people.

Coal, oil, gas and nuclear energy are the major sources of primary energy, followed by renewable combustible wastes (biomass, animal products, municipal wastes, and industrial wastes), hydro and other sources.

Table 2.1: Contributions to global energy supply by different energy sources (1999)

Source	Contribution to total energy supply (%)
Petroleum	35.1

Coal	23.5
Natural gas	20.7
Renewable combustible wastes	11.1
Nuclear	6.8
Hydro	2.3
Others	0.5

It is estimated that per capita energy consumption in developing countries is about one tenth of that in the industrialized world. Future growth in demand in developing countries may arise from an increased share of consumption attributable to domestic and commercial energy use.[1]

Coal sector:

Coal continues to be a key source of energy, especially for power generation. World coal consumption has increased, though the trend varies from region to region. Coal consumption is increasing in USA, Japan, and the developing Asian countries. Consumption has declined in western and eastern Europe and former Soviet Union countries. Poor coal quality is an emerging area of concern in many developing countries.

Oil Sector:

Crude oil prices are highly volatile. The supply of crude oil is price driven and there is still untapped potential worldwide. World oil consumption by developing countries is around 22 million barrels per day. Industrialized countries consume about 43 million barrels a day. The global oil-price shocks of 1973−74 and 1979−80 spurred energy-efficiency initiatives in a number of countries. Initiatives include-

- structural adjustments
- technical innovation
- economic incentives
- financial support and
- appropriate legislation.

Gas Sector:

Natural gas is the fastest growing source in world energy consumption. Natural gas is preferred for new power generation projects because it is a cleaner fuel, and of its high end-use efficiency.

World energy outlook, 2011 depicts a new scenario- *i.e.*, the Golden Age of Gas Scenario which describes a future in which natural gas plays a more prominent role in meeting the world's energy needs to 2035. China is currently the most important country in shaping future energy markets. Its existing energy demand and its potential for economic growth mean that its policy choices can dramatically affect the trajectory of global gas demand. China is encouraging natural gas use in all sectors in the long term. Industry, the largest gas user in China today, has strong demand growth potential and reduced emissions could be achieved by switching from coal.[2]

Global uncertainties afflicting the energy sector can be seen as opportunities for natural gas. When replacing other fossil fuels, natural gas can lead to lower emission of green house gases and local pollutants. It can help to diversify energy supply, and so improve energy security. It can provide the flexibility and back up capacity needed as more variable capacity comes online in power generation. Gas is a particularly attractive fuel for regions such as China, India and Middle East which are urbanizing and seeking to meet rapid growth in energy demand. Unconventional gas now makes up about 60% of marketed production in the United States. Coalbed methane (CBD) development is growing in Australia, while projects in India, China and Indonesia are in the early stages of development. Use of hydraulic fracturing in unconventional gas production has raised serious environmental concerns and tested existing regulatory regimes. Best practice in production, effectively monitored and regulated, can mitigate other potential environmental risks, such as excessive water use, contamination and disposal.

2.1.3 NON-CONVENTIONAL ENERGY SOURCES

The amount of electricity generated from conventional fossil fuels in the world has risen by a factor of 1.54 in the last two decades. It reached 8,800 billion kWh in 1999. In the same period, the electricity generated throughout the world from nuclear, hydro and renewable sources rose by a factor of 2.08. It reached 5,200 billion kWh in 1999. Development of renewable energy is largely dependent on fuel prices, tariffs and policy. It is predicted that the share of renewable energy sources will remain at around 8% of the world's total energy consumption. Many hydro-electric power projects are being pursued in Asia where 3.7% annual growth in renewable energy sources is envisaged over the next decade. With increasing capacity and development efforts, the capital costs of renewable technologies are falling.[1]

Amongst the most optimistic of energy scenarios is that developed for the environmental pressure group Greenpeace International by the Stockholm Environment Institute, Boston Centre, and USA. The FFES adopts the UN prediction of a world population of 11 billion by 2100, with world GDP by this date showing a fourteen- fold increase from 1988. In the FFES, world primary energy demand increases to 1000 EJ or about 24 Gtoe by 2100, and all fossil and nuclear fuels are assumed to have been phased out, to be replaced by a mixture of solar, hydroelectric, biomass, wind and geothermal energy resources. In the FFES, greenhouse gas emission specifically from fossil fuels are assumed to have been eliminated, resulting in a rise in global mean surface temperature of about 1.5, compared with the predicted 4^0C if the use of fossil fuels continues at present rates (IPCC,1994).[3]

2.2 INDIA'S ENERGY SCENARIO

Energy is one of the major drivers of a growing economy like India and is an essential building block of economic development. The challenge of meeting growing energy needs of the country is especially significant given the Indian Prime Minister's cherished goal of reaching 8% growth rates from the current threshold of around 5 to 6%. In an effort to meet the energy demands of the country, the Indian energy sector has witnessed a rapid growth. Areas like the resource exploration and exploitation, capacity additions, and energy sector reforms have been revolutionized. However, resource augmentation and growth in energy supply have failed to meet the ever increasing demands exerted by the multiplying population, rapid urbanization and progressing economy. Further, the development of the Indian energy sector has been constrained by capital, technology, environment and security issues arising out of internal and external consequences. Hence, serious energy shortages continue to plague India, forcing it to rely heavily on imports.

Energy intensity is an indicator to show how efficiently energy is used in the economy. The energy intensity of India is over twice that of the matured economies, which are represented by the OECD (Organization of Economic Co-operation and Development) member countries. India's energy intensity is also much higher than the emerging economies – the Asian countries, which include the ASEAN member countries as well as China. However, since 1999, India's energy intensity has been decreasing and is expected to continue this trend.

The energy sector holds the key in accelerating the economic growth of India. However, as mentioned earlier, the development of the Indian energy sector has been constrained by capital, technology, environment and security issues arising out of internal and external consequences. Energy is the prime driver of economic growth and is vital to the sustenance of a modern economy. Future economic growth crucially depends on the long-term availability of energy from sources that are affordable, accessible and environment friendly.[4]

India ranks sixth in the world in total energy consumption and needs to accelerate the development of energy sector to meet its growth aspirations. The country, though rich in coal and abundantly endowed with renewable energy in the form of solar, wind, hydro and biomass energy, has very small hydrocarbon reserves (0.4% of the world's reserve). India, like many other developing countries, is a net importer of energy, more than 25% of primary energy needs being met through imports mainly in the form of crude oil and natural gas. The rising oil import bill has been the focus of serious concerns due to the pressure it has placed on scarce foreign exchange resources and is also largely responsible for energy supply shortages. *The sub-optimal consumption of commercial energy adversely affects the productive sectors, which in turn hampers economic growth.*[4]

India is one of the countries where the present level of energy consumption, by world standards, is very low. The estimate of annual energy consumption in India is about 330 Million Tones Oil Equivalent (MTOE) for the year 2004. Accordingly, the per capita consumption of energy is about 290 Kilogram Oil Equivalent (KGOE). As compared to this, the energy consumption in some of the other countries is of higher order; about 597 for China, over 4000 for Japan and Germany, about 8080 for USA, about 4670 for OECD countries and the world average is about 1690.[5]

In the profile of energy sources in India, coal occupies a dominant position. Coal constitutes about 51% of India's primary energy resources, followed by Oil (36%), Natural Gas (9%), Nuclear (2%) and Hydro (2%).

The source wise detailed contribution of each of the sectors to the India's energy requirement is discussed in the following paragraphs.

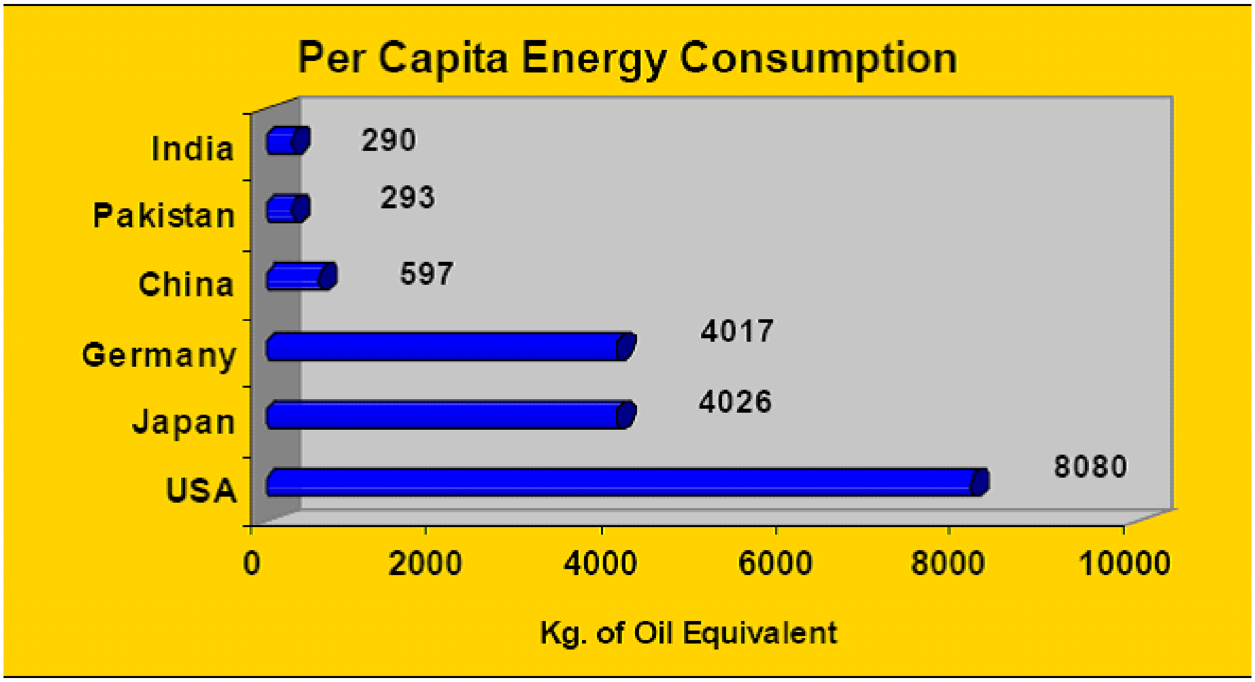


Fig 2.1: Per Capita Energy Consumption in some countries of the World.

Source: Centre for Monitoring Indian Economy

Coal sector:

Coal constitutes the most dominant constituent of the energy sector. In the year 2005-06, the coal production was over 370 million tones. Power Sector consumes almost 80% of coal that is produced. India has large coal reserves of the order of 200 Billion Tones, most of these are high ash content coal in the calorific value range of 3000 kilo calorie per kilogram to 4,500 kilo calorie per kilogram and ash content in the range of 30 – 45%. Using the high ash content coal for the power sector is a major challenge, from the point of view of achieving high level of efficiency of consumption, and more particularly, from the point of view of environmental management due to fly ash emissions.

Oil sector:

Oil constitutes about 36% of the primary energy consumption in India. The demand projection is placed at about 200 million metric tons by the end of the 11th Five Year plan *i.e.*, by 2011-12 and over 250 million metric tons by 2024-25. The present level of demand is about 120 million metric tons of oil equivalents.

Gas sector:

Natural gas constitutes about 9% in the India's energy profile, as compared to about 25% world average. About 45% of natural gas is consumed by power sector and about 40% by the fertilizer sector. The balance 15% goes for various other consumption. At present about 65 million cubic meters of gas per day is being consumed and it has the potential for increase. Both the Power Sector and Fertilizer Sector in India have been planning for larger consumption of gas and increased capacities so as to produce more power through this environment friendly fuel.

Nuclear power sector:

India has established its capability in design, engineering, construction and operation of nuclear power plants. The installed capacity is 3310 MW, (less than 3% of total installed capacity of power), consisting of two Boiling Water Reactors and twelve Pressurized Heavy Water Reactors. Eight more reactors (total capacity 3420 MW) are under construction. India believes that nuclear power proportion should increase from 2.6% to about 7 to 8% by 2030 which means a capacity of over 55,000 MW. Department of Atomic Energy, therefore, has evolved an approach and perspective which includes setting up of Pressurized Heavy Water Reactors in the first stage, Fast Breeder Reactors in the second stage and Reactors based on Uranium 233-Thorium 232 cycle in the third stage. Construction on two units of 1000 MW at Kudankulam in Tamil Nadu, as per the agreement between India and Russian Federation marks the beginning of introduction of Light Water Reactors (LWR). At present, entire development of nuclear power plants is made through Nuclear Power Corporation of India, a company under the control of Government of India.

2.2.1 NON-CONVENTIONAL ENERGY SOURCES:

Indian Government has accorded very high priority to develop and expand installed capacity base through non-conventional sources of electricity generation. There is a separate Ministry in the Government of India to exclusively focus on this important area of power generation. National Electricity Policy notified in 2005 in pursuance of the Electricity Act, 2003, prescribes that State Electricity Regulatory Commissions should prescribe a proportion of power which should be produced and supplied to the grid through the non-conventional sources. Ministry of Non-conventional Energy Sources (MNES) has set a target of achieving at least 10,000 MW capacity through various non-conventional sources, by the year 2012.

Source	Potential (MW)	Existing Capacity(MW)
Wind	45000	4400
Small Hydro (upto 25 MW)	15000	1700
Solar (Photovoltaic)	20MW/square km	Very little
Biogas plants	12 million	3.8 million
Urban/Industrial waste based plant	2700	Very little

Source: MNES[5]

2.2.2 CONVENTIONAL ENERGY SOURCES:

Fossil fuel based thermal power plant, hydro-electric, and nuclear constitute the conventional sources of power. Non-conventional sources are less than 5% of total installed capacity in India. The installed capacity in March 2006 was about 1, 25,000 MW, consisting of coal based plants (56%), gas based plants (10%), hydro-electric (26%), nuclear (3%) and non-conventional (5%).

2.3 ENERGY SCENARIO OF THE NORTH-EAST:

The Government of India is paying special attention to develop the north-eastern region of India, for the well-being of the people of the region, for its potential contribution to the Indian economy and for fostering links with the neighboring countries. Electricity is recognized as fundamental to industrialization and improving the quality of life of the people. Harnessing the immense untapped hydropower potential in the north-eastern region opens avenues for growth and provides an opportunity to improve the well-being of the people of the region, while making substantial contribution to the national economy. The large hydropower potential of the north-eastern region has remained mostly unexploited for a variety of reasons, such as the status of development of the grid systems in the country, availability of economic and accessible sites near to the load centers in the other regions of the country, low demand for power in the sparsely populated north-eastern region, and considerations regarding the impact of hydropower development on the livelihoods of the indigenous population, the river ecosystem and the safety of dam construction.

Power sector development and public utility supply in the country had its beginnings in 1897 with a small hydropower plant near Darjeeling (West Bengal), close to the north-eastern region. The north-eastern region comprises the states of Assam, Arunachal

Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, and Tripura, popularly known as the Seven Sisters. The power shortage in the north-eastern region was at about the same level (11.3 percent in peak capacity and 6.3 percent in energy) as that of the country as a whole. The actual shortages would be higher, particularly the peak shortages, if unscheduled power cuts and various control measures were taken into account. The situation in the north-eastern region is further constrained by the inadequacies in transmission, sub transmission and distribution. The development of the electricity grid systems and planning of generation capacity addition in the country has so far been on the basis of the five regions - each comprising a group of contiguous states. The region also has abundant resource of coal, oil and gas for thermal power generation. According to the estimates of the North Eastern Electric Power Corporation (NEEPCO), the north-eastern region has the potential of about 58971 MW hydro power *i.e.,* almost 40% of the country's total hydro potential but out of this only less than 2% (1095 MW) has so far been harnessed.

In spite of such huge potential, the region ranks lowest in the country in terms of power generation and per capita energy consumption, mainly due to lack of proper planning, inhospitable climatic conditions, remote location and inaccessibility. However, with continual improvement of infrastructure and communication facilities, the north-eastern region stands to become the power house of India by utilizing its surplus power potential, especially in hydropower sector. The region offers a large potential in renewable energy, which is also yet to be exploited.[6]

2.4 ENERGY AND DEVELOPMENT LINKAGE

The development of energy is the increased availability of energy in quantity and quality. The energy development is a part of enhanced economic development. This is evidenced from the fact that advanced industrialized societies use more energy per unit of economic output and far more energy per capita than poorer societies. Energy use per unit output eventually declines with development due to technology and output composition effects. Even so, total energy use and energy use per capita continue to grow in the advanced industrialized countries and even more rapid growth can be expected in the developing countries as their incomes advance. Development involves a number of other elements such as education, labor markets, financial institutions, agriculture modernization, infrastructure expansion etc. But it is hard to imagine overall economic development succeeding without energy development.

The linkages among energy, other inputs, and economic activity clearly change significantly as an economy moves through different stages of development. Barnes and Floor (1996) refer to the "energy ladder" to describe this phenomenon. At the lowest levels of income and social development, energy sources tend to be harvested predominantly or scavenged biological sources (wood, dung, sunshine for drying) and human effort (also biologically powered). More processed biofuels (charcoal), animal power, and some commercial energy become more prominent in the intermediate stages. Commercial fossil fuels and other energy forms such as primary fuels, and ultimately electricity become predominant in more advanced stages of industrialization and development.

The recognition of energy as a key input for economic development is evident from the fact that the two major international endorsements of the elements of sustainable development in recent times, the Millennium Development Goals (MDGs) and the World Summit on Sustainable Development (WSSD), have recognized universal access to energy as an important goal. The rationale for this is that there is a huge discrepancy in the energy consumption levels between the developed and the developing countries as more than two billion people in the world (largely in Latin America, Asia, and Africa) have no access to modern energy supplies.[7]

There are several ways in which increased availability of energy could augment the productivity and thus the effective supply of physical and human capital services, whether it is in final goods output or in other outputs, like human capital. Again, the transmission mechanisms are likely to differ across the stages of development. For medium and more advanced level industrializing countries, increased energy availability (quantity and quality, in particular for electricity) can facilitate the use of more modern machinery and techniques that expand the effective capital-labor ratio as well as increasing the productivity of workers. Whereas supply-side energy changes in less advanced countries economize on household labor, the energy availability can augment the productivity of industrial labor in the formal and informal sectors. Globally, the production and use of energy accounts for 50−60% of emissions of greenhouse gases (GHG) to the atmosphere.[8]

2.5 ENERGY SOURCES: CLASSIFICATION OF ENERGY SOURCES

2.5.1 INTRODUCTION

Energy consumption of a nation is usually considered as an index of its development. This is because almost all the developmental activities are directly or indirectly dependent upon energy.

Agriculture, industry, mining, transportation, lighting, cooling and heating all need energy. With the demands of growing population, the world is facing further energy deficit. The World Energy Forum has predicted that fossil-based oil, coal and gas reserves will be exhausted in less than another ten decades. Fossil fuels account for over 79% of the primary energy consumed in the world and 57% of that amount is used in the transport sector, diminishing the fossil fuels rapidly[9]. The exhaustion of natural resources and the accelerated demand of conventional energy have forced planners and policy makers to look for alternate sources. Developed countries like U.S.A and Canada constitute about 5% the world's population but consume one fourth of global energy resources. An average person there consumes 300 GJ (Giga Joules, equal to 60 barrels of oil) per year. By contrast, an average man in a poor country like Bhutan, Nepal or Ethiopia consumes less than 1G in a year. So a person in a rich country consumes almost as much energy in a single day as one poor person does in a whole year in a poor country. Energy security, economic growth and environment protection are the national energy policy drivers of any country of the world. The need to boost the efforts for further development and promotion of renewable energy sources has been felt world over in light of high prices of crude oil. All the sources of energy, currently available for harnessing, can be linked to two fundamental forces in nature- gravitational and nuclear. Nuclear fusion is the source of solar energy - the driving force for much of the energy consumed on earth today. Most of the energy sources are substitutable to each other due to the fact that some form of energy can be converted to other - such as coal to electricity, use of photo electricity to drive a chemical reaction, wind energy to pump and store water that could be used to produce electricity when required, or solid biomass to produce liquid or gaseous fuels of higher calorific value. All forms are ultimately converted into heat. This gives rise to the inter-fuel substitution process with which an economy can substitute its abundantly available resources to the scarcely endowed one.

2.5.2 CLASSIFICATION OF ENERGY SOURCES:

A source of energy is one that can provide adequate amount of energy in a usable form over a long period of time. These sources can be classified as follows:

Non-Renewable

- Conventional fossil fuel such as oil, Gas and coal
- Non-conventional fossil fuel such as Tar Sands, Shale oil etc.

Non-renewable but technologically extended Resources

- Nuclear fission potentially through introduction of new technologies like fast breeder reactors for indefinitely extending the life of the available Uranium & Thorium

b) Fusion power with indefinite potential due to the availability of Deuterium and Tritium in large quantities from hydrogen

Renewable resources

- Solar light and heat and other sun-based resources such as wind, hydro and biomass
- Geothermal and Tides

These sources are described in details as follows:

2.5.2.1 NON RENEWABLE SOURCES:

I. COAL

Coal is a solid fuel, is a combustible sedimentary organic rock which is composed mainly of carbon, oxygen and hydrogen. It is formed from vegetation which has been consolidated between other rock strata and altered by the combined affects pressure and heat over millions of years to form coal seams (World Coal Institute). Coal is the altered remains of prehistoric vegetation that originally accumulated in swamps and peat box.

II. PETROLEUM

Based on data gathered by geochemists, the main theory behind exploration of petroleum includes embedment of organic matter into source bed, conversion of this source material into fluid, migration of thin fluid into sedimentary rock and secondary transformation of oil in the reservoir rock. The probable sources of organic matter are planktons, sea animals, marine algae, sea grass and some terrestrial and fresh water plants. Petroleum is a cleaner fuel as compared to coal as it burns completely and leaves no residue. It is also easier to transport and use.

III. NATURAL GAS

Natural gas deposits mostly accompany oil deposits because it has been formed by decomposing remains of dead animals and plants buried under the earth. Natural gas is the cleanest fossil fuel. It can be easily transported through pipelines. It has a high calorific value of about 8400 – 9100 kcal/Nm^3 and burns without any smoke. It is used as a domestic and industrial fuel in thermal power plants for generating electricity. It is used as a source of hydrogen gas in fertilizer industry and as a source of carbon in the industry.

2.5.2.2 NON-RENEWABLE BUT TECHNOLOGICALLY EXTENDED RESOURCES

I. NUCLEAR ENERGY

Nuclear energy is known for its high destructive power as evidenced from nuclear weapons. The nuclear energy can also be harnessed for providing commercial energy. Nuclear energy can be generated by two types of reactions.

(A) NUCLEAR FISSION

It is the nuclear change in which nucleus of certain isotopes with large mass numbers are split into lighter nuclei on bombardment by neutrons and a large amount of energy is released through a chain reaction. Nuclear reactors make use of nuclear chain reaction. In order to control the rate of fission, only 1 neutron released is allowed to strike for splitting another nucleus. Uranium-235 nuclei are most commonly used in nuclear reactors.

(B) NUCLEAR FUSION

Here two isotopes of a light element are forced together at extremely high temperatures until they fuse to form a heavier nucleus releasing enormous energy in the process. It is difficult to initiate the process but it releases more energy than nuclear fission. Two hydrogen-2 (Deuterium) atoms may fuse to form the nucleus of Helium at 1 billion degree Celsius and release a huge amount of energy.

2.5.2.3 RENEWABLE RESOURCES

I. SOLAR ENERGY

Sun is the ultimate source of energy, directly or indirectly for all other forms of energy. The nuclear fusion reactions occurring inside the sun release enormous quantities of energy in the form of heat and light. The solar constant is defined as the quantity of solar energy (W/m^2) at normal incidence outside the atmosphere (extraterrestrial) at the mean sun-earth distance. Its mean value is 1367.7 W/m^2. Solar energy is the most abundant permanent energy resource on earth and it is available for use in its direct (solar radiation) and indirect (wind, biomass, hydro, ocean etc) forms. Solar energy experienced by us, as heat and light, can be used through two routes: the thermal route uses the heat for water heating, cooking, drying, water purification, power generation and other applications; the photovoltaic route converts the light in solar energy into electricity which can be used for lighting, pumping, communications and power supply in un electrified areas.

II. HYDROPOWER

Hydropower is another source of renewable energy that converts the potential energy that converts the potential energy or kinetic energy of water into mechanical energy in the form of watermills, textile machines etc or in the form of electrical energy. It refers to the energy produced from water. Hydropower is the largest renewable energy resource being used for generation of electricity. Hydropower does not cause any pollution.

III. WIND ENERGY

Winds are generated by complex mechanisms involving the rotation of the earth, heat energy from the sun, the cooling effects of the oceans and polar ice caps, temperature gradients between land and sea and the physical effects of mountains and other obstacles. Wind is a widely distributed energy resource. Wind energy is being developed in the industrialized world for environmental reasons and it has attractions in the developing world as it can be installed quickly in areas where electricity is urgently needed. In many instances it may be a cost effective solution if fossil fuel sources are not readily available.

IV. GEOTHERMAL ENERGY

Geothermal is energy generated from heat stored in the earth, or the collection of absorbed heat derived from underground. Immense amounts of thermal energy are generated and stored in the earth's core, mantle and crust.

V. BIOMASS ENERGY

Biomass is the organic matter produced by the plants or animals which include wood, crop residues, crop residues, cattle dung, manure, sewage, agricultural wastes etc. Biomass is of the following types; energy plantations like sugarcane, sweet sorghum and sugar beet, aquatic weeds like water hyacinth and sea weeds and carbohydrate rich potato, cereal etc.; petro crops like *Euphorbia's* and oil palms rich in hydrocarbons; agricultural and urban waste biomass like crop residues, bagasse, coconut shells, peanut shells etc.

2.5.3 SOME OTHER CLASSIFICATIONS OF SOURCES OF ENERGY:

The energy sources can be classified in a number of ways based on the nature of their transaction, as commercial and noncommercial sources of energy. All energy resources, particularly the commercial ones, are natural. Coal, oil and nuclear sources constitute commercial sources, while firewood, biomass and animal dung constitute non- commercial sources. Also, the energy sources are classified based on animate and inanimate characteristics. They are also classified as primary or secondary types - coal, firewood, etc., being primary sources and electricity, a secondary source. Energy in its primary form can be of different kinds. The main types are Chemical (fossil fuels- coal, oil, natural gas, peat; biomass - wood, agricultural residues, etc.), Potential (water at a certain height), Kinetic (wind, waves), Radiation (sun), Heat (geothermal reservoirs, ocean thermal reservoirs) and Nuclear (uranium). The primary form of energy must generally be converted into secondary or final forms of energy before it can be used. For instance, the potential energy of a waterfall (primary energy) is converted into electricity (secondary energy), which is transmitted and transformed to supply (final) energy to a factory, where it is converted into mechanical energy (useful energy) for productive operations. Important types of secondary energy are electricity and mechanical energy. But chemical energy is also important as a secondary energy, for instance, in the form of refined oil products. Final energy is the energy that reaches the consumer. This can be electricity at a suitable voltage, or chemical energy in kerosene or batteries. The consumer, finally, uses certain equipment to convert the final energy he buys, into useful energy for one of his end use activities, *e.g.,* irrigation, transport, cooking, etc.

2.6 ENERGY AND ENERGY QUALITY

Energy is *the* ‘fuel’ for dissipative systems, *i.e.,* systems that are sustained by converting energy and materials, *e.g.,* a living cell, an organism, an ecosystem, the earth's surface with its material cycles, or a society. The energy concept could therefore, in this sense, be used systematically to describe such systems scientifically. The energy concept has mostly been used within heat and power technology, where one works with heat of varying qualities. The field of application can be extended to the totality of energy and material conversions in the society. This yields a uniform description of the use of physical resources and the environmental impacts thereof.

Natural resources are traditionally divided into energy resources and other resources. This separation can often be only approximate. Oil, for example, is usually looked upon as an energy resource and wood is regarded as a material resource. This distinction is not very meaningful, however, because oil can also be used for producing useful materials and wood can be used as a fuel. It would be more appropriate to consider these resources together. The energy concept is, in this connection, an adequate resource measure. The energy content of the energy resources may be given by their energy content multiplied by a quality factor that applies to the energy form in question is given in Table 2.2.

Table 2.2. A list of some common energy forms

Energy form	**Quality factor**
Mechanical energy	1.0
Electrical energy	1.0
Chemical energy	~1.0 (may be more than 1, based on the system definition and states)
Nuclear energy	0.95
Sunlight	0.9
Hot steam (600°C)	0.6
District heating (90°C)	0.2–0.3 (depending on the outdoor temperature)
Moderate heating at room temperature (20°C)	0–0.2 (depending on the outdoor temperature)
Thermal radiation from the earth	0

Source: Wall, 1986.

Energy resources are usually measured in the same unit as that of energy. Other resources are usually measured in purely quantitative units, such as weight, volume, or number. In principle, a material can be quantified in energy units just by multiplying its quantity with a transformation factor for the material. The unit of such a transformation factor could then be, *e.g.*, J/m^3 or J/kg. This would be the beginning of an expanded resource budgeting and a first step towards an integration with the traditional energy budgeting. Energy per unit quantity is in fact the physical value of a resource relative to the environment. This can be compared to a price which is also partly defined by the environment through, for instance, demand.

Energy can only denote one extensive physical quality of goods. The energy content does not imply anything about intensive physical or biological qualities like electric conductivity, nutritive value, toxicity, or the like. However, when a material is used as an energy converter, the efficiency is then related to the quality of the material of interest. A material with bad electric conductivity gives a greater energy loss than a material with good electric conductivity does when being used as an electric conductor.

2.6.1 CONCENTRATION OF ENERGY SOURCES

2.6.1.1 RENEWABLE ENERGY

I. BIOMASS

In recent years, the interest in using biomass as an energy source has increased, representing approximately 14% of world's final energy consumption[12]. Estimates have indicated that 15-50% of the world's primary energy use could come from biomass by the year 2050. As per an estimate, globally photosynthesis produces 220 billion dry tones of biomass each year with 1% conversion efficiency. India is very rich in biomass and has a potential of 16,881 MW (agro-residues and plantations), 5,000MW (bagasse cogeneration) and 2700MW (energy recovery from waste[13]. Biomass power generation in India is an industry that attracts investments of over Rs.600crores every year, generating more than 5000 million units of electricity with yearly employment of more than 10 million man-days in the rural areas.

II. HYDROPOWER

Hydropower is the largest renewable energy resource being used for the generation of electricity. Only about 17% of the vast hydel potential of 1,50,000MW has been tapped so far. Countries like Norway, Canada, and Brazil have all been utilizing more than 30% of their hydro potential while India and China have lagged far behind. India ranks fifth in terms of exploitable hydro potential in the world. India has an estimated Small Hydro Power (SHP) potential of about 15,000MW, of which 11% has been tapped so far.

III. WIND ENERGY

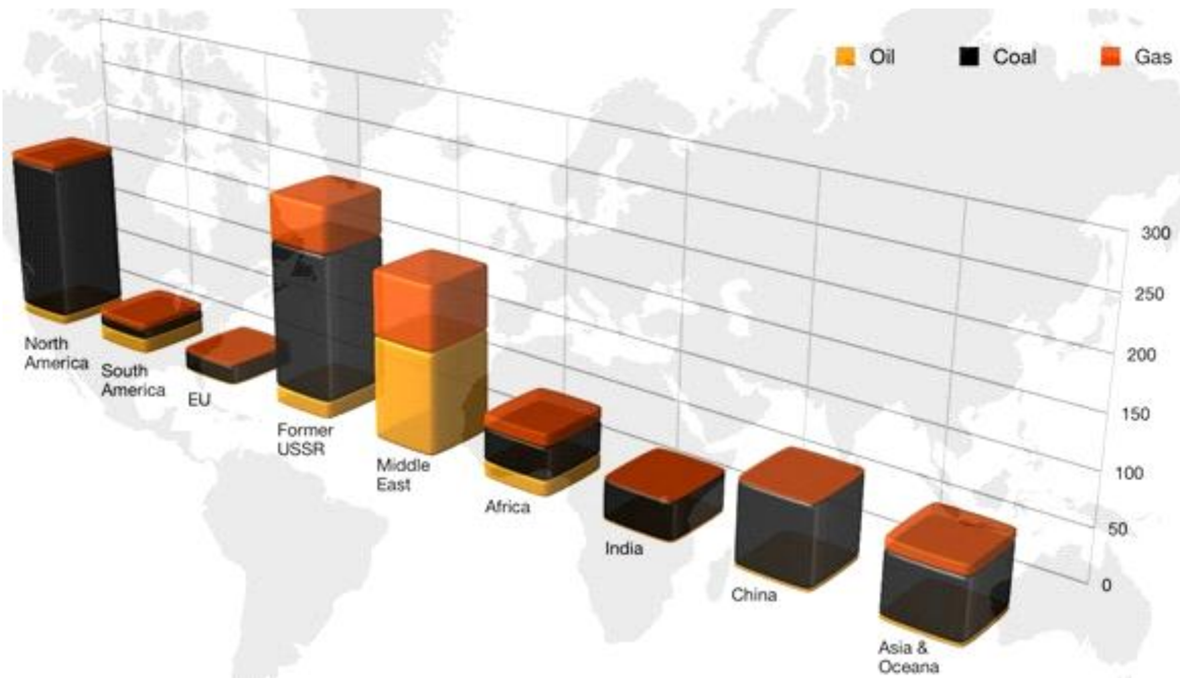
Total world wind capacity at the end of 2006 was around 72,000MW. Wind resources can be exploited mainly in areas where wind power density is at least 400W at 30m above the ground. An annual mean wind power density greater than 200W/m^2 at 50 m height has been recorded at 211 wind monitoring stations, covering 13 states and union territories in India. India's wind power potential has been assessed at 45,000 MW. A capacity of 8,757 MW up to 31 March 2008 has so far been added through wind. India is surpassed only by Germany as one of the World's fastest growing markets for wind energy.

IV. SOLAR ENERGY:

The total annual solar radiation falling on the earth is more than 7,500 times the world's total annual primary energy consumption of 450 EJ. The annual solar radiation reaching earth's surface approximately 3,400,000 EJ, is an order of magnitude greater than all the estimated non renewable sources including fossil fuel and nuclear.

V. GEOTHERMAL ENERGY:

Geothermal energy is at present contributing about 10,000MW over the world and India's small resources can augment the above percentage. 340 hot springs exist in the country. These are distributed in seven geothermal provinces. The resource is little used at the moment but the Government has an ambitious plan to raise to more than double the current total installed generating capacity by 2012.



Location of the World's Main Fossil Fuel Reserves (Gigatonnes of oil equivalent) *Source: BP 2008.*

2.6.1.2 NON RENEWABLE SOURCES:

I. COAL

Coal has an important role to play in meeting the demand for a secure energy supply. Coal is abundant and widespread. It is present in almost every country in the world with commercial mining taking place in over 50 countries. Coal is the most abundant and economic of fossil fuels.

At current production levels, coal will be available for at least the next 118 years - compared to 46 years for oil and 59 years for gas. Over 41% of global electricity is currently based on coal.

II. PETROLEUM

Saudi Arabia is the largest country in the Middle East, 14th largest country in the world and forerunner in producing crude oil with average production of around 10.8 million barrels per day. Russia, the largest country in the world by area is the second largest producer of crude oil in the world at 9.8 million barrels per day. The United States is the 3rd largest producer of oil in the world leads all countries in daily consumption of oil. It is the 4th largest country in the world by size and produces 8.5 million barrels of oil a day.

III. NATURAL GAS

Natural gas is commercially extracted from oil fields and natural gas fields. The world's largest proven gas reserves are located in Russia, with 4.757×10^{13} m^3 (1.68×10^{15} cubic feet). Countries with major proven resources (in billion cubic meters) are world 175,400 (2006), Russia 47,570 (2006), Iran 26,370 (2006), Qatar 25,790 (2007), Saudi Arabia 6,568 (2006) and United Arab Emirates 5,823 (2006). It is estimated that there are about 900 trillion cubic meters of *"unconventional"* gas such as shale gas, of which 180 trillion may be recoverable. The world's largest gas field is Qatar's offshore North Field, estimated to have 25 trillion cubic meters (9.0×10^{14}cubic feet) of gas in place—enough to last more than 420 year at optimum extraction levels. The second largest natural gas field is the South Pars Gas Field in Iranian waters in the Persian Gulf. Located next to Qatar's North Field, it has an estimated reserve of 8 to 14 trillion cubic meters (2.8×10^{14} to 5.0×10^{14} cubic feet) of gas.

2.6.1.3 NON RENEWABLE BUT TECHNOLOGICALLY EXTENDED RESOURCES

I. NUCLEAR POWER:

Installed nuclear capacity over the world initially rose relatively quickly, rising from less than 1 gigawatt (GW) in 1960 to 100 GW in the late 1970s, and 300 GW in the late 1980s. Since the late 1980s, the worldwide capacity has risen much more slowly, reaching 366 GW in 2005. Between around 1970 and 1990, more than 50 GW of capacity was under construction (peaking at over 150 GW in the late 70s and early 80s) — in 2005, around 25 GW of new capacity was planned. More than two-thirds of all nuclear plants ordered after January 1970 were eventually cancelled. A total of 63 nuclear units were cancelled in the USA between 1975 and 1980. During the 1970s and 1980s rising economic costs (related to extended construction times largely due to regulatory changes and pressure-group litigation) and falling fossil fuel prices made nuclear power plants which were under construction, less attractive[14]. In the 1980s (U.S.) and 1990s (Europe), flat load growth and electricity liberalization also made the addition of large new base load capacity unattractive. The 1973 oil crisis had a significant effect on countries, such as France and Japan, which had relied more heavily on oil for electric generation (39% and 73% respectively) to invest in nuclear power[15]. Today, nuclear power supplies about 80% and 30% of the electricity in those countries, respectively.

REFERENCES:

1. http://www.lged-rein.org/archive_file/publication_energy%20scenario.pdf
2. International Energy Agency. World Energy Outlook, 2011. Special Report (International Energy Agency)
3. Santra, S.C., *Environmental Science*, 2nd ed., New Central Book Agency (P) Ltd., Kolkata, 2005
4. Ghosh, S., and Raghuraman V., (2003) *Indo-U.S. Cooperation in Energy - Indian perspective.*
5. Shahi, R. V., Energy markets and technologies in India. *Keynote Address in Global Energy Dialogue at Hanover, Germany on April 25, 2006.*
6. http://www.asthabharati.org/Dia_July07/pall%20.htm
7. Srivastava, L., and Rehman, I.H. (2006). *Energy for sustainable development in India: Linkages and strategic direction*, J. Energy Policy, 34:643–654.
8. Toman, M., and Jemelkova, B., *Energy and Economic Development*: An assessment of the state of knowledge. Washington, DC., USA.
9. International Energy Agency (IEA). Key World Energy Statistics, 2007.
10. Wall, G., 1993. Energy, ecology and democracy-concepts of a vital society. In: Szargut, J. et al. (Eds.), Presented at "ENSEC' 93 International Conference on Energy Systems and Ecology", July 5–9, Cracow, Poland, pp. 111–121.
11. Wall, G., 1986. Energy- a useful concept. Ph.D. Thesis, Chalmers University of Technology, S-412 96 Goteborg, Sweden.
12. MNRE, 2009. India 2009. Energy Publication Division. Ministry of New and Renewable Energy. Government of India; 2009.
13. Subramanian V. Renewable energy in India; status and future prospects. Ministry of New and Renewable Energy; November 2007.
14. Bernard L. Cohen. *The Nuclear Energy Option,* Plenum Press. Retrieved on December 2007.
15. Sharon B. *The Japanese Situation*, English version "Power Play: The Fight to Control the World's Electricity", Sharon B., Soshisha, Japan, 2006.

UNIT: 3 MAJOR ENERGY RESOURCES OF THE WORLD

UNIT STRUCTURE

3.1 COAL

Coal is a fossil fuel. It is a combustible, sedimentary, organic rock, which is composed mainly of carbon, hydrogen and oxygen. It is formed from vegetation, which has been consolidated between other rock strata and altered by the combined effects of pressure and heat over millions of years to form coal seams.

3.1.1 COMPOSITION

Coal is classified according to its heating value and according to its relative content of elemental carbon of all forms of coal. For example, anthracite contains the highest proportion of pure carbon (about 86%-98%) and has the highest heat value: 13,500–15,600 BTU/lb (British Thermal Unit per pound)—. Bituminous coal generally has lower concentrations of pure carbon (from 46% to 86%) and lower heat values (8,300–15,600 BTU/lb). Bituminous coals are often sub-divided on the basis of their heat value, being classified as low, medium, and high volatile bituminous and sub-bituminous. Lignite, the poorest of the true coals in terms of heat value (5,500-8,300 BTU/lb) generally contains about 46%-60% pure carbon. All forms of coal also contain other elements present in living organisms, such as sulfur and nitrogen, that are very low in absolute numbers, but that have important environmental consequences when coals are used as fuels.

3.1.2 ORIGIN OF COAL

3.1.2.1 COAL-FORMING MATERIALS (PLANT MATTER):

It is generally accepted that most coals were formed from plants that grew in and adjacent to swamps in warm, humid regions. Material derived from these plants accumulated in low-lying areas that remained wet most of the time and was converted to peat through the activity of micro-organisms. (It should be noted that peat can occur in temperate regions *e.g.*, Ireland and the state of Michigan in the United States and even in subarctic regions *e.g.*, the Scandinavian countries.) Under certain conditions, this organic material continued to accumulate and was later converted into coal. Much of the plant matter that accumulates on the surface of the Earth is never converted to peat or to coal, because it is removed by fire or organic decomposition. Hence, the vast coal deposits found in ancient rocks must represent periods during which several favourable biological and physical processes occurred at the same time.

Evidence that coal was derived from plants comes from three principal sources. First, lignites, the lowest coal rank, often contain recognizable plant remains. Second, sedimentary rock layers above, below, and adjacent to coal seams contain plant fossils in the form of impressions and carbonized films (*e.g.*, leaves and stems) and casts of larger parts such as roots, branches, and trunks. Third, even coals of advanced rank may reveal the presence of precursor plant material. When examined microscopically in thin sections or polished blocks, cell walls, cuticles (the outer wall of leaves), spores, and other structures can still be recognized (*see below* Macerals). Algal and fungal remains may also be present. (Algae are major components in boghead coal, a type of sapropelic coal.)

3.1.2.2 THE FOSSIL RECORD

Anthracite (the highest coal rank) material, which appears to have been derived from algae, is known from the Proterozoic Eon of Precambrian time (approximately 540 million to 2.5 billion years ago). Siliceous rocks of the same age contains fossil algae and fungi. These early plants were primarily protists (solitary or aggregate unicellular organisms that include yellow-green algae, golden-brown algae, and diatoms) that lived in aqueous environments. It was not until the Late Silurian Period (approximately 420 million years ago) that plants are known to have developed the ability to survive on land. Fossil organisms that are reflective of this dramatic evolutionary event have been discovered in Wales and Australia.

Evidence for early coastal forests is preserved in strata of the Late Devonian Period (approximately 360 to 385 million years old). By the later half of the Paleozoic Era, plants had undergone extensive evolution and occupied many previously vacant environments (this phenomenon is sometimes called adaptive radiation).

There were two major eras of coal formation in geologic history. The older includes the Carboniferous Period (sometimes divided into the Mississippian and Pennsylvanian periods, from approximately 300 to 360 million years ago) and the Permian Period (from approximately 250 to 300 million years ago). Much of the bituminous coal of eastern North America and Europe is Carboniferous in age. Most coals in Siberia eastern Asia, and Australia are of Permian origin. The younger era began about 135 million years ago during the Cretaceous Period and reached its peak approximately 2.6 to 65.5 million years ago, during the Paleogene and Neogene periods of the Cenozoic Era. Most of the coals that formed during this second era are lignites and subbituminous (or brown) coals. These are widespread in such areas as western North America (including Alaska), southern France and central Europe, Japan, and Indonesia.

Late Paleozoic flora included sphenopsids, lycopsids, pteropsids, and the Cordaitales. The sphenopsid *Calamites* grew as trees in swamps. *Calamites* had long, jointed stems with sparse foliage. The lycopsids included species of *Lepidodendron* and *Sigillaria* (up to 30 metres or 100 feet tall) that grew in somewhat dry areas. Pteropsids included both true ferns (Filicineae) and extinct seed ferns (Pteridospermaphyta), which grew in relatively dry environments. The Cordaitales, which had tall stems and long, narrow, palmlike leaves, also favoured dry areas. During the Cretaceous and Cenozoic era, the angiosperms (flowering plants) evolved, producing a diversified flora from which the younger coals developed.

3.1.3 FORMATION PROCESSES:

3.1.3.1 PEAT

Although peat is used as a source of energy, it is not usually considered a coal. It is the precursor material from which coals are derived, and the process by which peat is formed is studied in existing swamps in many parts of the world (*e.g.*, in the Okefenokee Swamp of Georgia, U.S., and along the southwestern coast of New Guinea). The formation of peat is controlled by several factors including (1) the evolutionary development of plant life, (2) the climatic conditions (warm enough to sustain plant growth and wet enough to permit the partial decomposition of the plant material and preserve the peat), and (3) the physical conditions of the area (its geographic position relative to the sea or other bodies of water, rates of subsidence or uplift and so forth). Warm moist climates are thought to produce broad bands of bright coal. Cooler temperate climates, on the other hand, are thought to produce detrital coal with relatively little bright coal.

Initially, the area on which a future coal seam may be developed must be uplifted so that plant growth can be established. Areas near seacoasts or low-lying areas near streams stay moist enough for peat to form, but elevated swamps (some bogs and moors) can produce peat only if the annual precipitation exceeds annual evaporation and little percolation or drainage occurs. Thick peat deposits necessary for coal formation develop at sites where the following conditions exist: slow, continuous subsidence; the presence of such natural structures as levees, beaches, and bars that give protection from frequent inundation; and a restricted supply of incoming sediments that would interrupt peat formation. In such areas the water may become quite stagnant (except for a few rivers traversing the swamp), and plant material can continue to accumulate. Microorganisms attack the plant material and convert it to peat. Very close to the surface where oxygen is still readily available (aerobic, or oxidizing, conditions), the decomposition of the plant material produces mostly gaseous and liquid products. With increasing depth, however, the conditions become increasingly anaerobic (reducing), and molds and peats develop. The process of peat formation—biochemical coalification—is most active in the upper few metres of a peat deposit. Fungi are not found below about 0.5 metre (about 20 inches), and most forms of microbial life are eliminated at depths below about 10 metres (about 33 feet). If there is an increase in either the rate of subsidence or the rate of influx of new sediment. The peat will be buried and soon thereafter the coalification process—geochemical coalification—begins. The cycle may be repeated many times accounting for the numerous coal seams found in some sedimentary basins.

3.1.3.2 COALIFICATION:

The general sequence of coalification is lignite> subbituminous> bituminous >anthracite (*see below* Coal types and ranks). Since microbial activity ceases within a few metres of the Earth’s surface, the coalification process must be controlled primarily by changes in physical conditions that take place with depth. Some coal characteristics are determined by events that occur during peat formation—*e.g.*, charcoal-like material in coal is attributed to fires that occurred during dry periods while peat was still forming.

Three major physical factors—duration, increasing temperature, and increasing pressure may influence the coalification process. In laboratory experiments artificially prepared coals are influenced by the duration of the experiment, but in nature the length of time is substantially longer and the overall effect of time remains undetermined. Low-rank coal (*i.e.*, brown coal) in the Moscow Basin was deposited during Carboniferous time but was not buried deeply and never reached a higher rank. The most widely accepted explanation is that coalification takes place in response to increasing temperature. In general, temperature increases with depth. This geothermal gradient averages about 30, °C (about 85,. °F) per kilometre, but the gradient ranges from less than 10 °C (50 °F) per kilometre in regions undergoing very rapid subsidence to more than 100 °C (212 °F) per kilometre in areas of igneous activity. Measurements of thicknesses of sedimentary cover and corresponding coal ranks suggest that temperatures lower than 200 °C (about 390 °F) are sufficient to produce coal of anthracite rank. The effect of increasing pressure due to depth of burial is not considered to cause coalification. In fact, increasing overburden pressure might have the opposite effect if volatile compounds such as methane that must escape during coalification are retained. Pressure may influence the porosity and moisture content of coal.

3.1.4 PROPERTIES

Many of the properties of coal are strongly rank-dependent, although other factors such as maceral composition and the presence of mineral matter also influence its properties. Several techniques have been developed for studying the physical and chemical properties of coal, including density measurements, X-ray diffraction, scanning and transmission electron microscopy, infrared spectrophotometry, mass spectroscopy, gas chromatography, thermal analysis and electrical, optical and magnetic measurements.

3.1.4.1 DENSITY

Knowledge of the physical properties of coal is important in coal preparation and utilization. For example, coal density ranges from approximately 1.1 to about 1.5 megagrams per cubic metre, or grams per cubic centimetre (1 megagram per cubic metre equals 1 gram per cubic centimetre). Coal is slightly denser than water (1.0 megagram per cubic metre) and significantly less dense than most rock and mineral matter (e.g., shale has a density of about 2.7 megagrams per cubic metre and pyrite of 5.0 megagrams per cubic metre). Density differences make it possible to improve the quality of a coal by removing most of the rock matter and sulfide-rich fragments by means of heavy liquid separation (fragments with densities greater than about 1.5 megagrams per cubic metre settle out while the coal floats on top of the liquid). Devices such as cyclones and shaker tables also separate coal particles from rock and pyrite on the basis of their varying densities.

3.1.4.2 POROSITY

Coal density is controlled in part by the presence of pores that persist throughout coalification. Measurement of pore sizes and pore distribution is difficult; however, there appear to be three size ranges of pores: (1) macropores (diameter greater than 50 nanometres), (2) mesopores (diameter 2 to 50 nanometres), and (3) micropores (diameter less than 2 nanometres). (One nanometre 10^{-9} metre.) Most of the effective surface area of a coal—about 200 square metres per gram—is not on the outer surface of a piece of coal but is located inside the coal in its pores. The presence of pore space is important in the production of coke, gasification, liquefaction, and the generation of high-surface-area carbon for purifying water and gases. From the standpoint of safety, coal pores may contain significant amounts of adsorbed methane that may be released during mining operations and form explosive mixtures with air. The risk of explosion can be reduced by adequate ventilation during mining or by prior removal of coal-bed methane.

3.1.4.3 REFLECTIVITY

An important property of coal is its reflectivity (or reflectance)—*i.e.*, its ability to reflect light. Reflectivity is measured by shining a beam of monochromatic light (with a wavelength of 546 nanometres) on a polished surface of the vitrinite macerals in a coal sample and measuring the percentage of the light reflected with a photometer. Vitrinite is used because its reflectivity changes gradually with increasing rank. Fusinite reflectivities are too high due to its origin as charcoal, and liptinites tend to disappear with increasing rank. Although little of the incident light is reflected (ranging from a few tenths of a percent to 12 percent), the value increases with rank and can be used to determine the rank of most coal**s** without measuring the percentage of volatile matter present.

The study of coal**s** (and coaly particles called phyterals) in sedimentary basins containing oil and/or gas reveals a close relationship between coalification and the maturation of liquid and gaseous hydrocarbons. During the initial stages of coalification (to a reflectivity of almost 0.5 and near the boundary between sub-bituminous and high-volatile C bituminous coal), hydrocarbon generation produces chiefly methane. The maximum generation of liquid petroleum occurs during the development of high-volatile bituminous coals (in the reflectivity range from roughly 0.5 to about 1.3). With increasing depth and temperature, petroleum liquids break down and finally, only natural gas (methane) remains. Geologists can use coal reflectivity to anticipate the potential for finding liquid or gaseous hydrocarbons during petroleum expoloration.

3.1.4.4 OTHER PROPERTIES

Other properties, such as hardness, grindability, ash-fusion temperature, and free-swelling index (a visual measurement of the amount of swelling that occurs when a coal sample is heated in a covered crucible), may affect coal mining and preparation, as well as the way in which a coal is utilized. Hardness and grindability determine the kinds of equipment used for mining, crushing, and grinding coals in addition to the amount of power consumed during processing. Ash-fusion temperature influences furnace design and operating conditions. The free-swelling index provides preliminary information concerning the suitability of a coal for coke production.

3.1.5 COAL IN INDIA

Exploration, development, and sale of coal and lignite resources in India are completely under the oversight of the Indian Government, through the Ministry of Coal. The Ministry of Coal effectively determines all matters relating to the production, supply, distribution and sale price of coal. The Ministry reserves administrative control of major coal-producing companies including Coal India Limited (CIL), Singareni Colliery Company Limited (SCCL),6 and Neyveli Lignite Corporation (NLC). After nationalizing the coal mines between 1972 and 1973, the Government of India held the rights to nearly all coal mines in the country, and CIL was the public-sector holding company for these mines. CIL has seven coal-mining companies as its subsidiaries; the eighth subsidiary, Central Mine Planning and Design Institute Limited (CMPDIL), provides technical support in planning, exploration, mine development, and research and development in coal technologies7. More than 90% of coal and lignite produced in India is from the CIL, SCCL, and NLC mines, as only a small amount of captive coal mining is allowed for private steel, power and cement companies. The Geological Survey of India (GSI), the Mineral Exploration Corporation (MEC), SCCL, and CMPDIL map India's coal resources by undertaking prospecting surveys in areas with potential coal resources. The GSI and MEC are under the jurisdiction of the Ministry of Mines. The Coal Ministry also enjoys the administrative control of the Coal Controller's Organization, which, among others, gives grants for opening new seams/mines, collects and publishes data on the coal sector, collects excise duties, and monitors progress in captive mining (Ministry of Coal, 2006a).

In addition to the Ministry of Coal, the Ministry of Power plays a key role in recommending coal linkages to power projects and in recommending coal block allocations for captive mining. A similar role is played by the Ministry of Steel for the steel sector. The Planning Commission of India sets the long-term vision and priorities for the government and provides overall policy guidance and sectoral growth targets for all government ministries through its national plans. The Power and Energy Division of the Planning Commission also provides support to an Energy Coordination Committee under the chairmanship of the Prime Minister that addresses all key energy sector issues.

Among the other government entities involved in coal, the Ministry of Environment and Forests plays an important role in regulating the environmental impacts of mining and in providing clearances for mining in forest lands. The Ministry of Mines (through the GSI and MEC) also facilitates coal resource exploration.

The Directorate General of Mines Safety, in the Ministry of Labor, helps protect occupational health and safety of mine workers in India through legislation, examination, inspection and investigations.

3.1.6 COAL RESOURSCES

Total resources of hard coal and lignite in India are estimated at some 21 trillion tonnes, of which around 80% is hard coal. Reserves are sufficient to cover future demand for many decades.

- The costs to develop and produce coal from the first 100 billion tonnes of coal reserves are estimated to remain low. Environmental and sustainability issues are more likely to constrain growth in coal demand.
- The soaring price of crude oil in 2007-08 renewed interest in coal as a raw material for conversion into liquid and gaseous fuels. Coal gasification technologies are being deployed in chemicals production and power generation.
- When the energy needs for conversion and refining are included, CO_2 emissions of the coal-to-liquid (CTL) fuel cycle are double those of conventional petroleum-based fuels. Application of carbon capture and storage can only partially offset this major obstacle to deployment of the technology.

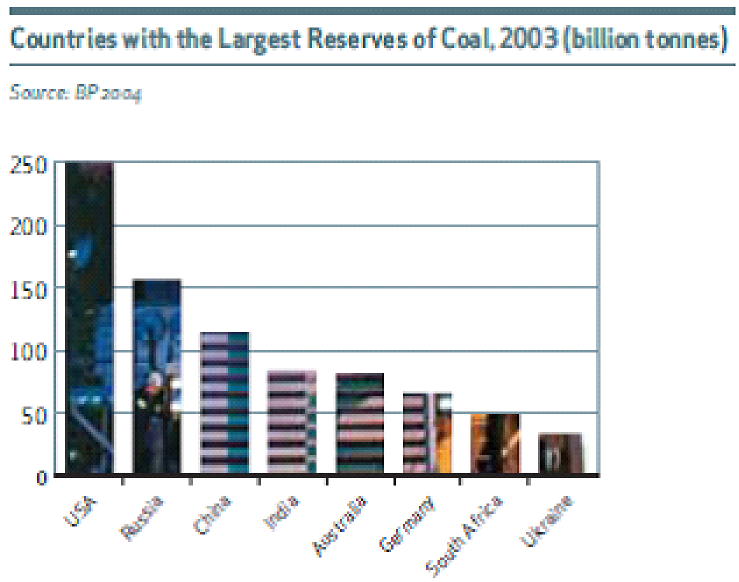
3.1.6.1 COAL RESOURCES IN INDIA

Source: IEA, 2002

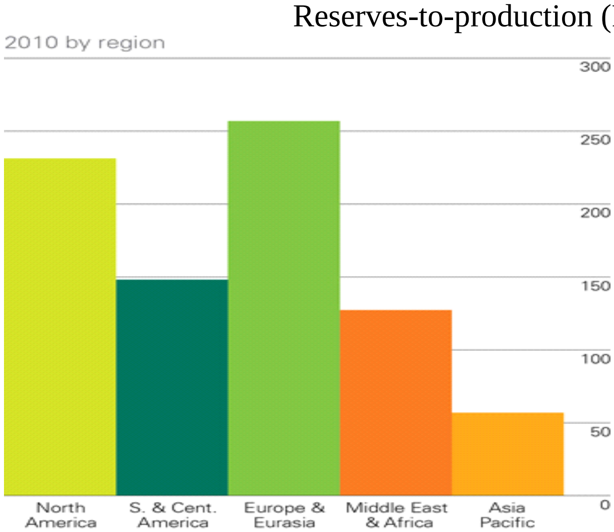
Although India has significant domestic coal resources, estimates of coal reserves are uncertain. India has an estimated 22,400 square kilometers (sq. km) of potential coal-bearing area, of which GSI has systematically explored only about 45% (10,200 sq. km) (Ministry of Coal, 2006b9). Indian coal deposits generally occur in two main geological horizons: a) the Lower Gondwana sediments (Permian); and b) the early Tertiary sediments (Eocene). Most of the major coal deposits are Gondwana coals in the eastern and southeastern parts of India; the Tertiary coals are located in Assam and other northeastern states, as well as Jammu and Kashmir (see Figure 1). Indian coal is primarily bituminous and sub-bituminous; there are nearly 36 gigatons (GT) of lignite resources in Tamil Nadu, Gujarat, Rajasthan, Jammu and Kashmir (Ministry of Coal, 2006a).

3.1.6.2 WORLD RESERVE

Reserves can be defined in terms of proved (or measured) reserves and probable (or indicated) reserves. Probable reserves have been estimated with a lower degree of confidence than proved reserves. Reserves that are not only considered to be recoverable but can also be recovered economically. This means one need to take into account what current mining technology can achieve and the economics of recovery. Proved reserves will therefore change according to the price of coal; if the price of coal is low, proved reserves will decrease.



Reserves-to-production (R/P) ratios for coal by 2010



Source: BP Statistical Review of World Energy, June 2010

World proved reserves of coal in 2010 were sufficient to meet 118 years of global production – by far the largest Reserve to Production (R/P) ratio of any fossil fuel, but well below the 2000 R/P ratio of 210 years. Europe & Eurasia holds the largest regional coal reserves and has the highest regional R/P ratio.

3.1.7 CONVERSION

In general, coal can be considered a hydrogen-deficient hydrocarbon with a hydrogen-to-carbon ratio near 0.8, as compared with a liquid hydrocarbons ratio near 2 and a gaseous hydrocarbon ratio near 4. For this reason, any process used to convert coal to alternative fuels must add hydrogen (either directly or in the form of water). Gasification refers to the conversion of coal to a mixture of gases, including carbon monoxide, hydrogen, methane, and other hydrocarbons, depending on the conditions involved. Gasification may be accomplished either *in situ* or in processing plants. *In situ* gasification is accomplished by controlled, incomplete burning of a coal bed underground while adding air and steam. The gases are withdrawn and may be burned to produce heat or generate electricity, or they may be used as synthesis gas in indirect liquefaction or the production of chemicals.

Liquefaction may be either direct or indirect (*i.e.*, by using the gaseous products obtained by breaking down the chemical structure of coal). Four general methods are used for liquefaction: (1) pyrolysis and hydrocarbonization (coal is heated in the absence of air or in a stream of hydrogen), (2) solvent extraction (coal hydrocarbons are selectively dissolved and hydrogen is added to produce the desired liquids), (3) catalytic liquefaction (hydrogenation takes place in the presence of a catalyst—for example, zinc chloride), and (4) indirect liquefaction (carbon monoxide and hydrogen are combined in the presence of a catalyst).

3.2 NATURAL GAS

3.2.1 DEFINITION

Natural gas is a vital component of the world's supply of energy. It is one of the cleanest, safest, and most useful energy sources. Despite its importance, however, there are many misconceptions about natural gas. For instance, the word 'gas' itself has a variety of different uses, and meanings. When we fuel our car, we put 'gas' in it. However, the gasoline that goes into your vehicle, while a fossil fuel itself, is very different from natural gas. The 'gas' in the common barbecue is actually propane, which, while closely associated and commonly found in natural gas, is not really natural gas itself. While commonly grouped with other fossil fuels and sources of energy, there are many characteristics of natural gas that make it unique. Below is a bit of background information about natural gas, what it is exactly, how it is formed, and how it is found in nature.

Natural gas, in itself, might be considered an uninteresting gas - it is colorless, shapeless, and odorless in its pure form. Quite uninteresting - except that natural gas is combustible, abundant in the United States and when burned it gives off a great deal of energy and few emissions. Unlike other fossil fuels, natural gas is clean burning and emits lower levels of potentially harmful byproducts into the air. We require energy constantly, to heat our homes, cook our food, and generate our electricity. It is this need for energy that has elevated natural gas to such a level of importance in our society, and in our lives.

3.2.2 COMPOSITION

Natural gas is a combustible mixture of hydrocarbon gases. While natural gas is formed primarily of methane, it can also include ethane, propane, butane and pentane. The composition of natural gas can vary widely, but below is a chart outlining the typical makeup of natural gas before it is refined.

Natural gas is considered 'dry' when it is almost pure methane, having had most of the other commonly associated hydrocarbons removed. When other hydrocarbons are present, the natural gas is 'wet'.

Table: Typical composition of Natural Gas

METHANE	CH_4	70-90%
ETHANE	C_2H_6	-
PROPANE	C_3H_8	0-20%
BUTANE	C_4H_{10}	-
CARBON DIOXIDE	CO_2	0-8%
OXYGEN	O_2	0-0.2%
NITROGEN	N_2	0-5%
HYDROGEN SULPHIDE	H_2S	0-5%
RARE GAS	A, He, Ne, Xe	Trace

3.2.3 ORIGIN OF NATURAL GAS

Natural gas is a fossil fuel. Like oil and coal, it is essentially, the remains of plants and animals and microorganisms that lived millions and millions of years ago. But how do these once living organisms become an inanimate mixture of gases?

There are many different theories as to the origins of fossil fuels. The most widely accepted theory says that fossil fuels are formed when organic matter (such as the remains of a plant or animal) is compressed under the earth, at very high pressure for a very long time. This is referred to as thermogenic methane. Similar to the formation of oil, thermogenic methane is formed from organic particles that are covered in mud and sediment. Over time, more and more sediment, mud and other debris are piled on top of the organic matter. The sediment and debris put a great deal of pressure to compress the organic matter. This compression, combined with high temperature found deep underneath the earth, breaks down the carbon bonds in the organic matter. As one gets deeper and deeper under the earth's crust, the temperature gets higher and higher. At low temperatures (shallower deposits), more oil is produced relative to natural gas. At higher temperatures, however, more natural gas is created, as opposed to oil. That is why natural gas is usually associated with oil in deposits that are 1 to 2 miles below the earth's crust. Deeper deposits, very far underground, usually contain primarily natural gas, and in many cases, pure methane.

Natural gas can also be formed through the transformation of organic matter by tiny microorganisms. This type of methane is referred to as biogenic methane. Methanogens, tiny methane-producing microorganisms, chemically break down organic matter to produce methane. These microorganisms are commonly found in areas near the surface of the earth that are void of oxygen. These microorganisms also live in the intestines of most animals, including human. Formation of methane in this manner usually takes place close to the surface of the earth, and the methane produced is usually lost into the atmosphere. In certain circumstances, however, this methane can be trapped underground, recoverable as natural gas. An example of biogenic methane is landfill gas. Waste-containing landfills produce a relatively large amount of natural gas from the decomposition of the waste materials. New technologies are allowing this gas to be harvested and add to the supply of natural gas.

A third way in which methane (and natural gas) may be formed is through abiogenic processes. Extremely deep under the earth's crust, there exist hydrogen-rich gases and carbon molecules. As these gases gradually rise towards the surface of the earth, they may interact with minerals that also exist underground, in the absence of oxygen. This interaction may result in a reaction, forming elements and compounds that are found in the atmosphere (including nitrogen, oxygen, carbon dioxide, argon, and water). If these gases are under very high pressure they are likely to form methane deposits, similar to thermogenic methane; as they move toward the surface of the earth.

3.2.4 PROPERTIES

3.2.4.1 PHYSICAL PROPERTIES

The physical properties of natural gas include colour, odour, and flammability. The principal ingredient of gas is methane, which is colourless, odourless, and highly flammable. However, some of the associated gases in natural gas, especially hydrogen sulfide, have a distinct and penetrating odour, and a few parts per million is sufficient to impart a decided odour to natural gas. So natural gas is:

- Nontoxic
- Lighter than air
- Colorless
- Odorless
- Contributes to a cleaner environment

3.2.4.2 CHEMICAL COMPONENTS:

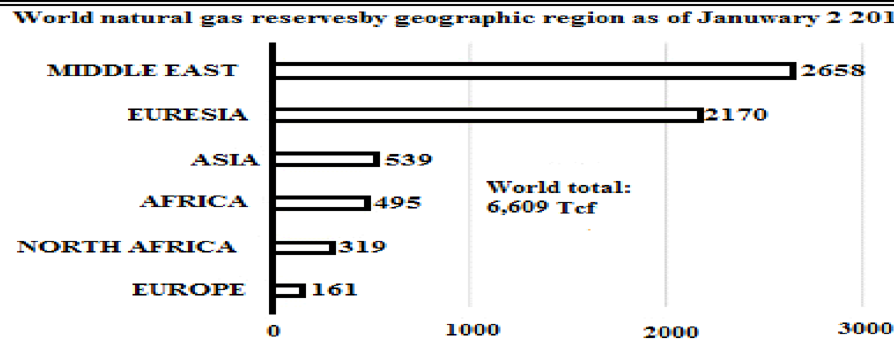
Component	**wt. %**
Methane	70-90
Ethane	5-15
Propane and Butane	< 5
CO_2, N_2, H_2S, etc.	Balance

3.2.5 NATURAL GAS RESOURCES

Conventional reserves of natural gas can satisfy demand for decades, but unconventional gas resources, such as shale gas or coalbed methane, have not yet been systematically assessed. Resources yet to be discovered could affect the global energy balance. Getting gas to global markets is the central issue, as major conventional reserves tend to be remote from demand centres, and natural gas transportation is complex and costly.

- Technology has reduced the costs and increased the flexibility of gas transportation; these developments could bring currently stranded gas resources to the market.
- Global tight gas (including shale) reserves are estimated at 3 trillion cubic metres. New methods for completing shale gas wells may underpin a significant growth in gas reserves. If effective capture methods are developed, coal bed methane could become an additional cost-effective source.
- Opportunities for deriving natural gas from methane hydrate are advancing. Additional work is needed to quantify reserves and assess the economic feasibility of production.

3.2.5.1 WORLD RESERVE



The EIA, in conjunction with the *Oil and Gas Journal* and *World Oil* publications, estimates proved natural gas reserves in the entire world to be around 6,609 Trillion cubic feet. As can be seen from the graph, most of these reserves are located in the Middle East with 2,658 Trillion cubic feet, or 40 percent of the world total, and Europe and the Former U.S.S.R. with 2,331, or 35 percent of total world reserves. The United States, by this calculation, possesses slightly over 4% of the world total natural gas reserves.

3.2.5.2 PRODUCTION AND RESERVES OF NATURAL GAS IN INDIA

Natural Gas (Billion Cubic Metres) Reserve

AREA	2005	2006	2007	2008	2009	2010
ONSHORE	340	330	270	264	267	829
OFFSHORE	741	745	785	786	787	608
TOTAL	1101	1075	1055	1050	1074	1437

Source: ONGC, OIL and DGH.

Natural Gas (Million Cubic Metres) Production

ITEM	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
• ONSHORE					
Gujarat	3831	3294	2931	2605	2444
Assam/Nagaland	2408	2526	2598	2573	2704
Arunachal Pradesh	48	35	30	30	40
Tripura	480	520	534	553	562
Tamil Nadu	906	1130	1169	1242	1178
Andhra Pradesh	1663	1525	1567	1524	1479
Rajasthan	242	242	255	216	239
West Bengal (CBM)	--	--	15	20	38

TOTAL (a)	**9578**	**9272**	**9099**	**8763**	**8684**
Of which					
OIL	2270	2265	2340	2268	2416
ONGC	5751	5876	5877	5753	5633
JVC/Private	1557	1131	882	742	635
• **OFFSHORE**					
ONGC (Mumbai High)	16823	16567	16457	16738	17476
JVC/ Private	5801	5908	6861	7374	21350
TOTAL (b)	**22624**	**22475**	**23318**	**24086**	**38826**
GRAND TOTAL (a+b)	**32202**	**31747**	**32417**	**32849**	**47510**

Source: ONGC, OIL, DGH and GAIL

3.2.6 USES

3.2.6.1 POWER GENERATION

Natural gas is a major source of electricity generation through the use of gas turbines and steam turbines. Most grid peaking power plants and some off-grid engine-generators use natural gas. Particularly high efficiencies can be achieved through combining gas turbines with a steam turbine in combined cycle mode. Natural gas burns more cleanly than other Hydrocarbon fuels, such as oil and coal, and produces less carbon dioxide per unit of energy released. For an equivalent amount of heat, burning natural gas produces about 30% less carbon dioxide than burning petroleum and about 45% less than burning coal. Combined cycle power generation using natural gas is thus the cleanest source of power available using hydrocarbon fuels and this technology is widely used wherever gas can be obtained at a reasonable cost. Fuel cell technology may eventually provide cleaner options for converting natural gas into electricity, but as yet it is not price-competitive.

3.2.6.2 DOMESTIC USE

Natural gas dispensed from a simple stovetop can generate heat in excess of 2000°F (1093°C) making it a powerful domestic cooking and heating fuel. In much of the developed world it is supplied to homes via pipes where it is used for many purposes including natural gas-powered ranges and ovens, natural gas-heated clothes dryers, heating/cooling, and central heating. Home or other building heating may include boilers, furnaces, and water heaters. Compressed natural gas (CNG) is used in rural homes without connections to piped-in public utility services, or with portable grills. Natural gas is also supplied by independent natural gas suppliers through Natural Gas Choice programs throughout the United States. However, due to CNG being less economical than LPG, LPG (propane) is the dominant source of rural gas.

3.2.6.3 TRANSPORTATION

CNG is a cleaner alternative to other automobile fuels such as gasoline (petrol) and diesel. As of 2008 there were 9.6 million natural gas vehicles worldwide, led by Pakistan (2.0 million), Argentina (1.7 million), Brazil (1.6 million), Iran (1.0 million), and India (650,000). The energy efficiency is generally equal to that of gasoline engines, but lower compared with modern diesel engines. Gasoline/petrol vehicles converted to run on natural gas suffer because of the low compression ratio of their engines, resulting in a cropping of delivered power while running on natural gas (10%–15%). CNG-specific engines, however, use a higher compression ratio due to this fuel's higher octane number of 120–130.

3.2.6.4 FERTILIZERS

Natural gas is a major feedstock for the production of ammonia, via the Haber process, for use in fertilizer production.

3.2.6.5 AVIATION

Russian aircraft manufacturer Tupolev is currently running a development program to produce LNG- and hydrogen-powered aircraft. The program has been running since the mid-1970s, and seeks to develop LNG and hydrogen variants of the Tu-204 and Tu-334 passenger aircraft, and also the Tu-330 cargo aircraft. It claims that at current market prices, an LNG-powered aircraft would cost 5,000 roubles (~ $218/ £112) less to operate per ton, roughly equivalent to 60%, with considerable reductions to carbon monoxide, hydrocarbon and nitrogen oxide emissions.

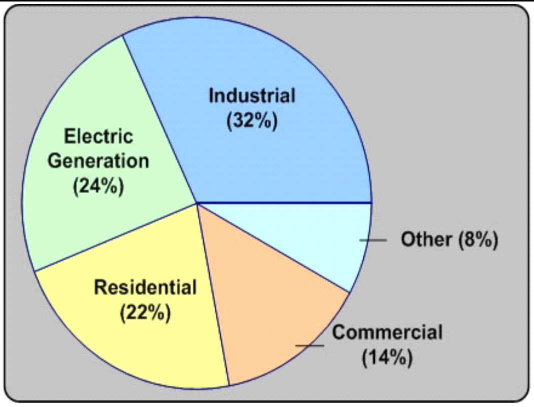
The advantages of liquid methane as a jet engine fuel are that it has more specific energy than the standard kerosene mixes do and that its low temperature can help cool the air which the engine compresses for greater volumetric efficiency, in effect replacing an intercooler. Alternatively, it can be used to lower the temperature of the exhaust.

3.2.6.6 HYDROGEN PRODUCTION

Natural gas can be used to produce hydrogen, with one common method being the hydrogen reformer. Hydrogen has many applications: it is a primary feedstock for the chemical industry, a hydrogenating agent, an important commodity for oil refineries, and the fuel source in hydrogen vehicles.

3.2.6.7 OTHER

Natural gas is also used in the manufacture of fabrics, glass, steel, plastics, paint, and other products. Natural gas is used for heating buildings, heating water, cooking, drying clothes, lighting, and industrial purposes. Some household appliances that use natural gas include:



Natural Gas use by sector

Source: IEA - Annual Energy Outlook, 2002

- Furnaces
- Pool and Spa Heaters
- Clothes Dryers
- Outdoor Lights
- Barbecues
- Water Heaters
- Stoves/Ranges
- Fireplace Logs
- Patio Heaters and Fire Pits

There are so many different applications for this fossil fuel that it is hard to provide an exhaustive list of everything it is used for. And no doubt, new uses are being discovered all the time.

According to the Energy Information Administration, energy from natural gas accounts for 24 percent of total energy consumed in the United States, making it a vital component of the nation's energy supply.

Natural gas is used across all sectors, in varying amounts. The gives an idea of the proportion of natural gas use per sector. The industrial sector accounts for the greatest proportion of natural gas use in the United States, with the residential sector consuming the second greatest quantity of natural gas.

3.3 PETROLEUM

A thick, flammable, yellow-to-black mixture of gaseous, liquid, and solid hydrocarbons that occurs naturally beneath the earth's surface, can be separated into fractions including natural gas, gasoline, naphtha, kerosene, fuel and lubricating oils, paraffin wax, and asphalt and is used as raw material for a wide variety of derivative products.

3.3.1 CHEMICAL COMPOSITION

3.3.1.1 HYDROCARBON CONTENT

Although oil consists basically of compounds of only two elements, carbon and hydrogen, these elements form a large variety of complex molecular structures. Regardless of physical or chemical variations, however, almost all crude oil ranges from 82- 87% carbon by weight and 12-15% hydrogen. The more viscous bitumen generally vary from 80-85% carbon and from 8-11% hydrogen.

Crude oil can be grouped into three basic chemical series: paraffins, naphthenes and aromatics. Most crude oils are mixtures of these three series in various and seemingly endless proportions. No two crude oils from different sources are completely identical.

The paraffin series of hydrocarbons, also called the methane (CH_4) series, comprises the most common hydrocarbons in crude oil. It is a saturated straight-chain series that has the general formula C_nH_{2n+2}, in which C is carbon, H is hydrogen, and *n* is an integer. The paraffins that are liquid at normal temperatures but boil between 40 and 200 °C (approximately between 100 and 400 °F) are the major constituents of gasoline. The residues obtained by refining lower-density paraffins are both plastic and solid paraffin waxes.

The naphthene series has the general formula C_nH_{2n} and is a saturated closed-ring series. This series is an important part of all liquid refinery products, but it also forms most of the complex residues from the higher boiling-point ranges. For this reason, the series is generally heavier. The residue of the refinery process is an asphalt, and the crude oils in which this series predominates are called asphalt-base crudes.

The aromatic series has the general formula C_nH_{2n-6} and is an unsaturated closed-ring series. Its most common member, benzene (C_6H_6), is present in all crude oils, but the aromatics as a series generally constitute only a small percentage of most crude.

3.3.1.2 NON-HYDROCARBON CONTENT

In addition to the practically infinite mixtures of hydrocarbon compounds that form crude oil, sulfur, nitrogen, and oxygen are usually present in small but often important quantities. Sulfur is the third most abundant atomic constituent of crude oils. It is present in the medium and heavy fractions of crude oils. In the low and medium molecular ranges, sulfur is associated only with carbon and hydrogen, while in the heavier fractions it is frequently incorporated in the large polycyclic molecules that also contain nitrogen and oxygen. The total sulfur in crude oil varies from below 0.05 percent (by weight), as in some Pennsylvania oils, to about 2 percent for average Middle Eastern crudes and up to 5 percent or more in heavy Mexican or Mississippi oils. Generally, the higher the specific gravity of the crude oil, the greater is its sulfur content. The excess sulfur is removed from crude oil during refining, because sulfur oxides released into the atmosphere during the combustion of oil would constitute a major pollutant.

The oxygen content of crude oil is usually less than 2 percent by weight and is present as part of the heavier hydrocarbon compounds in most cases. For this reason, the mostly heavier oils contain oxygen. Nitrogen is present in almost all crude oils, usually in quantities of less than 0.1 percent by weight. Sodium chloride is also found in most crudes and is usually removed like sulfur.

Many metallic elements are found in crude oils, including most of those that occur in seawater. This is probably due to the close association between seawater and the organic forms from which oil is generated. Among the most common metallic elements in oil are vanadium and nickel, which apparently occur in organic combinations as they do in living plants and animals.

Crude oil may also contain a small amount of decay-resistant organic remains, such as siliceous skeletal fragments, wood, spores, resins, coal and various other remnants of former life.

Table : Elemental composition of Petroleum by weight

ELEMENT	**PERCENTAGE RANGE**
Carbon	83-87%
Hydrogen	10-14%
Sulfur	0.05 to 6.0%
Nitrogen	0.1-2%
Oxygen	0.05-1.5%

Metals	< 0.1%

Table : Composition (Hydrocarbon type) of Petroleum by weight

HYDROCARBON TYPE	Average	Range
Paraffins	30%	15 to 60%
Naphthenes	49%	30 to 60%
Aromatics	15%	3 to 30%
Asphaltics	6%	Remainder

3.3.2 GENERAL PROPERTIES OF CRUDE OIL

- Crude oils are complex mixtures containing many different hydrocarbon compounds that vary in appearance and composition from one oil field to another. Crude oils range in composition from water to tar-like solids, and in color from clear to black.

- An *average* crude oil contains about 84% carbon, 14% hydrogen, 1%-3% sulfur, and less than 1% each of nitrogen, oxygen, metals and salts.

- Crude oils are generally classified as paraffinic, naphthenic, or aromatic, based on the **predominant proportion of similar hydrocarbon molecules**. Mixed-base crudes have varying amounts of each type of hydrocarbon. Refinery crude base stocks usually consist of mixtures of two or more different crude oils.

- Relatively simple crude oil assays are used to classify crude oils as paraffinic (West Texas crude, Brent), naphthenic (Louisiana crude, Nigerian Light), aromatic (Maya Crude), or mixed (Assam crude). One assay method (United States Bureau of Mines) is based on distillation, and another method (UOP "K" factor) is based on gravity and boiling points. More comprehensive crude assays determine the value of the crude (i.e., its yield and quality of useful products) and processing parameters. Crude oils are usually grouped according to yield structure.

- Crude oils are also defined in terms of API (American Petroleum Institute) gravity. The higher the API gravity, the lighter is the crude. For example, light crude oils have high API gravities and low specific gravities. Crude oils with low carbon, high hydrogen and high API gravity are usually rich in paraffin’s and tend to yield greater proportions of gasoline and light petroleum products; those with high carbon, low hydrogen, and low API gravities are usually rich in aromatics. **The price of a crude oil is usually based on its API gravity, with high gravity oils commanding higher prices.**

- Crude oils that contain appreciable quantities of hydrogen sulfide or other reactive sulfur compounds are called "sour." Those with less sulfur are called "sweet." Some exceptions to this rule are West Texas crudes, which are always considered "sour" regardless of their H_2S content, and Arabian high-sulfur crudes, which are not considered "sour" because their sulfur compounds are not highly reactive.

About Hydrocarbon Groups

The main constituents of petroleum can be grouped into four categories:

- **Paraffin**: A series of saturated straight chain or branched hydrocarbons, the lowest members of which are methane, ethane and propane.
- **Olefins**: Double-bonded hydrocarbons that are not normally present in crude oil but are formed during refinery processing and vehicle combustion of fuel. Olefins help improve the octane rating, but their use may lead to gum formation or deposits in engine intake systems.
- **Aromatic**: Unsaturated cyclic hydrocarbons are known as aromatics. Aromatics occur naturally in crude oil and can also be produced in some refining processes. Aromatics common in petrol include benzene, toluene and xylene. Controlling the level of aromatics directly limits evaporative losses and exhaust emissions.
- **Naphthenes**: Naphthenes are a class of compounds that are saturated hydrocarbons typified by cyclic hydrocarbon molecular structure. The general formula for cyclic hydrocarbons is C_nH_{2n}.

3.3.3 PROPERTIES OF PETROLEUM

3.3.3.1 FLASH POINT

The flash point of a fuel is the temperature to which the fuel must be heated to produce a vapour/air mixture above the liquid fuel that is ignitable when exposed to an open flame under specified test conditions. Flash point is important primarily from a fuel-handling standpoint. Too low a flash point will cause fuel to be a fire hazard, subject to flashing, and possible continued ignition and explosion. In addition, a low-flash point may indicate contamination by more volatile and explosive fuels, such as gasoline. A very important reason to maintain the flash point as high as possible is due to the electrostatic hazards in pumping distillate fuels.

3.3.3.2 FIRE POINT

Fire point is the lowest temperature, corrected to one atmosphere pressure (101.3 kPa), at which the application of a test flame to the oil sample surface causes the vapour of the oil to ignite and burn for at least five seconds. For ordinary commercial lubricating oils, the fire point usually runs about $30^{o}C$ above the flash point .The test is carried out in open cup rather then in a close one. ASTM D 92 method offers the advantage of open flash point and fire point determination. Low fire point petroleum products are potential fire hazards.

3.3.3.3 SMOKE POINT

Smoke is an indication of clean burning quality of kerosene. Illumination depends upon the flame dimension although it is not related to flame height. Many paraffins may be endowed with better flame height but illumination may be poor. Smoke point is defined as the maximum height of flame in millimeters at which the given oil will burn without giving smoke. Different flame heights are obtained due to the presence of different components such as paraffins, naphthenes and aromatics. Aromatic contributes smoke, hence removal of aromatics increases the smoke point. Naphthenes with side chain one inevitably retained to give good illumination. In India, marketable kerosene should possess a smoke point of 18mm.

3.3.3.4 SIGNIFICANCE OF ANILINE POINT

Aniline point is defined as the minimum temperature at which equal volumes of anhydrous aniline and oil mix together. Aniline being an aromatic compound freely mixes with aromatic so a low aniline point indicates low diesel index (because of high percentage of aromatics).

Significance: High aniline point indicates that the fuel is highly paraffinic and hence has a high Diesel index and very good ignition quality. In case of aromatics the aniline point is low and the ignition quality is poor.

This test is useful for calculating Diesel Index.

3.3.3.5 DIESEL INDEX

Diesel index is a measure of ignition quality of fuel. Diesel engine works on the principle of compression ignition. During compression, adiabatically the air temperature reaches around 60^0C, when the fuel in finely atomised form is fed in, it instantaneously explodes. Self ignition temperature is low for paraffins while it is high for aromatics. Thus a fuel rich in aromatics cause ignition delay and gives rise to what is known as diesel knock. For this reason all diesel fuels are processed to have a diesel index in the range of 45 to 55.

Significance: High aniline point indicates that the fuel is highly paraffinic and hence a high Diesel Index and a very good ignition quality. In case of aromatics the aniline point is low and the ignition quality is poor.

3.3.3.6 CETANE NUMBER

This is a measure of the tendency of diesel fuels to knock in a diesel engine. This is determined by CFR (Cooperative Fuels Research) engine having a single cylinder. The sample fuel is compared with that reference blend of fuel of known Cetane Number. The reference fuels used are Normal Cetane (100 cetane number) and Hepta Methyl Nonane (15 cetane number). Cetane number is a whole number which is indicative of the ignition quality of fuel. High Cetane Number fuels give good ignition and reduced roughness.

Significance: Cetane number is the index of ignition quality of a fuel. High cetane number fuel will enhance easy starting of compression ignition engines and lessen engine roughness.

This test is required mainly for HSD.

3.3.3.7 OCTANE NUMBER

Octane number is defined as percentage (volume) of Iso-octane (2,2,4-trimethyl pentane) in a mixture of Iso-octane and n-heptane that gives the same knocking charactristic as the fuel under consideration. Knocking is due to untimely burning of fuel in a spark ignition engine, which results in loss of power and sometimes it is powerful enough to cause damage to engine parts. With the advent of petrol engines of high compression ratios the tendency of knocking has also increased. Being a blend, gasoline responds in different ways, even in the same engine, depending on the components present. Iso-paraffins and aromatics have high octane number while n-paraffins have very low value, unsaturates do have high octane values but not preferred due to gum contribution.

Octane number is influenced by different factors like speed of engine, ambient weather conditions, altitude, combustion chamber deposits and coolant temperature. Knocking rating is tested by CFR engine for different purposes. Motor method gives the octane rating of highway driving (high speed), while research method gives for city driving (low speed) conditions and aviation method is for aviation gasoline. The rating can be done by either Research Method or Motor Method. If the fuel meets the minimum requirements in respect of Octane number it ensures trouble free operation. Apart from being a nuisance, the knocking in an engine may result in loss of energy and at times may cause severe damage to the engine.

3.3.3.8 ANTIKNOCKING INDEX (AKI)

The AKI of a motor fuel is the average of the Research Octane Number (RON) and Motor Octane Number (MON) or (R+M)/2 and it remains the most important quality criteria for motorists. Thc Research Octane Number (RON) simulates fuel performance under low severity engine operation. The Motor Octane Number (MON) simulates more severe operation that might be incurred at high speed or high load. In practice the octane of a gasoline is reported as the average of RON and MON or (R+M)/2.

Significance: Today it is accepted that no single octane rating covers the entire spectrum of use. The combination of vehicle and engine can result in specific requirements for octane that depend on the fuel. If the octane is distributed differently throughout the boiling range of a fuel, then engines can knock on one brand of 87 *i.e* (RON+MON)/2, but not on another brand. This octane *distribution* is especially important when sudden changes in load occur, such as high load, full throttle, and acceleration. Optimum performance and fuel economy is achieved when the AKI is adequate for the engine in which it is combusted. There is no advantage in using gasoline with a higher AKI than the engine requires to operate knock-free. In India Current BIS specification of AKI is 84 (unleaded regular) and 88 (unleaded premium).

3.3.3.9 METHYL TERTIARY BUTYL ETHER (MTBE)

MTBE is an ether compound in the same boiling range as gasoline. Ethers have an oxygen atom in each molecule and a characteristic smell. MTBE is made by combining isobutylene (from various refining and chemical processes) and methanol (usually made from natural gas). MTBE has been used as a gasoline-blending component since 1979. Originally, it was used to help raise the octane of gasoline. Now, it is also used to raise the oxygen content of gasoline. The oxygen atom in MTBE helps provide extra oxygen for complete combustion. Ideally, an oxygenate reduces the amount of unburned hydrocarbons and carbon monoxide in the exhaust. Chemical formula for MTBE is $CH_3OC\ (CH_3)_3$.

3.3.3.10 OXYGENATES

Finished motor gasoline, having oxygen content of 2.7% or higher by weight is known as

Oxygenated Gasoline. *Oxygenated gasoline* is a mixture of conventional gasoline and one or more combustible liquids which contain oxygen oxygenates. At present, the most common oxygenates are ethanol and MTBE (Methyl Tertiary Butyl Ether). Oxygenated gasoline reduces fuel economy an average of 2%-3% because oxygenates contain less energy than non-oxygenated gasoline. Oxygenated gasoline helps engines run leaner, which helps engines, particularly older engines, produce less carbon monoxide.
Fuel Ethanol: Blends of up to 10% by volume anhydrous ethanol.
MTBE (Methyl Tertiary Butyl Ether): Blends of up to 15.0 percent by volume MTBE which must meet the ASTM D4814 specifications.

Other Oxygenates: Ethyl tertiary butyl ether (ETBE), tertiary amyl methyl ether (TAME), Methanol.and other oxygenates improve gasoline octane ratings and reduce carbon monoxide emissions.

3.3.3.11 VISCOSITY

Viscosity is a measure of a fluid's resistance to flow; the lower the viscosity of a fluid, the more easily it flows. Like density, viscosity is affected by temperature. As temperature decreases, viscosity increases. The SI unit of dynamic viscosity is the millipascal-second (mPa.s). *Thin* liquids, like water or gasoline, have low viscosities; *thick* liquids, like Lubricating oils have higher viscosities.

Viscosity is an important characteristic of diesel. Fuels outside the required range may cause power loss or improper atomization of the fuel in a diesel engine. Lubrications assist in removing the frictional forces between two moving bodies. Absolute viscosity divided by fluid density equals kinematic viscosity. Absolute viscosity and kinematic viscosity are expressed in fundamental units. Commercial viscosity such as Saybolt viscosity is expressed in arbitrary units of time, usually seconds.

3.3.3.12 ATMOSPHERIC CRUDE OIL DISTILLATION

The refining process of separating crude oil components at atmospheric pressure is done by heating to temperatures of about 600 ^{o}F to 750 ^{o}F (depending on the nature of the crude oil and desired products) and subsequent condensing of the fractions by cooling.

3.3.3.13 VACUUM DISTILLATION

A secondary refining process in which straight-run residue is distilled in a vacuum in order to separate more light hydrocarbons than through atmospheric distillation. The output of the process is vacuum gas oil, which can be used as feedstock for cracking units and vacuum bottoms or residue are usually used as boiler fuel.

3.3.3.14 CATALYTIC CRACKING

This refining process is of breaking down the larger, heavier, and more complex hydrocarbon molecules into simpler and lighter molecules. Catalytic cracking is accomplished by the use of a catalytic agent and is an effective process for increasing the yield of gasoline from crude oil. Catalytic cracking processes fresh feeds and recycled feeds.

3.3.3.15 CATALYTIC HYDROCRACKING

A refining process that uses hydrogen and catalysts with relatively low temperatures and high pressures for converting middle boiling or residual material to high-octane gasoline, reformer charge stock, jet fuel, and/or high grade fuel oil. The process uses one or more catalysts, depending upon product output, and can handle high sulphur feedstocks without prior desulphurization.

3.3.3.16 CATALYTIC HYDROTREATING

This is a refining process for treating petroleum fractions from atmospheric or vacuum distillation units (*e.g.*, naphtha, middle distillates, reformer feeds, residual fuel oil and heavy gas oil) and other petroleum (*e.g.*, cat cracked naphtha, coker naphtha, gas oil etc.) in the presence of catalysts and substantial quantities of hydrogen. Hydrotreating includes desulphurization, removal of substances (*e.g.*, nitrogen compounds) that deactivate catalysts, conversion of olefins to paraffins for reduceing gum formation in gasoline and other processes to upgrade the quality of the fractions.

3.3.3.17 CATALYTIC REFORMING

Catalytic referring is a refining process using controlled heat and pressure with catalysts to rearrange certain hydrocarbon molecules, thereby converting paraffinic and naphthenic type hydrocarbons (*e.g.*, low-octane gasoline boiling range fractions) into petrochemical feedstocks and higher octane stocks suitable for blending into finished products.

3.3.3.18 ISO SIEVE PROCESS

Another way of increasing octane number of gasoline is by removing altogether low octane hydrocarbon molecules specially straight run n-paraffin from the product (gasoline) by physical absorption process with the help of a specific catalyst which has the ability to trape n-paraffin molecules.

3.3.3.19 DELAYED COKING

A process by which heavier crude oil fractions can be thermally decomposed under conditions of elevated temperatures and pressure to produce a mixture of lighter oils and petroleum coke. The light oils can be processed further in other refinery units to meet product specifications. The coke can be used either as a fuel or in other applications such as the manufacturing of steel or aluminium.

3.3.3.20 API GRAVITY

API gravity is a measure of the weight of hydrocarbons according to a scale established by the American Petroleum Institute. Crude oils with higher values of API gravity are lighter and tend to produce larger volumes of high-value lighter products in atmospheric distillation, which makes them relatively more valuable. Crude oil grades that are lower on the API scale tend to be less highly valued because they produce smaller yields of lighter products.

3.3.3.21 CLOUD POINT

Cloud point and pour point are measures of winter temperature behavior properties of distillate fuels. Cloud point is the temperature where paraffin first forms in fuel. In practice, cloud point helps to determine the temperature at which paraffin crystals will begin to block fuel filters and lines and cause starting and stalling problems for diesel engines.

3.3.3.22 POUR POINT

The pour point of an oil is the lowest temperature at which the oil will just flow, under standard test conditions. The failure to flow at the pour point is usually attributed to the separation of waxes from the oil, but can also be due to the effect of viscosity in the case of very viscous oils. This test is required for HSD and FO. Pour point requirement is 6 ˚C for Normal diesel and -12 ˚C for winter grade diesel.

3.3.3.23 FLUID CATALYTIC CRACKING (FCC)

FCC uses a catalyst in the form of a very fine powder which flows like a liquid when agitated by steam, air or vapour. Feedstock entering the process immediately meets a stream of very hot catalyst and vaporises. The resulting vapours keep the catalyst fluidised as it passes into the reactor, where the cracking takes place and where it is fluidised by the hydrocarbon vapour. The catalyst next passes to a steam stripping section where most of the volatile hydrocarbons are removed. It then passes to a regenerator vessel where it is fluidised by a mixture of air and the products of combustion which are produced as the coke on the catalyst is burnt off. The catalyst then flows back to the reactor. The catalyst thus undergoes a continuous circulation between the reactor, stripper and regenerator sections.

The catalyst is usually a mixture of aluminium oxide and silica. Most recently, the introduction of synthetic zeolite catalysts has allowed much shorter reaction times and improved yields and octane numbers of the cracked gasolines.

3.3.3.24 ISOMERISATION

Isomerisation refers to chemical rearrangement of straight-chain hydrocarbons (paraffins), so that they contain branches attached to the main chain (isoparaffins). This is done for two reasons: they create extra isobutane feed for alkylationthey improve the octane of straight run pentanes and hexanes and hence make them into better petrol blending components.

Isomerisation is achieved by mixing normal butane with a little hydrogen and chloride and allowed to react in the presence of a catalyst to form isobutane, with a small amount of normal butane and some lighter gases. Products are separated in a fractionator. The lighter gases are used as refinery fuel and the butane is recycled as feed.

Pentanes and hexanes are the lighter components of petrol. Isomerisation can be used to improve petrol quality by converting these hydrocarbons to higher octane isomers. The process is the same as the for butane isomerisation.

3.3.3.25 VISBREAKING

Visbreaking, a mild form of thermal cracking, significantly lowers the viscosity of heavy crude-oil residue without affecting the boiling point range. Residual from the atmospheric distillation tower is heated (800°-950° F) at atmospheric pressure and mildly cracked in a heater. It is then quenched with cool gas oil to control overcracking, and flashed in a distillation tower. Visbreaking is used to reduce the pour point of waxy residues and reduce the viscosity of residues used for blending with lighter fuel oils. Middle distillates may also be produced, depending on product demand. The thermally cracked residue tar, which accumulates in the bottom of the fractionation tower, is vacuum flashed in a stripper and the distillate recycled.

3.3.3.26 HYDROFINISHING PROCESS

A catalytic treating process carried out in the presence of hydrogen to improve the properties of low viscosity-index naphthenic and medium viscosity-index naphthenic oils. It is also applied to paraffin waxes and microcrystalline waxes for the removal of undesirable components. This process consumes hydrogen and is used in lieu of acid treating

3.3.4 ORIGIN OF PETROLEUM

- A number of theories have been suggested from time to time for the origin of petrolum. Theories like inorganic origin of petroleum or formation of the same from organic sources-both animal and plant by a process called destructive distillation were rejected because of their involvement of either some improbable materials or processes.
- Collations of information on petroleum by researchers in its different aspects and their analysis has lead to the emergence of a rational views on petroleum genesis.
- **The genesis of petroleum can be thought to occur in four phases, viz.,**
    - Embedment of organic matter in source bed;
    - Conversion of source material into fluid;
    - Migration of oil into reservoir rock and
    - Secondary transformation of oil in the reservoir rock.
- **Raw material of petroleum formation:**

  Crude is thought to be originated from organic matter originally present in marine sediments. The probable sources are planktron, marine algae, sea grass, large marine animals. Some terrestrial and fresh water plants may have also taken part in petroleum formation. Absence of reasonable amounts of phosphorus in petroleum is an argument against the involvement of fish in the process.

- **Embedment of organic matter in source bed**

  The dead organic matter settles down in the bottom of shallow seas and lagoons and is facilitated by the presence of mineral particles that are transported by flowing water to places where the current is not very strong.

- **Process of formation of petroleum like substance**

i. The settled debris is attacked by anaerobic bacteria and most of the organic matter is destroyed and lost.

ii. Unsaturated fatty oils and fatty acids can be acted upon by bacteria instead and undergo polymerization into insoluble solids.

iii. These are buried under the steadily increasing cover of sediments, while anaerobic bacteria continue to act on them.

iv. As a result of compaction, water content diminishes from 70-80 % to about 10% or less.

v. As a result of continued bacterial decomposition under anaerobic condition, decarboxylation and other reduction processes take place and the composition of the organic matter becomes more and more petroleum like.

vi. Formation of oil from the consolidated organic material of the source bed needs a considerable degree of degradation. The presence of thermo-labile and optically active substances like porphyrines and some nitrogen and sulphur containing complexes in crudes rule out he involvement of high temperature, say, above 200^0C in the genesis of petroleum.

vii. The probable processes are therefore

(a) anaerobic bacterial action

(b) low temperature cracking in presence of clay and mineral catalysts

(c) irradiation by radioactive material associated with sedimentary rocks. But out of all these, low temperature catalytic cracking is believed to be the major process by which oil is produced from consolidated organic source material

Migration of oil

- With the increase in the overburden, the source rocks are subjected to compression and cause the liquids to migrate to the reservoir rocks.

- During migration, the composition of oil may change by filtration, solution, adsorption, etc. Both vertical and lateral migrations are possible. Oil reserves were built up by migration of oil from a number of source bed

viii. Secondary transformation of oil in the reservoir rock

After reaching the reservoir rock, oil may undergo secondary transformation by agencies like radioactivity, bacterial action and calatytic influence of rocks etc.

3.3.4.1 GEOLOGICAL TIMES OF PETROLEUM FORMATION

The petroleum occurring reservoir rocks have been found to belong to widely varying geological eras, namely Palaeozoic, Mesozoic, tertiary and quaternary. The bulk of oil fields are from Mesozoic (120 to 200 million years) and tertiary (Oligocene-miocene periods, 20-40 million years) eras. Unlike coal, it has not been possible to establish the precise rank or degree of maturity of crudes of different geological ages. It appears from general observation that crudes from older reservoir rocks are lighter and more simple in structure and yield larger distillates compared to younger crudes.

3.3.4.2 OIL TRAPS

After secondary migration in carrier beds, oil finally collects in a trap. The fundamental characteristic of a trap is an upward convex form of porous and permeable reservoir rock that is sealed above by a denser, relatively impermeable cap rock (*e.g.*, shale or evaporites). The trap may be of any shape, the critical factor being that it is a closed, inverted container. A rare exception is hydrodynamic trapping, in which high water saturation of low-permeability sediments reduces hydrocarbon permeability to near zero, resulting in a water block and an accumulation of petroleum down the structural dip of a sedimentary bed below the water in the sedimentary formation.

3.3.5 RESOURCES OF PETROLEUM

Resources of conventional oil have increased by some 400 billion barrels since 2005. Together with unconventional resources, current resources amount to around 6.5 trillion barrels.

- Technology development in improved and enhanced oil recovery is vital to meeting future demand. Improvements in the average recovery factor could substantially increase global oil reserves.
- Unconventional resources, such as oil sands, could add up to 2.4 trillion barrels, but technologies, CO_2 emissions and water requirements present significant challenges. Higher prices are needed to make production of unconventional oil competitive and environmentally sustainable.
- The transition from exploiting conventional to unconventional sources could result in significantly increased greenhouse-gas emissions. New technologies, such as carbon capture and storage, will be critical to mitigating environmental impacts.

3.3.5.1 PETROLEUM RESERVE IN INDIA

Table No: Crude oil (in Million Metric Tonnes) reserves in India

AREA	2005	2006	2007	2008	2009	2010
ONSHORE	**376**	**387**	**357**	**403**	**405**	**614**
OFFSHORE	**410**	**369**	**368**	**366**	**369**	**587**
TOTAL	**786**	**756**	**725**	**769**	**775**	**1201**

Source: ONGC, OIL and DGH

Table: Production of Crude Oil (In '000' Tonnes) in India

ITEM	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
ONSHORE					
Gujarat	6251	6212	6177	5944	5961
Assam/ Nagaland	4474	4400	4357	4673.4	4740
Arunachal Pradesh	104	109	102	102.4	131
Tamil Nadu	385	353	298	265	238
Andhra Pradesh	216	252	279	289	304
Rajasthan	--	--	--	--	447
TOTAL (a)	**11430**	**11326**	**11213**	**11274**	**11821**
Of which					
OIL	3234	3107	3100	3468	3572
ONGC	8095	8058	7921	7563	7515
JVC/Private	101	161	192	243	734
OFFSHORE					
ONGC	16309	17993	18020	17801	17341
JVC/ Private	4451	4669	4885	4431	4529
TOTAL (b)	**20760**	**22662**	**22905**	**22232**	**21870**
GRAND TOTAL (a+b)	**32190**	**33988**	**34118**	**33506**	**33691**

Source: ONGC, OIL and DGH

3.3.6 USES

Oil supplies about 40% of the nation's energy needs. The most common use of crude oil is:

- Production of gasoline (47%)
- Heating oil and diesel fuel (23%)

- Petrochemical feedstock (products derived from petroleum) for the manufacturing of chemicals, synthetic rubber, and plastics (18%)
- Jet fuel (10%)
- Propane (4%); and
- Asphalt (3%).

The total is over 100% because there is more than a 5% processing gain from refining.

Natural gas supplies about 22% of the nation's energy needs. End uses for natural gas (in 2005) included:

- Electric power generation (26.4%),
- Industrial use (30.3%),
- Residential use (21.6%),
- Commercial use (13.9%),
- Lease and plant fuel consumption (5%),
- Pipeline and distribution (2.6%), and
- Vehicle use (0.1%).

References

i. http://www.coalindia.in
ii. http://www.dgms.net.
iii. http://www.iea.org
iv. http://www.worldcoal.org
v. http://www.naturalgas.org, retrieved on 2011-02-06.
vi. Potential Gas Committee, *Potential Gas Committee reports unprecedented increase in magnitude of U.S. natural gas resource base*, 18 June 2009. Retrieved 2011-06-25.
vii. Kiner, Shirin and Aldis, Anne, ed (2004). *The Caspian: Politics, Energy and Security*. New York: Routledge.
viii. Bauer Georg, Bandy Mark Chance (tr.) and Bandy Jean A.(tr.) (in **(Latin)**). *De Natura Fossilium*. translated 1955.
ix. Hyne, Norman J. (2001). *Nontechnical Guide to Petroleum Geology, Exploration, Drilling, and Production*. PennWell Corporation.
x. Mabro, Robert; Organization of Petroleum Exporting Countries (2006). *Oil in the 21st century: issues, challenges and opportunities*. Oxford Press.
xi. Maugeri, Leonardo (2005). *The Age of Oil: What They Don't Want You to Know About the World's Most Controversial Resource*. Guilford, CT: Globe Pequot. p. 15.
xii. Speight, James G. (1999). *The Chemistry and Technology of Petroleum*. Marcel Dekker.

UNIT 4: ENVIRONMENT CONCERNS OF ENERGY EXTRACTION

UNIT STRUCTURE

1. INTRODUCTION

The development of modern civilization has been dependent on both the availability and the advancement of energy. Because of our dependence on energy sources, it is also important to understand the effects of energy use on the environment. All aspects of energy, the way it is produced, distributed and consumed can affect local, regional and global environments through land use and degradation, air pollution, the acidification of water and soils, and through global climate change via greenhouse gas emissions. All energy sources affect the environment so far there is no completely “clean” energy source. Energy is lost to the environment during any energy transformation, usually as heat. The topics of energy and the environment are obviously crucial to all of us. This is in view of the growing evidence of the problems becoming more severe with time, as our fossil fuels diminish and underdeveloped countries become more and more energy dependent. Most important environmental impacts caused by energy sources are global climate change and acid rain – both of which have the origin in the combustion of fossil fuels and lead to global or transboundary effects. Fortunately, the energy industry has become increasingly aware of the importance of environmental protection and is working to reduce its long-term impact.

1.1 IMPACT OF CONVENTIONAL FUEL USE ON ENVIRONMENT.

Harvesting, processing, and distributing conventional fossil fuels can create environmental concerns. The majority of our energy stems from fossil fuels such as coal, oil and natural gas; their burning is a large source of carbon dioxide emissions which contributes to the greenhouse effect. The combustion of fossil fuels produces greenhouse gases and other air pollutants as byproducts including nitrogen oxides, sulphur dioxide, volatile organic compounds and heavy metals. These emissions in the long run form sulfuric, carbonic and nitric acids which fall into earth as acid precipitation, impacting both natural areas and the built environment. Fossil fuels also contain radioactive materials, mainly uranium and thorium, which are released into the atmosphere during use.

Coal, a fossil fuel, is the largest source of energy for the generation of electricity worldwide, as well as one of the largest worldwide anthropogenic sources of carbon dioxide releases. In addition to deadly atmospheric pollution, coal burning produces hundreds of millions of tons of solid waste products annually, including fly ash, bottom ash, and flue-gas desulfurization sludge, that contain mercury, uranium, thorium arsenic, and other heavy metals, Acid mine drainage (AMD) etc. Now a days "Clean coal" technology is being developed to remove harmful materials or to minimize the impacts.

Oil accounts for a large percentage of the world's energy consumption but the problem associated with this dependence on oil is the extremely damaging effects that production, distribution, and use have on the environment. Oil waste dumping, production, pollution, and spills wreak havoc on the surrounding wildlife and habitat. These include acid drainage, the introduction of toxic metals including mercury into water, increased erosion, sulphur-gas emissions, and air pollution caused by the production of particulates during processing, transport, and support activities. The atmospheric emissions from oil shale processing and combustion include carbon dioxide, a greenhouse gas. Run-offs from petroleum processing and petrochemical plants dump tons of toxic wastes into nearby waters. Some petroleum industry operations have been responsible for water pollution through by-products of refining and oil spills. When burned, petroleum products emit carbon dioxide, carbon monoxide and other air toxins, all of which have a negative impact on the environment. Now great strides have been made to ensure that oil and gas producers make as little impact as possible on the natural environments in which they operate. These include drilling multiple wells from a single location to minimize damages to the surface, using environmentally sound chemicals to stimulate well production and restoring the surface as nearly as possible to pre-drilling conditions.

1.2 MAJOR CONCERNS OF ENERGY EXTRACTION: GREEN HOUSE EFFECT, GLOBAL WARMING, ACID RAIN, POLLUTION

Since the industrial revolution, humans have been adding huge quantities of greenhouse gases, especially carbon dioxide to the atmosphere, the most important single component of this greenhouse effect whose sources are power plants, automobiles, and industry. Combustion of fossil fuels contributes around 80 percent to total world-wide anthropogenic CO_2 emissions. Massive deforestation around the globe is releasing large amounts of CO_2 and decreasing the forests' ability to take CO_2 from the atmosphere. The second major greenhouse gas is methane which is a minor by-product of burning coal, venting of natural gas.

Different fossil fuels produce different amounts of CO_2 per unit of energy released. Coal is largely carbon, and so most of its combustion products are CO_2. Natural gas emits less CO_2 per unit of energy than coal. Oil falls somewhere between gas and coal in terms of CO_2 emissions, as it is made up of a mixture of hydrocarbons. The amount of CO_2 produced per unit of energy from coal, oil and gas is in the approximate proportion of 2:15:1. This is one of the reasons why there is a move towards greater use of natural gas instead of coal or oil in power stations, despite the much greater abundance of coal. Over the past century, increases in industry, transportation and electricity production have led to an increase of gas concentrations in the atmosphere faster than natural processes. The result is the human-caused warming of the globe. The evidence of consequences of global warming shows that global average temperature has increased by about 0.5 ^{0}C and sea level has risen by about 30 cm in the past century. The climatic zones are shifting and the past two decades have witnessed a stream of new heat and precipitation records. All these changes exemplify the environmental impact of global climate change.

Another side effect of fossil fuels combustion and resulting emissions of pollutants is acid deposition. In the process of burning fossil fuels, some gases, in particular sulphur dioxide (SO_2) and nitrogen oxides (NOx) are created. Although natural sources of sulphur oxides and nitrogen oxides do exist, more than 90% of the sulphur and 95% of the nitrogen emissions occurring in North America and Europe are of human origin. Once released into the atmosphere, they can be converted chemically into such secondary pollutants as nitric acid and sulphuric acid, both of which dissolve easily in water. The result is that any rain which follows is slightly acidic. The acidic water droplets can be carried long distances by prevailing winds, returning to Earth as acid rain, snow, or fog. This acid rain can cause damage to plant life, in some cases seriously affecting the growth of forests and can erode buildings and corrode metal objects. The highest emissions of sulphur come from sectors using the energy produced from the highest sulphur-content fuels, that is, solid fuels and high sulphur heavy fuel oil. These fuels range from hard coals to soft brown coals and lignites, which have high proportion of combustion waste and pollutants such as sulphur, heavy metals, moisture and ash content.

Beside greenhouse gases, SO_2 and NO_x emissions, emissions of particulate matter contribute to degradation of air quality. Fuel combustion and evaporative emissions from motor vehicles are the main sources of anthropogenic volatile organic compounds (VOCs). NOx emissions also contribute to the formation of tropospheric photochemical oxidants. Photochemical oxidants, especially ozone (O3), are among the most important trace gases in the atmosphere. Their distributions show signs of change due to increasing emissions of ozone precursors (nitrogen oxides, or VOCs, methane and carbon monoxide). Heavy metals like arsenic (As), cadmium (Cd), mercury (Hg), lead (Pb) and zinc (Zn) are also released during fuel combustion. Beside emissions of pollutants there are also some other impacts of fossil fuel combustion on local environment. Some microclimatic impacts like origination of fogs, less sunshine etc. are the results of large amounts of water vapour effluents from cooling towers of power plants.

1.3 IMPACT OF USE OF RENEWABLE ENERGY SOURCES

While fossil fuels will remain our largest source of energy for the foreseeable future, they are ultimately finite resources. With concern over domestic supply and reliance on foreign supplies, increasing costs and environmental impacts, there is an increasing push to utilize alternative fuel sources. In contrast to conventional energy sources, non conventional renewable energy technologies have been considered to be substantially safer by offering a solution to many environmental problems associated with conventional, particularly fossil fuel. Of course, in recent times the cumulative adverse impact by the use of renewable energy on the environment have been realized. All renewable energy technologies are not appropriate to all applications or locations. As with conventional energy production, there are environmental issues to be considered.

Biofuels: Biomass and Biodiesel

Biomass power, derived from the burning of living matter, raises more serious environmental issues than any other renewable resource except hydropower. Combustion of biomass and biomass-derived fuels produces air pollution; beyond this, there are concerns about the impacts of using land to grow energy crops. There is no single biomass technology, but rather a wide variety of production and conversion methods, each with different environmental impacts. The various environmental impact related to biomass energy are requirement of large land and water resources, enhanced soil erosion and water run off, nutrient removal and biotic losses by harvesting biomass energy crops, generation of solid waste, organic emission and air pollution. On first sight, biofuels look like an ideal energy solution. Since plants absorb carbon dioxide as they grow, crops could counteract the carbon dioxide released by transport sector. They are also renewable, and can be planted to replenish supplies. But it takes a tremendous amount of energy to grow crops, make fertilizers and pesticides and process plants into fuel. Also, fossil fuels provide much of the energy in biofuels production, so biofuels may not replace as much oil as they use. Biomass creates harmful emissions like carbon dioxide and sulfur when it is burnt, but causes less pollution than fossil fuels. When burnt, biodiesel creates less sulfur oxides, particulate matter, carbon monoxide and hydrocarbons when burned than traditional petroleum diesel. But biodiesel creates more nitrogen oxide than petroleum diesel.

Geothermal energy

Geothermal power plants have relatively little environmental impact as they burn no fuel to create electricity but they raise a common set of environmental issues. Air and water pollution are two leading concerns, along with the safe disposal of hazardous waste, land subsidence, but geothermal emissions are far smaller than those created by fossil fuel power plants. The major gases of concern are CO_2, H_2S, CH_4, NH_3. The method used to convert geothermal steam or hot water to electricity directly affects the amount of waste generated. Closed-loop systems are almost totally benign, since gases or fluids removed from the well are not exposed to the atmosphere and are usually injected back into the ground after the emission of their heat.

Hydropower

While hydropower does not cause water or air pollution, it does have an environmental impact as hydroelectric power plants may harm aquatic populations, change water temperature and normal course of water flow disturbing plants and animals. Hydropower plants can also cause low dissolved oxygen levels in the water, which is harmful to river habitats. Reservoirs may also lead to the creation of methane, a harmful greenhouse gas. The reservoirs created by such projects frequently inundate large areas of forest, farmland, and wildlife habitats. In addition, the dams can cause radical changes in river ecosystems both upstream and downstream.

Solar energy

The largest of renewable energy source solar energy produces no air or water pollution or greenhouse gases. Since solar power systems generate no air pollution during operation, the primary environmental, health, and safety issues involve how they are manufactured, installed, and ultimately disposed off. For example, the manufacturing of photovoltaic cells (PV) produces some toxic materials and chemicals. Energy is required to manufacture and install solar components and any fossil fuels used for this purpose will generate emissions. In particular, the manufacturing of photovoltaic cells often requires hazardous materials such as arsenic and cadmium. The large amount of land required for utility-scale solar power plants poses an additional problem, especially where wildlife protection is a concern. Solar-thermal plants also require cooling water, which may be costly or scarce in desert areas.

Nuclear Energy

Nuclear power plants produce no air pollution or carbon dioxide, but they do produce byproducts like nuclear waste and spent fuels. Most nuclear waste is low level (for example, disposable items that have come into contact with small amounts of radioactive dust), and special regulations are in place to prevent them from harming the environment. But some spent fuel is highly radioactive and must be stored in specially designed facilities. Nuclear energy provides nearly a fifth of the world's electricity without harmful by-products. Yet, concern over safe storage and disposal of radioactive waste, along with the potential for accidents, radiation contamination and exposure continues.

Wind energy

Wind is a one of the most clean energy sources. It produces no air or water pollution because no fuel is burnt to generate electricity. It is hard to imagine an energy source more benign to the environment than wind power; it produces no air or water pollution, involves no toxic or hazardous substances, and poses no threat to public safety. One serious obstacle the wind industry facing is public opposition reflecting concern over the visibility and noise of wind turbines, and their impacts on wilderness areas. Wind power development can also create serious land-use conflicts.

1.4 REMEDIAL MEASURES

Inevitably, the combustion of biomass produces air pollutants, including carbon monoxide, nitrogen oxides, and particulates such as soot and ash. The amount of pollution emitted per unit of energy generated varies widely by technology. Emissions from conventional biomass-fueled power plants are generally similar to emissions from coal-fired power plants, with the notable difference that biomass facilities produce very little sulfur dioxide or toxic metals (cadmium, mercury, and others). The most serious problem is their particulate emissions.

Using biomass-derived methanol and ethanol as vehicle fuels in place of conventional gasoline, could substantially reduce some types of pollution from automobiles. Both methanol and ethanol evaporate more slowly than gasoline, thus helping to reduce evaporative emissions of volatile organic compounds, which react with heat and sunlight to generate ground-level ozone, a secondary pollutant. Facilities that burn raw municipal waste present a unique pollution-control problem. This waste often contains toxic metals, chlorinated compounds and plastics, which generate harmful emissions. Since this problem is much less severe in facilities, burning refuse-derived fuel (RDF)-pelletized or shredded paper and other waste with most inorganic material removed-most waste-to-energy plants keep some promising scope.

Moreover, energy crops could be used to stabilize cropland or rangeland prone to erosion and flooding. Energy farms may present a perfect opportunity to promote low-impact sustainable agriculture, or, as it is sometimes called, organic farming. A relatively new federal effort for food crops emphasizes crop rotation, integrated pest management, and sound soil husbandry to increase profits and improve long-term productivity. These methods could be adapted to energy farming. Increasing the amount of forest wood harvested for energy in an unsustainable fashion can be checked by tighter government controls on forestry practices and by following the principles of "excellent" forestry that can make possible to extract energy from forests indefinitely.

Hydrogen is the most abundant element in the universe and could be an important factor in our energy future since it can both carry and store energy. A significant challenge in the availability of hydrogen energy is the large amount of energy (fossil, nuclear, hydro) that will be needed to generate the hydrogen.

A major benefit of substituting biomass for fossil fuels is that, if done in a sustainable fashion, it would greatly reduce emissions of greenhouses gases. The amount of carbon dioxide released when biomass is burnt is very nearly the same as the amount required to replenish the plants grown to produce the biomass. Thus, in a sustainable fuel cycle, there would be no net emissions of carbon dioxide, although some fossil-fuel inputs may be required for planting, harvesting, transporting, and processing biomass. But if efficient cultivation and conversion processes are used, the resulting emissions would be as small as around 20 percent of the emissions created by fossil fuels alone. The remedial measures can be (1) to do elaborative environmental planning based on preventive adverse impact assessment before any renewable energy source is in actually installed, (2) selection of rational site selection for a renewable energy project so as to ensure maximum compatibility with the environment and minimum adverse impact, (3) generation of awareness towards the niches of various renewable energy systems, (4) forecasting of long term environmental impact of those renewable resources before those are put into use.

Primary pollutant and secondary pollutant

Primary pollutants cause pollution by their direct release into the environment. The substance released may already be present in some quantities, but it is considered a primary pollutant if the additional release brings the total quantity of the substance to pollution levels. For example, carbon dioxide is already naturally present in the atmosphere, but it becomes toxic when additional releases cause it to rise above its natural concentrations. A primary pollutant can be generated by many sources: pesticide dust sprayed in agricultural areas, emissions from car and industrial exhausts, dust from mining operations, smoke, soot, dust etc released by the burning of fuel or other industrial or agricultural processes, or natural sources like ash, grit and dust from volcanic explosions, gaseous pollution that originates from marshes or other decomposing matter. In contrast, secondary pollutants are not emitted as such, but are formed within the atmosphere itself. When two or more primary pollutants react in the atmosphere and cause additional atmospheric pollution, the result is called secondary pollution. The most commonly considered secondary pollutant is ozone, formed as a result of photolysis of O_2 in the stratosphere and NO_2 in the troposphere.

2. POLLUTION DUE TO ENERGY USE : SOURCES, EFFECTS

Air pollution: sources, effects

Air pollution is the presence of substances in air in sufficient concentration and for sufficient time, threatend to be injurious to human, plant or animal life, property, or which reasonably interferes with the comfortable enjoyment of life and property. Air pollutants may exist in gaseous and particulate form. Former includes substances such as sulfur dioxide, ozone etc. Particulate air pollutants are highly diverse in chemical composition and size including both solid particles and liquid droplets.

Table 1: **Common air pollutants and their sources**.

pollutants	sources
Suspended Particulate Matter (SPM)	Automobile, power plants, boilers, Industries requiring crushing and grinding such as quarry and cement, pollen dispersal, wind erosion
Sulphur dioxide	Fossil fuel combustion, Power plants, boilers, sulphuric acid manufacture, ore refining, petroleum refining. Lead Ore refining, battery manufacturing, automobiles, forest fire, volcanic eruption
Oxides of nitrogen	Automobiles, power plants, nitric NO, NO_2 (NO_X) acid manufacture,
Ozone, PAN	Automobiles, jet airplane
Carbon monoxide	Petrol vehicles and other automobiles
hydrocarbons	Road traffic, use of solvents, petroleum refinery

Effects

1. Health effects: Irritation of eyes, nose, mouth and throat Respiratory symptoms such as coughing and wheezing, Increased respiratory disease such as bronchitis, Reduced energy levels, Disruption of endocrine, reproductive and immune systems, Neurobehavioral disorders, Cardiovascular problems, Premature death
2. Excessive ultraviolet radiation coming from the sun through the ozone layer in the upper atmosphere which is eroded largely by the emission of chlorofluorocarbons (CFCs) from refrigerators, air conditioners, and aerosols threatens life on earth.
3. The dramatic and debilitating effects of severe air pollution episodes in cities throughout the world, is the formation of smog.
4. Formation of acid rain that damages life environment.

Water pollution: sources, effects

It involves the release of toxic substances, pathogenic germs, substances that require much oxygen to decompose, that becomes deposited at the bottom and their accumulations interfere with the condition of aquatic ecosystems. For example, the eutrophication: lack of oxygen in a water body caused by excessive algae growths because of enrichment of pollutants.

Changes in the photosynthetic action in general, increases in the biomass of microorganisms, phytoplankton and zooplankton are the characteristic of the eutrophication .

Sources

- Petroleum products
- Synthetic agricultural chemicals
- Heavy metals
- Hzardous wastes
- Sediment
- Infectious organisms
- Air pollution
- Thermal pollution

Effects

- Health hazards: Waterborne diseases caused by polluted drinking water: Typhoid, Amoebiasis, Giardiasis, Ascariasis
- Terrestrial and aquatic plants may absorb pollutants from water (as their main nutrient source) and pass them up the food chain to consumer animals and humans
- Nutrient pollution (nitrogen, phosphates etc) causes overgrowth of toxic algae eaten by other aquatic animals, and may cause death
- Oil pollution negatively affect development of marine organisms, increase susceptibility to disease and affect reproductive processes; can also cause gastrointestinal irritation, liver and kidney damage, and damage to the nervous system
- Toxic elements in polluted water can cause behavioural change, retarded growth and development, reduced reproduction even death
- Persistent organic pollutants (POPs) may cause declines, deformities and death of aquatic life.

Soil pollution: sources, effects

Soil pollution mainly is a result of penetration of harmful pesticides and insecticides, which on one hand serve whatever their main purpose is, but on the other hand bring about deterioration in the soil quality, thus making it contaminated and unfit for use later.

Sources

- Industrial wastes such as harmful gases and chemicals, agricultural pesticides, fertilizers and insecticides.
- Ignorance towards soil management and related systems.
- Percolation of contaminated water into the soil
- Acid rains.
- Fuel leakages from automobiles, that gets washed away due to rain and seep into the nearby soil.
- Unhealthy waste management techniques, which are characterized by release of sewage into the large dumping grounds and nearby streams or rivers.
- Mining and quarrying practices.
- Demolitions and constructions works.

Effects

The effects of pollution on soil are quite alarming and can cause huge disturbances in the ecological balance. Some of the most serious soil pollution effects are:

- Decrease in soil fertility; consequently decrease in the soil yield.
- Loss of soil and natural nutrients present in it making plants unable to thrive in such soil, which would further result in soil erosion.
- Disturbance in the balance of flora and fauna residing in the soil.
- Increase in salinity of the soil, which therefore makes it unfit for vegetation, thus making it useless and barren.
- Contamination of crops grown in polluted soil brings up problems with food security
- Creation of toxic dust.
- Soil pollutants would bring in alteration in the soil structure, which would lead to death of many essential organisms in it disrupting the whole food webs.

Noise pollution: sources, effects

Noise is termed as a pollution problem when affects human health and can contribute to a general deterioration of environmental quality. The term “noise pollution” is used to signify the hazard of sounds which are consequence of modern day development, leading to health hazards of different type.

Sources

There are several sources of noise pollution that contribute to both indoor and outdoor noise pollution.

- Road traffic noise
- Air traffic
- Rail traffic
- Neighborhood and domestic noise
- Industrial noises
- Constructional works.

Effects

Continuous exposure to high decibel noise can result in some adverse effects on health like-

- Acoustic trauma to the ears with the sound of an intensity of 85 dB or more without respite.
- Physiological hazards: hearing loss, hypertension, disturbance in sleep patterns etc.,
- Psychological hazards: annoyance, aggression , stress. irritability, anxiety
- Interference with the communication of the animals, thus resulting in disturbance in their various life processes.
- The most direct harmful effect of excessive noise is physical damage to the ear and the temporary or permanent hearing loss often called a 'temporary threshold shift' (TIS). Permanent loss, usually called 'noise-induced permanent threshold shift' (NIPTS) represents a loss of hearing ability from which there is no recovery.
- Excessive sound levels can cause harmful effects on the circulatory system by raising blood pressure and altering pulse rates.

- As noise interferes with normal auditory communication, it may mask auditory warning signals and hence increases the rate of accidents especially in industries.
- It can also lead to lowered work efficiency and productivity

Thermal Pollution: sources, effects

Thermal pollution is the degradation of *water quality* by any process that changes ambient water *temperature.*

Source

- Use of water as a coolant by power plants creating electricity from fossil fuel
- Water as a cooling agent in industrial facilities
- Deforestation of the shoreline
- Urban runoff--storm water discharged to surface waters from roads and parking lots.

Effects

- Elevated temperature typically decreases the level of dissolved oxygen in water. This can harm aquatic organism.
- Less amount of oxygen decreases the rate of decomposition of organic matter. Green algae are replaced by less desirable blue green algae.
- Some fish species will avoid stream segments or coastal areas adjacent to a thermal discharge. Biodiversity can be decreased as a result.
- Thermal pollution may also increase the metabolic rate of aquatic animals, as enzyme activity, resulting in these organisms consuming more food in a shorter time,as a result food chains of the old and new environments may be compromised
- High temperature limits oxygen dispersion into deeper waters, contributing to anaerobic conditions. This can lead to increased bacteria levels when there is ample food supply.
- Many aquatic species fail to reproduce at elevated temperatures.
- Primary producers are affected by warm water because higher water temperature increases plant growth rates, resulting in a shorter lifespan and species overpopulation. This can cause an algae bloom which reduces oxygen levels.
- Temperature changes can cause significant changes in organism metabolism and other adverse cellular biology effects that can adversely affect mortality and reproduction.

3. POLLUTION CONTROL METHODS

Pollution control methods can be broadly of two types input control and output control. Input control involves preventing a problem before it occurs, or at least limiting the effects the process will produce. Five major input control methods exist- restrict population growth, use less energy, improve energy efficiency, reduce waste, and move to non-polluting renewable forms of energy production. Also, automobile-produced pollution can be decreased with highly beneficial results. On the other hand output control, seeks to fix the problems caused by air pollution. This usually means cleaning up an area that has been damaged by pollution. Input controls are usually more effective than output controls.

Air pollution control.

Air pollution control takes into account the source, the type of pollution, meteorological condition including wind speed and geographical terrain around the place. Pollution control methods include collection, conversion, minimization and dispersal protocols. Control from point sources (industrial installations)is relatively easy compared to random and mobile sources(transport, agricultural, domestic operation etc.)

General and routinely employed methods are precipitation, absorption, adsorption, chemical conversion and thermal oxidation.

Precipitation methods: Gravitational settling, centrifugal separation, fabric filtration, wet collection, electric precipitation and chemical methods of precipitation are used.

Absorption methods: It is carried out by selective wet scrubbers or packed towers for soluble pollutant gases. Water is the most commonly used solvent in these absorption systems.

Adsorption methods: Contaminant gases are adsorbed by porous solid material and released later by elution or thermal treatment. Common adsorbent materials are activated carbon, alumina, silica gel and diatomaceous earth.

Chemical conversion: These are often employed for collection and control of gaseous pollutant.

Thermal oxidation method: Thermal oxidation (combustion, incineration and flaring) is a method for converting combustible gaseous compounds to CO_2 and H_2O, halogens to HX and S to SO_2.

Water pollution control

- Incorporation of erosion control and sediment control system.
- Installation of a pre-treatment system to remove the toxic components from the effluents generated in industries.

- Effective control of urban run off by Runoff mitigation systems including infiltration basins, bioretention systems, constructed wetlands, retention basins and similar devices
- Strict legal enforcement in the discharge of industrial effluent.
- Protection of ground water from contamination by controlling leachate from waste dumping.
- Controlled use of chemical fertilizer in agricultural systems, swithing to biofertilizer.

Soil pollution control

- The soil binding grass must be planted and the large trees must be placed along the banks.
- Limited use of fertilizers and pesticides, enhanced use of biofertilizer
- Industrial wastes can be treated physically, chemically and biologically until they are less hazardous. before being disposed.
- Control of land loss and soil erosion can be attempted through restoring forest and grass cover to check wastelands, soil erosion and floods. Crop rotation or mixed cropping can improve the fertility of the land.

Noise Control

There are four fundamental ways in which noise can be controlled: reduce noise at the source, block the path of noise, increase the path-length, and protect the recipient. In general, the best control method is to reduce noise levels at the source. Noise levels at construction sites can be controlled using proper construction planning and scheduling techniques. Locating noisy air-compressors and other equipment away from the site boundary, along with creating temporary barriers to physically block the noise, can contribute to reducing noise pollution. Well maintained vehicles can add to reduced traffic noise levels. Traffic volume and speed also have significant effects on the overall sound. For example, doubling the speed increases

Thermal pollution control

- Cooling ponds, man-made bodies of water designed for cooling by evaporation, convection, and radiation
- Cooling towers, which transfer waste heat to the atmosphere through evaporation and/or heat transfer
- Cogeneration, a process where waste heat is recycled for domestic and/or industrial heating purposes.

- Storm water management facilities that absorb runoff or direct it into groundwater, such as bioretention systems and infiltration basins.

4. LEGAL PROVISION FOR ENVIRONMENT POLLUTION PREVENTION

There were provisions existing in various enactments to tackle environmental pollution under Indian constitution. Act, Rule etc. have provisions for regulation and legal action for some specific environmental issues. However, with our country's emerging environmental scenario with industrialization in the post-independence era, these were found either inadequate or being not effectively applicable to check the degradation of our environment. Same situation prevails in many other countries as a fall-out of Stockholm Conference on Human Environment in June, 1972. It was considered appropriate to have uniform laws all over the country for broad environmental problems endangering the health and safety of people as well as of flora and fauna.

The Water (Prevention and Control of Pollution) Act, 1974, is the first enactment by the Parliament in this direction. This is also the first specific and comprehensive legislation institutionalizing simultaneously the regulatory agencies for controlling water pollution. This is an act to provide for the prevention and control of water pollution and maintaining and restoring of wholesomeness of water, for the establishment, with a view to carrying out the purposes aforesaid, of boards for the prevention and control of water pollution, for conferring on and assigning to such Boards powers and functions relating thereto and for matters connected therewith. The Pollution Control Boards at the Centre and in the States came into being in terms of this Act.

Thereafter, The **Air (Prevention and Control of Pollution)** Act was likewise enacted in the year 1981 for the purpose of providing the prevention, control and abatement of air pollution and the task of implementation of this legislation was also entrusted to the same regulatory agencies created under the Water (Prevention and Control of Pollution) Act, 1974.

As the Water (Prevention and Control of Pollution) Act and the Air (Prevention and Control of Pollution) Act were designed to deal with only water and air pollution problems, it was in the year 1986 that the Parliament enacted a comprehensive or umbrella legislation for environment in its entirety. This is the **Environment (Protection) Act, 1986**. The responsibility for implementation of provisions of the Environment (Protection) Act has to a large extent been entrusted to the same regulatory agencies created under the Water (Prevention and Control of Pollution) Act, 1974. Other agencies besides the Central and State governments are also entrusted with the responsibility of implementing specific provisions of this Act and the Rules made there under depending on their operational requirements. Over the years, several amendments have also been made in the various existing statutes to meet the requirements of the unfolding environmental issues. Relevance of some recent developments like E/A and other may be brought in.

5. CONCLUSION

Between increasing costs and concern over the environmental effects related to fossil fuel use, and controversy over the use of nuclear power, research and development in the area of renewable sources of energy continues to flourish. These sources wind, solar, geothermal, and water have been used in one form or another for many centuries, but require additional advancement before they can become cost-competitive with conventional energy sources. As human consumption of energy continues to increase, further research and development will be necessary to produce alternative and/or renewable sources of energy that are readily available, affordable, and less harmful to the environment than conventional fossil fuels. While our dependence on energy is not likely to decrease, it will be important to foster new innovations in energy technologies with a larger focus on energy efficiency and conservation.

REFERENCES:

1. Emil Bedi,Cancee and Hakan Falk, *Environmental effects of energy use*, , "*Energy Saving Now*".
2. *Pollution causes, effects and control, Roy M.Harrison.*
3. *Renewable energy resources, basic principles and applications,G.N. Tiwari, M.K Ghosal.*
4. *www.cpcb.nic.in*
5. *www.envfor.nic.in*
6. *http://www.rrcap.unep.org/male/manual/national/02chapter2.pdf*
7. *Michael Brower, Cool Energy: Renewable Solutions to Environmental Problems*, (MIT Press, 1992), 220 pp
8. http://depssa.ignou.ac.in/wiki/images/0/0b/Effects_of_Pollution.pdf
9. http://library.thinkquest.org/26026/Environmental_Problems/water_pollution__effects.html
10. http://nsdl.niscair.res.in/bitstream/123456789/990/1/Soil_Pollution.pdf

UNIT-5: ENERGY USE & CLIMATE CHANGE

UNIT STRUCTURE

5.1. GLOBAL WARMING

5.1.1. INTRODUCTION

The world is facing ecological problems like increasing environmental degradation, energy crisis, soil erosion and consequent food security and so on. An outcome of the atmospheric pollution is warming of the earth's environment. Warming of the earth atmosphere is a serious problem and in twenty-first century, this may be a problem of global concern.

There is a clear indication that the temperature of the earth has increased slightly during the past 50 years. This increase in temperature of atmosphere is very dangerous for living organisms. The graph depicts global temperature anomalies between 1800 and 2006 using data from NASA.

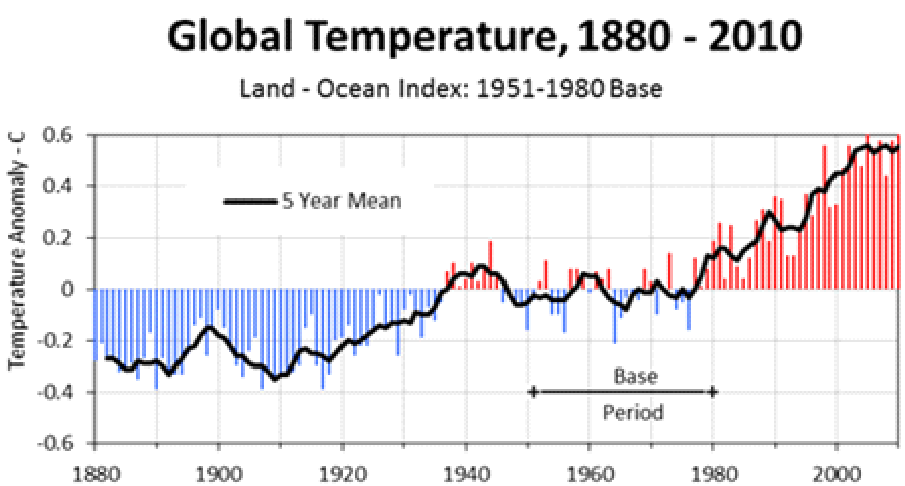


Fig 5.1: Average increase in temperature recorded in different years

(Source: Goddard Institute for Space Studies (GISS) and Climate Research Unit (CRU), prepared by ProcessTrends.com, updated by globalissues.org)

Troposphere, the lowermost layer of the atmosphere, traps heat by a natural process due to the presence of certain gases. Infra-red radiation coming to earth from the sun are of short wavelength but the infra-red rays reflected from the earth and its various objects are of long wave lengths. The infra-red radiation reflected from the earth cannot escape out from the carbon dioxide layer present in the atmosphere. CO_2 and some other gases like methane, Nitrogen oxides and chlorofluorocarbon (CFCs) have the ability to absorb infra-red radiation reflected from the earth surface. Therefore, the blanket of these gases in the atmosphere traps all the infra-red rays in the atmosphere and these trapped infra-red rays produce heat on the earth surface. The heating up of earth's atmosphere due to trapped infrared rays reflected from the earth surface by atmospheric gases is called ***Green- House Effect*** which causes ***Global Warming*** and the gases responsible for raising the temperature of earth and its atmosphere are referred to as ***greenhouse gases***. The important green house gases and their percent ratios are as follows: [1]

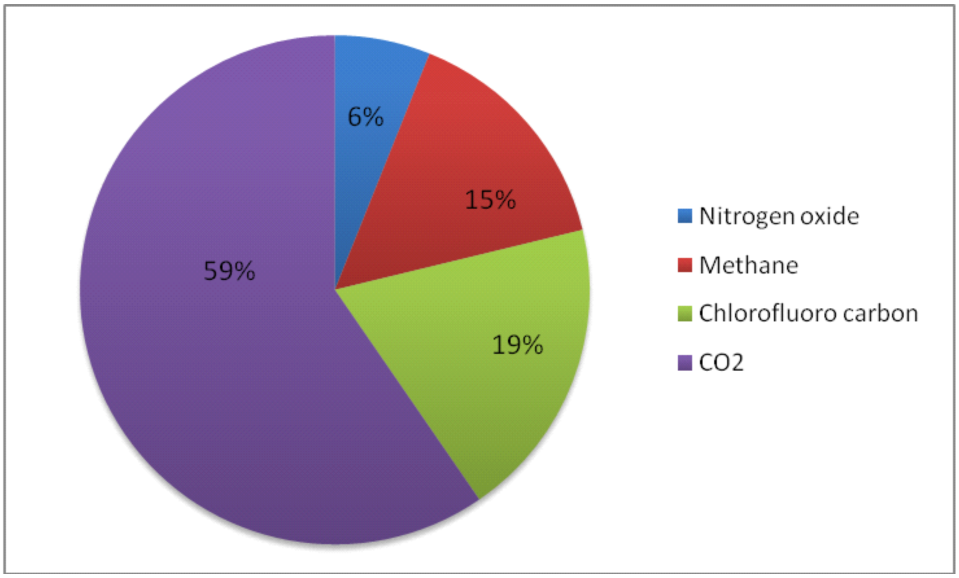


Fig 5.2: Green house gases and their ratio (%)

The rise in temperature of earth's atmosphere caused due to green house effect depends on the amount of CO_2 present in the atmosphere. At normal CO_2 concentration (0.03%) in the atmosphere, the surface temperature of the earth remains constant due to energy balance of the sun rays which strike on the earth, heat it and then radiate back into the space. This is called energy budget. But when there is increase in CO_2 concentration in the atmosphere, the thick layer of CO_2 prevents the heat from being radiated out into space. This layer of CO_2 thus functions as a glass panel of green house or glass window of a motor car which allows the sunlight to filter through it but prevents heat from being radiated back into the outer space. Thus most of the heat energy absorbed by CO_2 layer of the atmosphere warms up the air in the troposphere.

Carbon dioxide gas is confined only to lower level of atmosphere (troposphere). The main sources through which the CO_2 is released into the atmosphere are as follows:

- Burning of fossil fuels;
- Decay of dead organisms;
- Automobile exhaust;
- Thermal power plants;
- Cultivation of land and;

- Forest fire

In the recent years, the past average volume of CO_2 in the atmosphere has increased from 316.8 ppm in 1960 to 366.7 ppm in 2000 (Table 5.1) and in the beginning of 21st century it may reach to about 400 ppm. According to an estimate, by the year 2040, the concentration of CO_2 may reach upto 500 ppm [1].

Table 5.1: CO_2 concentration and average temperature of the earth

Year	CO_2 concentration in atmosphere (ppm)	Average temperature (^{0}C)
1950	_	13.84
1960	316.8	13.96
1970	325.6	14.02
1980	338.5	14.18
1990	354.0	14.40
2000	366.7	16.60

5.1.2. CAUSES OF GLOBAL WARMING

The issue of global warming is most often blamed on human beings' ecologically irresponsible practices and technologies. In fact, global warming is quite a complex phenomena brought about not only by human being but also by nature itself.

5.1.2.1. NATURAL CAUSES OF GLOBAL WARMING

i. Among the most common and most significant contributors to global warming is deforestation caused by forest fires. Fires are natural occurrences in many forests as it is nature's way to clear up old growth to encourage new ones. The fires also cause much carbon-filled smoke to rise from the forests to the atmosphere. Both results have dramatic effects on the rate at which global warming is currently occurring.

ii. Oceans are also significant contributors to global warming as it naturally contains much polluting carbon due to the ecosystems they support.

iii. Both the North and South Poles also contribute a lot to global warming. It is in those areas where permafrost soil contains large amounts of carbon that have frozen over time. Disturbances to these areas cause the permafrost soil to melt and release the pollutants into the atmosphere.

5.1.2.2. MAN- MADE CAUSES OF GLOBAL WARMING

Pollution is one of the biggest man-made problem which helps in global warming. Burning fossil fuels is one thing that causes pollution. When fossil fuels are burned they give off green house gas like CO_2. Also mining of coal and oil allows methane to escape. Though there are numerous causes for the global warming, the following two factors are considered to be very significant:

- *Industrialization*
- *Deforestation*

During the last two decades there has been tremendous growth of industries in the world. These industries release toxic gases, chemicals and effluents in huge quantities in to the environment. The toxic gases and effluents released into the environment causes pollution of air, water and soil. Deforestation is taking place at an alarming rate. After 1950, about 4.2 million hectre forest were destroyed and since 1980 every year about 1.5 million hectre forest area is either converted into agricultural land or used for some other purposes. Due to these two aforesaid reasons, the concentrations of CO_2 gas is increasing in the atmosphere.

5.1.3. IMPACTS OF GLOBAL WARMING

There are many predicted effects for the environment and for human life due to global warming. The main effect centres around an increase in the global average temperature. It has been confirmed by at least 20 scientific societies and academies of science, as well as all the national academies of science of the G8 states, that the Earth's global average air temperature near its surface rose by 0.56-0.92 C (0.98-1.62 F) degrees during the last 100 years. The Intergovernmental Panel on Climate Change (IPCC) concludes that this increase is very likely due to the "observed increase in anthropogenic greenhouse gas concentrations, which leads to the warming of the surface and lower atmosphere by increasing the greenhouse effect" [2].

Other effects of global warming include a rising sea level and changes in the amount and pattern of precipitation. In addition, there may be more frequent and intense weather events, such as more intense hurricanes, tornados, tsunamis, thunderstorms, blizzards, etc., though it is difficult to connect specific events to global warming. Global warming is also causing changes in agricultural yields, glacier retreat, reduced summer stream flows, species extinctions, and increases in the ranges of disease vectors [3]. The increased volumes of carbon dioxide and other greenhouse gases released by the burning of fossil fuels, land clearing, agriculture, and other human activities are the major reasons why global warming has been occurring and increasing over the last 50 years.

Effects of global warming are expected to cause more changes as it becomes more pronounced. Some global changes published by the United Nations Environment Programme in November, 2003 are: [1]

5.1.3.1 The polar regions will warm faster

Observed changes:

1. Arctic air temperatures increased by about 5°C in the 20th century – ten times faster than the global-mean surface temperature – while Arctic sea-surface temperatures rose by 1°C over the past 20 years.
2. In the Northern Hemisphere, spring and summer sea-ice cover decreased by about 10 to 15% from the 1950s to the year 2000; sea-ice extent in the Nordic sea has shrunk by 30% over the last 130 years.
3. Arctic sea-ice thickness declined by about 40% during late summer and early autumn in the last three decades of the 20th century.

4. Precipitation has increased over the Antarctic; the Antarctic Peninsula has experienced a marked warming trend over the past 50 years, while the rest of the continent also seems to have warmed.

5. Both the Arctic and the Antarctic are expected to continue warming. More sea ice will disappear; in the Arctic, this will allow ships to move safely through wide expanses of ocean formerly blocked by ice.

6. Most of the Antarctic will warm more slowly, with the largest changes likely to occur later in the century.

5.1.3.2 NEW RAINFALL PATTERNS WILL THREATEN WATER SUPPLIES

Observed changes:

- Precipitation over many mid- to high latitude land areas in the Northern Hemisphere has become more and more intense.
- Rainfall has generally declined in the tropics and subtropics of both hemispheres; when rain does fall, it is frequently so heavy that it causes erosion and flooding.
- Desertification has been exacerbated by lower average annual rainfall, runoff and soil moisture, especially in southern, northern and western Africa.
- Increased summer drying and the associated risk of drought have been observed in a few continental areas, including Central Asia and the Sahel.
- Some observations of tropical cyclones show an increase in both mean precipitation and in extremes.

5.1.3.3 WILDLIFE AND ECOSYSTEM WILL FACE ADDITIONAL STRESS

Observed changes:

- Some bird species in Europe, North America, and Latin America are breeding earlier in the season; in Europe, egg-laying has advanced over the last 23 years; in the UK, 20 of 65 species, including long-distant migrants, advanced their egg-laying dates by an average of eight days between 1971 and 1995.
- Cold and cool-water fish are losing suitable habitat; warm-water fish are expanding their ranges in both the northern and southern hemispheres.
- Remarkable species such as the tiny golden frog living in Costa Rica's misty forests are becoming extinct because their habitat has become drier.

5.1.3.4 THE SEA LEVEL WILL RISE AS OCEAN WATERS WARM

Observed changes:

6. The global mean sea level has risen by 10 - 20 cm during the 20th century – ten times faster than the rate for the previous three thousand years.
7. More water is evaporating from the sea surface; this has likely resulted in total atmospheric water vapour increasing by several percent per decade over many regions of the Northern Hemisphere.
8. Seventy per cent of sandy shorelines have retreated over the past 100 years; 20 - 30 percent is stable, while less than 10 percent are advancing.

5.1.4. PEOPLE, SOCIETY AND GLOBAL WARMING

New environmental conditions could affect food security:

The effects of global warming on agriculture will vary widely both from region to region and from place to place. Changes in local and regional temperatures, precipitation, soil moisture, sunshine and cloudiness, and extreme events such as storms and hail will all have an influence. Other important variables will include the species and cultivar (variety) being farmed, soil properties, pests, pathogens and air quality [4].

In the tropics, many crops are already near their maximum temperature tolerance and farmers are often unable to irrigate because water supplies are inadequate. Where dry land agriculture relies solely on rain – as in sub-Saharan Africa – yields would decrease generally with even minimal increases in temperature. More extremes and a shift in precipitation zones could worsen food security in Africa. While climate change could be linked to local or regional food shortages, the world as a whole would still require to grow enough foodcrops to satisfy demand if global temperatures rise by less than 2.5^0C.

Environmental changes will harm human health:

The World Health Organization (WHO) defines health as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”. Global climate change will have a wide range of affects on human health. New patterns of heat waves and cold snaps, floods and droughts, and local pollution and allergens would affect health directly. Indirect effects will result from changes to ecological and social systems. Such impacts will include changes in infectious diseases, freshwater supplies, local food production, population movements and economic activities.

With some 790 million people currently undernourished, changes in food supply resulting from climate change could affect the nutrition and health of the poor in some regions. Isolated areas with poor access to markets will be particularly vulnerable to local problems with the food supply. Undernourishment is a fundamental cause of stunted physical and intellectual development in children, low productivity in adults and increased susceptibility to infectious diseases. Climate change would exacerbate these conditions in the developing world, particularly in the tropics.

5.1.5. CHECK ON GLOBAL WARMING

Global warming can be checked by reducing the concentration of CO_2, CH_4, N_2O and CFCs in the atmosphere by adopting following measures:

- Plantation of trees at large scale
- Increasing diffusing capacity of oceans for CO_2.

Global warming is something that we all have to take part in learning how to prevent. We all play a part in contributing to global warming and the only way to help prevent the devastating affects is to work together. Each of the governments throughout the world are striving to develop a prevention plan that can help reduce the amount of emissions they are creating in the atmosphere and enhance what they are doing to contribute to the solution instead of the problem. Today's international debate on climate change is focussed on the challenge of reducing greenhouse gas emissions. To gain a better understanding of how global warming will affect human and natural systems and how we can minimize the negative consequences, the IPCC will continue assessing key findings and uncertainties in all areas of climate change research. Its Fourth Assessment Report, released in 2007, will highlight the improved understanding of how the climate system works and of how to adapt to climate change and build sustainable economies.

The IPCC's new assessment will also address growing concerns over humanity's access to freshwater supplies and focus on how climate impacts and adaptation strategies can interact with biodiversity loss, desertification, ozone depletion and other harmful trends. This more integrated approach will give decision-makers more useful, policy-relevant information on how to adapt to future climate change and achieve other internationally agreed goals on environment and development.

United Nations Conference on Environment and Development (UNCED) or Earth Summit at Rio de Janeiro was held from 3-14 June, 1992 in which more than hundred countries participated. In the Earth Summit, Global Warming was one of the important topics. In the Earth Summit, USA and other developed countries including EEC signed convention on climate change, but they refused to make a specific time bound commitments to bring down the levels of emission of CO_2 and other green house gases.

The second Earth Summit was organised in 2002 by UNCED in Johannesburg in which 110 countries participated. The main theme of the summit was sustainable development. In the protocol of the summit, it was reiterated that the activities responsible for global warming should be checked and the use of CFCs should be completely banned by the end of 2010.

Climate change affects the entire globe. Developed and developing countries are working together to find solutions to climate change. In June 1992, the United Nations Framework Convention on Climate Change (UNFCC) was signed by 154 countries that agreed to stabilize the amount of greenhouse gases in the atmosphere at levels that won't cause harm. In December 1997, in Kyoto, Japan, Canada and 160 industrialized nations committed to reduce their greenhouse gas emissions, as part of an international agreement on climate change called the Kyoto Protocol.

Conclusion

Our climate may already be changing because of the existing build up of greenhouse gases in the atmosphere, and we must be prepared to adapt to those changes. While action now to reduce emissions is critical, the existing build-up of Green House Gas (GHG) concentrations means that some climate change in the coming decades is inevitable and planning must start now on adapting our economy and society to these changes. Adaptation involves taking action to minimize the negative impacts of climate change and taking advantage of new opportunities that may arise. The types of adaptation measures adopted will depend on the impact of climate change on particular regions and economic sectors. Increasing our capacity to adapt reduces our vulnerability to the effects of climate change. However, we must start planning our adaptive responses now; by doing so, we may help to lessen some of the environmental, economic and social costs of climate change.

5.2 GREEN HOUSE GAS EMISSION, IMPACTS AND MITIGATION

5.2.1 INTRODUCTION

Gases that trap heat in the atmosphere are often called green house gases. Although these gases occur in only trace amounts, they block significant amounts of heat from escaping out into space, thus keeping the Earth warm enough for us to survive. The increasing concentration of greenhouse gases in the atmosphere has become a serious environmental concern as the emissions of GHGs can intensify climate change. The primary greenhouse gases in the Earth's atmosphere are nitrous oxide, methane, chlorofluorocarbons (CFCs), carbon dioxide, water vapor and ozone.

5.2.2 EMISSION OF GREENHOUSE GASES

Since the beginning of the Industrial revolution, the burning of fossil fuels has contributed to the increase in carbon dioxide in the atmosphere from 280 ppm to 390 ppm, despite the uptake of a large portion of the emissions through various natural "sinks" involved in the carbon cycle. It is emitted naturally through the carbon cycle and through human activities like the burning of fossil fuels. Carbon dioxide emissions come from combustion of carbonaceous fuels such as coal, oil, and natural gas. To put U.S. emissions in a global perspective, the United States produced about 20% of the worldwide energy-related carbon emissions in 2006, which totalled 29.02 billion metric tons. Although continued increases in carbon emissions are expected for the United States and other industrialized countries, much more rapid increases are projected for the developing countries of Asia, the Middle East, Africa, and Central and South America. As a result, global carbon emissions from energy use are expected to increase at an average annual rate of 1.4% from 2006 through 2030, reaching 40.18 billion metric tons, to which the United States would contribute about 15.4%. Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills. Nitrous oxide (N_2O) is a potent greenhouse gas with a global warming potential of approximately 296 times that of carbon dioxide(7). The N_2O concentration has increased from pre-industrial concentrations of 270 ppb to 319 ppb in 2005. Due to its long atmospheric lifetime (114 years) and heat trapping effects, N_2O acts as an important greenhouse gas. It also affects climate by playing a significant role in the destruction of stratospheric ozone. Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste. Soils are the most important source of atmospheric nitrous oxide (N_2O), contributing an estimated 70% to the total globally emitted N_2O (8). Other sources of N_2O are the oceans, biomass burning and emissions from industrial processes and automobiles. Agricultural activities and animal production systems are the largest anthropogenic sources of N_2O emissions. While CO_2 is emitted mainly from industrial sources, the two major agricultural greenhouse gases are CH_4 and N_2O. Agriculture accounts for 10-12% of total global anthropogenic emissions of GHGs(9). It contributes about 47% and 58% of total anthropogenic emissions of CH_4 and N_2O, respectively(7). The main sources of chlorofluorocarbons (CFCs) include leaking air conditioners and refrigerators. Ozone is formed in the atmosphere through chemical reactions involving certain pollutants on absorption of UV-radiations. The main emission sources categories of O_3 are:

- Area - bakeries, paint shops, dry cleaners, etc.
- Non-road - construction, aircraft, locomotive, lawn & garden, etc.
- On-road - cars, trucks, and buses
- Point - cement and power plants
- Biogenic/Natural – forest fires, vegetation

During the past century human did substantially add to the amount of greenhouse gases in the atmosphere by burning fossil fuels such as coal, natural gas, oil and gasoline to power our cars, factories, utilities and appliances. The added gases — primarily carbon dioxide and methane — are enhancing the natural greenhouse effect and likely contributing to an increase in global average temperature and related climate changes. The Greenhouse Effect is the capacity of certain gases in the atmosphere to trap heat emitted from the Earth's surface, thereby insulating and warming the Earth. Carbon dioxide, methane, nitrous oxide, water vapour gases etc. absorb and re-emit infra-red radiation. This creates a natural "greenhouse effect" that raises the global temperature.

5.2.3 IMPACTS OF GREENHOUSE GASES

The amount of greenhouse gases in the atmosphere is directly related to the temperature of the atmosphere. Increased concentrations of greenhouse gases increase the temperature of the atmosphere leading to the warming of the earth's surface. The warming impact of different types of greenhouse gases varies according to the warming power of the gas and the length of time it stays in the atmosphere. Carbon dioxide has an atmospheric life of 50 to 200 years. So once emitted into the atmosphere, it has a warming effect over a long period of time. Methane, for example, has a life of about 12 years, much shorter than carbon dioxide. The warming power of each gas varies greatly. For example, methane is a much more powerful greenhouse gas than carbon dioxide. Over a 100 year period, a molecule of methane (CH_4) has 21 times the warming effect as a molecule of carbon dioxide (CO_2), even though it stays in the atmosphere for only about 12 years of the 100 year period.

The enhanced green house effect will not only cause global warming but will also affect various other climatic and natural processes. They are as follows:

(i) **Global temperature increase**: It is estimated that the earth's mean temperature will rise between 1.5 to 5.5^{0}C by 2050 if input greenhouse gases continues to rise at the present rate. Even at the lower value, earth would be warmer than it has been for 10,000 years.

(ii) **Rise in Sea Level**: With the increase in global temperature sea water will expand. Heating will melt the polar ice sheets and glaciers resulting in further rise in sea level. People have had to relocate to higher ground on low-lying islands in the South Pacific and off the coast of India as a result of the effects of global warming. Further sea level rise could cause great suffering. In Bangladesh alone, there are 15 million people living within 1 metres of sea level and another 8 million in a similar circumstance in India. Inhabited land could be inundated if sea levels continue to rise. (Much of the world's best farmland is low-lying, as are many of the world's largest cities.) Even a very modest rise in sea levels would have an enormous impact on millions of people around the world.

(iii) **Effects on Human Health:** Global warming will lead to changes in the rainfall pattern in many areas, thereby affecting the distribution of vector-borne diseases like malaria, filarial, elephantiasis etc. Areas which are presently free from diseases like malaria, schistosomiasis etc. may become the breeding grounds for the vectors of such diseases. Warmer temperature and more water stagnation would favour the breeding of mosquitoes, snails and some insects, which are the vectors of such diseases. Higher temperature and humidity will aggravate respiratory and skin diseases.

iv) **Effects on Agriculture:** It may show positive or negative effects on various types of crops in different regions of the world. Tropical and subtropical regions will be more affected since the average temperature in these regions is still on the higher side. Even a rise of 2^0C may be quite harmful to crops. Soil moisture will decrease and evapo-transpiration will increase, which may drastically affect wheat and maize production. Increase in temperature will increase pest growth like the growth of vectors for various diseases.

v) **Droughts and Floods:** Changes in the climate due to excess greenhouse gases are causing both increased drought and increased flooding. Violent storm activity will increase as temperatures rise and more water evaporates from the oceans. This includes more powerful hurricanes, pacific typhoons, and an increased frequency of severe localized storms and tornadoes. As these storms often result in flooding and property damage, insurance premiums are skyrocketing in coastal areas as insurance companies struggle to cover escalating costs. Warming also causes faster evaporation on land. Many dry areas, including the American West, Southern Africa, and Australia are experiencing more severe droughts. The amount of land on the Earth suffering from drought conditions has doubled since 1970.

5.2.4 MITIGATION

Increasingly, concerns are being expressed about the potential implications of the build-up in atmospheric concentrations of greenhouse gases (GHG). Agriculture can play an important role in mitigating three greenhouse gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Agriculture can potentially play a role in an effort to reduce net emissions of greenhouse gases. While agriculture is a small emitter of the most prevalent greenhouse gas (carbon dioxide – CO_2), it is important in the total picture. According to the latest United States EPA inventory, anthropogenic GHG emissions from agriculture contribute 7% of total carbon equivalent (CE) emissions releasing about 28 percent of methane and almost 70 percent of nitrous oxide. Furthermore, agriculture has substantial potential for absorbing emissions, particularly CO_2, through changes in tillage or land use including conversion of cropland to grassland or forest. Agriculture can also offset GHG emissions by increasing production of biomass commodities, which can serve either as feedstock for electricity generating power plants or as a substitute for fossil fuel based gasoline. Biofuels mitigate GHG emissions because their usage reduces total use of fossil fuels.

5.2.4.1 METHANE EMISSIONS

Methane emissions from irrigated rice can be reduced by temporarily draining the field during the growing period to allow aerobic decomposition. We estimate that with a single midseason drying, annual methane emissions would drop by about 18% with only a 1.5% yield decline. Implementing midseason drying on all irrigated rice areas would stabilize methane emissions at 2000 levels even as production grows substantially. Interaction between rice plant, microbe, the environmental conditions of the soil must be considered. Appropriate selection of soil and cultivars, proper cultivation practices to reduce substrate for methanogenesis, appropriate water management, type, time and dose of fertilizer application, breeding programme for high yielding, low methane emitting cultivar can be effective mitigation options. Biological mitigation option of methane from rice fields seems to be economically viable, environmentally sound and technically realistic approach for solving this global problem.

5.2.4.2 N_2O EMISSIONS

The N_2O emission from agricultural fields can be reduced by use of the following:

- **Nitrification inhibitors** – Nitrogen applied must be nitrified to nitrate before it is available for denitrification. Nitrification inhibitors delay the transformation of ammonium to nitrate They can reduce the loss of nitrogen and permit crop production at constant or improved yields at given fertilizer application rates. Furthermore, application of nitrification inhibitors with urea-based fertilizers also reduces N_2O emission considerably and reduce the chances of N loss by various mechanisms, thereby enhancing N use by crops. Recently, focus has been laid on the use of nitrification inhibitors of biological origin to control N_2O emission. Neem (*Azadiracta indica*) based formulations like neem coated urea are already proven biological material to reduce total N_2O emission form rice and wheat respectively.

- **Urease inhibitors** – Urease inhibitors delay the transformation of urea to ammonium to help matching the timing of nitrogen supply with crop demand.

- **Alternative tillage systems** – Some studies suggested that N_2O emissions could decline as a result of reduced nitrogen application rates following a shift to no till agriculture (Lemke et al., *1999*). Conversion from conventional tillage to no till will cause less disturbance to soils and more crop residual is retained (USEPA, 2006b)

- **Changes in irrigation practices** – Because soil-water content is an important factor in volatilization as well as nitrification/denitrification, irrigation practices can have an important impact on N_2O emissions from agriculture. (*Lemke et al., 1999*). However, the appropriate use of irrigation water is site-, crop-, soil- and temperature-specific, therefore this option may not be easy for practical application.

- **Improving drainage and avoiding soil compaction** – Improving drainage and preventing soil compaction can reduce N_2O emission.

- **Residue management**: Proper residue management is an important option for achieving sustainability in agriculture (*Wassmann et al., 2004*). Carbon nitrogen ratio of the residue is linked with the soil nitrogen mineralization and thereby regulates nitrous oxide emission (*Shelp et al., 2000; Aulakh et al., 2001*). Incorporation of fresh wheat straw at a high rate during rice growing season is an effective management practice of N_2O emissions from rice – wheat rotation system (*Yao et al., 2010*).

- **Fertilizer management such as use of slow or controlled release fertilizers :** Use of controlled release or slow release fertilizers are considered as important option for reducing emission by increasing the nitrogen use efficiency. The application of chemically altered or biochemically altered nitrogen fertilizers would have great potential to mitigate N_2O

emissions (*Jiang et al., 2010*). Plant uptake of fertilizer N can be improved by incorporation or deep placement, by using inter seasonal cover crops to minimize the accumulation of nitrate and by better water management. Strategies to enhance the N use efficiency of crops, such as matching N supply with crop demand can lower N_2O emissions considerably (*Langfang and Zucong, 2007*).

- **Use of nitrification inhibitors:** Application of nitrification inhibitors with urea-based fertilizers reduces N_2O emission considerably and reduce the chances of N loss by various mechanisms, thereby enhancing N use by crops. Recently, focus has been laid on the use of nitrification inhibitors of biological origin to control N_2O emission. Neem (*Azadiracta indica*) based formulations like neem coated urea are already proven biological material to reduce total N_2O emission form rice and wheat respectively.
- **Varietal selection**: Biological mitigation by varietal selection is the most eco-friendly mitigation option for nitrous oxide. Selection and breeding of low emitting varieties on the basis of photosynthate allocation, morphological and yield characteristics is important for effective biological mitigation (*Das and Baruah 2008*). Further research on xylem and phloem characteristics which determines gas transport and photosynthate allocation respectively is important.

Several previous studies have independently estimated the economic mitigation potential of specific agricultural strategies. For example, afforestation has been examined by Stavins and Moulton and Richards; biofuels have been assessed by Wang, Saricks, and Santini, Mann and Spath, McCarl, Adams, and Alig and Lal et al., and soil carbon sequestration on U.S. croplands has been analyzed by Pautsch et al. To determine the true economic potential of all agricultural strategies, it is important to examine them simultaneously.

5.3 CAUSES OF GLOBAL, REGIONAL AND LOCAL CLIMATE CHANGE

5.3.1 INTRODUCTION

The most general definition of climate change is a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause. Over the last few decades, as leaders and decision makers have increasingly realized that climate change could have catastrophic consequences across the globe, much attention has rightfully focused on attempting to reduce the magnitude of climate change by reducing greenhouse gas emissions and increasing carbon sequestration. As greenhouse gas emissions continue to rise and the effects of climate change are increasingly being felt by individuals and communities, adaptation to climate change also needs to be implemented. Climate changes are felt at local level as well as by communities across the globe.

As climate change affects variables such as the intensity and frequency of flooding, wildfire, severe heat days, and coastal erosion, the natural environment plays an important role in buffering those impacts to local communities.

There are a variety of potential causes for global climate change, including both natural and human induced mechanisms. Science has made great strides recently in determining which potential causes are actually responsible for the climate change that occurred during the twentieth century, providing strong evidence that greenhouse gases released to the atmosphere by human activities are the main causes of contemporary global warming.

To understand climate change fully the causes of climate change must be first identified. Scientists divided the main causes of climate change into two catagories one is **natural** and another is the **anthropogenic**.

5.3.2 Causes of climate change

5.3.2.1 Natural causes

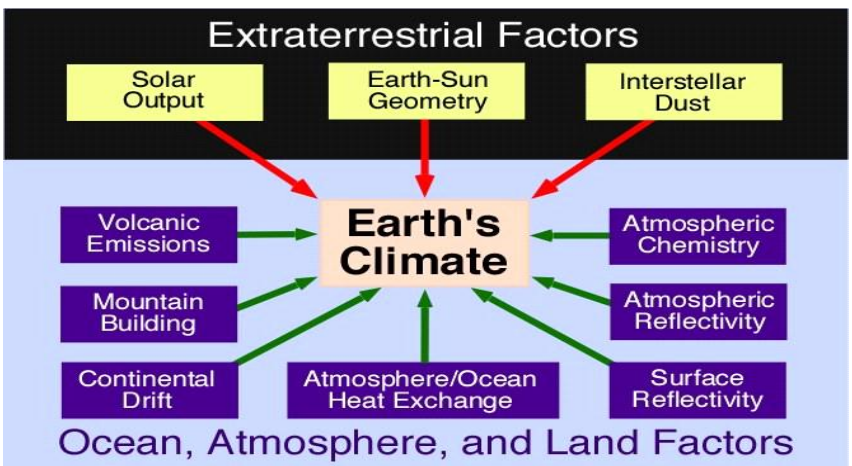


Fig 5.3: Basic components that influence the state of the earth's climate system

The work of climatologists has found evidence that only a limited number of factors are primarily responsible for most of the past episodes of climate change on the Earth. These factors include:

- Variations in the Earth's orbital characteristics.

- Atmospheric carbon dioxide variations
- Volcanic eruptions
- Variatios in solar output

I. Variations in the Earth's orbital Characteristics

According to the Milankovitch theory, the three cyclic events of the earth's orbit cause to vary the amount of solar radiation that is received on the Earth's surface.

The first cyclical variation, known as eccentricity, controls the shape of the Earth's orbit around the Sun. The orbit gradually changes from being elliptical to being nearly circular and then back to elliptical in a period of about 1,00,000 years. The greater the eccentricity of the orbit (*i.e., the more elliptical it is*), the greater the variation in solar energy received at the top of the atmosphere between the Earth's closest (perihelion) and farthest (aphelion) approach to the Sun. Currently, the Earth is experiencing a period of low eccentricity. The difference in the Earth's distance from the sun between perihelion and aphelion (which is only about 3%) is responsible for approximately a 7% variation in the amount of solar energy received at the top of the atmosphere. When the difference in this distance is at its maximum (9%), the difference in solar energy received is about 20%. The second cyclical variation results from the fact that as the Earth rotates on its polar axis, it wobbles like a spinning top changing the orbital timing of the equinoxes and solstices. This effect is known as the precession of the equinox. The precession of the equinox has a cycle of approximately 26,000 years.

II. **Volcanic eruptions**

When a volcano erupts, it throws out large volumes of sulphur dioxide, water vapour, dust, and ash into the atmosphere. Large volumes of gases and ash can influence climatic patterns for years by increasing planetary reflectivity causing atmospheric cooling. Tiny particles called aerosols are produced by volcanoes. Because they reflect solar energy back into space, they have cooling effect on the world. The greenhouse gas, carbon dioxide is also produced, however the CO_2 produced is insignificant when compared to emissions created by humans.

III. **Ocean current**

The ocean are a major component of the climate system. Ocean currents move vast amounts of heat acroos the planet. Winds push horizontally against the sea surface and drive ocean current patterns. Interactions between the ocean and atmosphere can also produce phenomena such as El Nino which occur every 2 to 6 years. Deep ocean circulation of cold water from the poles towards the equator and movement of warm water from the equator back towards the poles.

Without this movement, the poles would be colder and the equator warmer. The oceans play an important role in determining the atmospheric concentration of CO_2 into or out of the atmosphere.

IV. Earth orbital changes

The earth is tilted at an angle of 23.5^0 to the perpendicular plane of its orbital path. Changes in the tilt of the earth can lead to small but climatically and colder winters; less tilt means cooler summers and milder winters. Slow changes in the Earth's orbit lead to small but climatically important changes in the strength of the season, more tilt means warmer summer and milder winters. Slow changes in the Earth's orbit lead to small but climatically important changes in the strength of the seasons over tens of thousands of years. Climate feedbacks amplify these small changes, thereby producing ice ages.

V. Solar variations

The Sun is the source of energy for the Earth's climate system. Although the Sun's energy output appears constant from an everyday point of view, small changes over an extended period of time can lead to climate changes. Scientific studies demonstrate that solar variations have performed a role in past climate changes. For instance a decrease in solar activity was thought to have triggered the Little Ice Age between approximately 1650 and 1850, when Greenland was largely cut off by ice from 1410 to the 1720s and glaciers advanced in the Alps.

5.3.2.2 ANTHROPOGENIC SOURCES OF CLIMATE CHANGE

Anthropogenic causes of climate change are mainly including those sources of green house gas emitter such as agriculture, deforestation, automobiles, industries such as power plants, chemical producing industries, land use patterns, modification in the land cover such as the construction of the concrete buildings, uses of reflective surfaces and even introduction of various harmful pesticides and other chemicals etc.

I. Agriculture as a contributor to the causes of climate change

According to the Intergovernmental Panel on Climate Change (IPCC), the three main causes of the increase in greenhouse gases observed over the past 250 years have been fossil fuels, land use, and agriculture. Agriculture has been shown to produce significant effects on climate change, primarily through the production and release of greenhouse gases such as carbon dioxide, methane, and nitrous oxide. Another contributing cause of climate change is when agriculture alters the Earth's land cover, which can change its ability to absorb or reflect heat and light. Land use change such as deforestation and desertification and emissions from agricultural field act as a major contributor for climate change in the local as well as regional level.

Methane is the main greenhouse gas emitted from the agricultural sector. Methane (CH_4) is more abundant in the Earth's atmosphere now than at any time in at least the past 650,000 years [2, 5]. Methane concentrations increased sharply during most of the 20th century and are now 148% above pre-industrial levels.

II. Land cover and land use change

In addition to changes in the atmosphere's composition, changes in the land surface can have important effects on climate. For example, a change in land use and cover can affect temperature by changing how much solar radiation the land reflects and absorbs. Processes such as deforestation, reforestation, desertification and urbanization often contribute to changes in climate (including temperature, wind and precipitation) in the places they occur. These effects may be significant regionally, but reduced when averaged over the entire globe.

It is important to understand what a the precious resource rainforests play in the globe. They form part of a delicate ecosystem that has taken millions of years to evolve. Rainforest every year help to absorb almost 20% of manmade CO_2 emissions. Therefore, deforestation can be classed as a major contributor to the causes of climate change. Cutting down rain forests faster than they can be replaced has a devastating effect on the carbon emission cycle producing an extra 17% of greenhouse gases. Remember trees absorb CO_2. More deforestation means more CO_2 build up in the atmosphere. Forest reduces greenhouse gas emissions to combat global warming. 20% of global greenhouse gas emissions result from deforestation and degradation of forest, more than all world's cars, trucks, ships and planes combined.

Land use change can have significant effects on radiative forcing (and the climate) at the local level by changing the reflectivity of the land surface (or albedo). For example, because farmland is more reflective than forests (which are strong absorbers of heat), replacing forests with farmland would negatively contribute to radiative forcing or have a cooling effect. Averaged over the earth, the net radiative forcing contribution of land use changes, while uncertain, is estimated to be -0.2 Watts per square metre [2, 5] resulting in a relatively small cooling effect.

According to Narain *et al.,* [7] it is seen that in the past century India has faced 21 large scale droughts. Among them, monsoon of 2000 was the 13th consecutive normal monsoon considering country as a whole. But on a regional basis this was the third consecutive drought year in areas covered by the states of Rajasthan, Gujarat and Andhra Pradesh. The El Nino phases of the Southern Oscillations (ENSO) have direct impact on drought in India cause weak or enhanced summer monsoon (WMO, 1994). The frequency of droughts and floods are also likely to be influenced by climatic changes as a result of increased green house gas emissions. IPCC of the World Meteorological Organization projected an increase of 0.1 to 0.3^{o}C by 2010 and 0.4 to 2.0^{0}C by 2020 in South Asia which may result in a decrease in cereals production and an increase in rainfall by 5-15% in the South Asia region (Houghton *et al.*, 1990) [8]. Climate change studies over the Jodhpur region in Rajasthan showed that the rainfall and air temperatures were favourable but the manifold increase in human and livestock population were the main causative factors for acceleration of adverse effects of droughts and desertification in the region (Rao and Miyazaki, 1997) [9].

A report from "The Assam Tribune" dated 17th November 2011, described the fate of some local endemic flora and fauna of North eastern region affected by climate change. Species such as Pygmy hog, some biota restricted to islands or wetland areas are very much vulnerable to the habitat change as well as climate change. The threats to biodiversity arising from climate change are likely to be very acute in this region on account of ecological fragility, economic marginality and richness of threatened and endemic species with restricted distributions. The severity of the impact is also likely to be increased due to habitat fragmentations and heavy biotic pressure on natural resources. In the Regional and Sectoral Analysis for 2030 of the Indian Network of Climate Change Assessment (INCCA) assessment, the Ministry of Environment and Forest has claimed that the temperature of the North East region is set to increase by 1.8-2.1 ^{o}C during the next two decades.

Conclusion

From the above discussion it is clear that mainly the anthropogenic activities are the intense factor for climate change. The impact of climate change is projected to have different effects within and between countries. Developing countries have to carefully evaluate the need for, and the roles of global and national institutions in promoting both mitigation and adaptation programmes. Mitigation and adaptation actions can, if appropriately designed, advance sustainable development and equity both within and across countries and between generations. The persiveness of inertia and the possibility of irreversibility in the consequences of the interactions among climate, ecological and socio-economic systems are major reasons why anticipatory adaptation and mitigation actions are beneficial.

SUGGESTED READINGS:

1. Shukla, S.K and Chandel, P.S., *A Textbook of Plant Ecology*. S. Chand publication, New Delhi-110055.

2. IPCC (2007a), Climate change 2007: The physical science basis, Contribution of working group I to IV assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK & New York, USA.
3. http://timeforchange.org/cause-and-effect-for-global-warming
4. A simplified guide to the IPCC's "Climate Change 2001: Impacts, Adaptation and Vulnerability. Published by the United Nations Environment Programme in November 2003.
5. IPCC (2007b), Climate change 2007: Mitigation, Contribution of working group III to the fourth assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.
6. http://www.enviroliteracy.org/article.php/1334.html
7. Narain Pratap, Rao A. S. & Abrol I. P.; Managing droughts and Desertification In India Lessons from the past and future strategies; Central Arid Zone Research Institute, Jodhpur, India.
8. Houghton, J.T., Jenkins, G.I. and Ephraums, J.J., 1990; Climate change. The IPCC scientific assessment WMO/UNEP Cambridge, U.K. pp 365.
9. Rao, A.S. and Miyazaki, T., 1997; Climatic Changes and Other Causative Factors Influencing Desertification in Osian (Jodhpur) Region of the Indian Arid Zone. Journal of Arid Land Studies, 1:1-11.

UNIT 6: SUSTAINABILITY ISSUES OF ENERGY USE

UNIT STRUCTURE

1. CONCEPT OF THE SUSTAINABLE ENERGY

1.1. INTRODUCTION

Sustainable development: a definition 'Sustainable development' has been defined best by the Brundtland Commission as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs'. [1]

Energy is one of the biggest and most complex systems, created by the mankind. Adequate and affordable energy supplies have been the key to economic development and the transition from subsistence agricultural economies to modern industrial and service-oriented societies. The strategy to sustainability should be adequate to its systems features and the present and future energy challenges.

Energy as a system: The system features of energy have been an area of extensive academic investigations. [2, 3, 4]. Here we only enumerate some of them of great importance to the energy analysis, innovation and development policy.

- The systems unity of energy expressed by interchangeability of energy resources and energy carriers at all stages of their transformation and utilization;
- Strong ties of energy with economy, environment and society;
- Global, regional, national and local levels of energy problems and prospects;
- Functioning and development determined by internal and external factors;
- Inertial structural evolution, requiring long-term development modeling and strategy.

Challenges to sustainable energy development:

- Limited conventional energy resources;
- Increasing energy consumption;
- Environmental impacts of energy resources production, transport, conversions and end-use.
- Low energy efficiency;
- Economic and social constraints to energy functioning and development

Energy policy is a goal oriented activity to:

- Reliable energy supply;
- Efficient energy transformation and end-use;
- Environment preservation corresponding to international norms and agreements;
- Strategically oriented energy development;
- Socially acceptable cost and prices.

1.2 EXTERNALITIES OR EXTERNAL IMPACTS

An external cost, also known as an externality, arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted or compensated for, by the first group. The term externality has become part of the jargon of the energy field. As such, it tends to be used loosely to refer to all external impacts of economic consequence, not just the externalities (unpriced costs).

There are some points which mark these externalities

I. Some externalities known to have a profound effect on energy policy, and on shaping public opinion, even though their costs have actually been priced into the product. For example, the costs of disposal of nuclear wastes and decommissioning of nuclear power plants are included in the price of nuclear power in OECD countries, and producers of nuclear power take into account 'virtually all life cycle costs' (UMPNER Report, 2006, Chapter 4).

II. There are some environmental impacts that influence policy and public opinion. Risks to rare or endangered species is an example of an impact that can perhaps be described qualitatively but seems unlikely to be amenable to monetary evaluation, at least with any acceptable degree of precision.

III. Life Cycle Assessment: External impacts of an energy technology need to be assessed over its complete life cycle. Ignoring this will lead to wrong assessments and to misconceptions about the environmental credentials of a fuel, a technology or a product.

IV. The cost of climate impacts of greenhouse emissions is central to evaluation of energy externalities. The field of economic modeling of climate change costs is large and complex as indicated by the following long list of factors that have been taken into account:

- Impacts of sea level rise, erosion, loss of land/coastal wetlands, and need for coastal protection;
- Effects on agriculture;
- Effects on energy use (including heating and cooling);
- Effects to human health from changes in cold related and heat related effects;
- Effects to human health from the disease burden (and other secondary effects);
- Effects on water resources, water supply and water quality;
- Changes to tourism potential and destinations;
- Effects on ecosystems (loss of productivity and bio-diversity);
- Impacts from drought;
- Impacts from flooding;
- Impacts from storm damage and extreme weather (including costs to infrastructure);
- Socially contingent effects (arising from multiple stresses and leading to migration, famine, etc);
- Impacts from major events (*e.g.* loss of thermo-haline circulation (ocean circulation driven by density gradients, collapse of West-Antarctic ice sheet, methane hydrates).

1.3 EXTERNAL COST OF ENERGY

1.3.1 EUROPEAN EXTERNE PROJECT

European ExternE Project is widely acknowledged as the ‘gold standard’ of energy externality research and the scientific quality of its work is recognized internationally. ExternE work covers externalities of stationary power generation as well as transport and other activities such as incineration. Health impacts and climate change contribute the largest costs in the ExternE work.

Activities like electricity and heat generation or transport cause substantial environmental and human health damages for the most part not integrated into the pricing system. By societal welfare principles, policy should aim to ensure that prices reflect total costs of an activity, incorporating the cost of damages caused by employing taxes, subsidies, or other economic instruments.

To support this internalization, socio-environmental damages must first be estimated and monetized. Over the past 15 years, there has been much progress in the analysis of environmental damage costs, particularly through the "ExternE" (External costs of Energy) European Research Network. Since 1991, the ExternE project has involved more than 50 research teams in over 20 countries.

The Damages assessed. The current research aims at constantly enlarging list of health and environmental effects covering “Impact Category”(Human Health-mortality, Human Health-morbidity, Building Materials, Crops, Global Warming, Amenity Loses, Ecosystems), large number of Pollutant/Burden and Effects.

The ExternE methodology. The impact pathway approach - and coming along with this approach, the EcoSense model, an integrated software tool for environmental impact pathway assessment - was developed within the ExternE project series and represents its core. Impact pathway assessment is a bottom-up-approach in which environmental benefits and costs are estimated by following the pathway from source emissions via quality changes of air, soil and water to physical impacts, before being expressed in monetary benefits and costs.

Applications: ExternE methodology has been applied for a large number of European and national studies to give advice for environmental, energy and transport policies. One of the first objectives of the ExternE program was to make a comparative evaluation of different technologies and fuel cycles for electricity generation. A decade of research has resulted in detailed set of data for impacts from a wide range of fuels, technologies and locations. They include:

- fossil fuels : coal and oil technologies with varying degrees of flue gas cleaning, natural gas, centralized systems and CHP;
- nuclear : PWR, open and closed systems for fuel provision;

- Renewable: onshore and offshore wind, hydro, a wide range of biomass fuels (waste wood, crops) and technologies.

Uncertainty and Reliability: Individual sources of uncertainty have to be identified and quantified. It is appropriate to group them into different categories, even though there may be some overlap:

i. data uncertainty, *e.g.*, slope of a dose-response function, cost of a day of restricted activity, and deposition velocity of a pollutant;
ii. model uncertainty, *e.g.*, assumptions about causal links between a pollutant and a health impact, assumptions about form of a dose-response function (e.g. with or without threshold), and choice of models for atmospheric dispersion and chemistry;
iii. uncertainty about policy and ethical choices, *e.g.*, discount rate for intergenerational costs, and value of statistical life;
iv. uncertainty about the future *e.g.*, the potential for reducing crop losses by the development of more resistant species;
v. idiosyncrasies of the analyst *e.g.*, interpretation of ambiguous or incomplete information

ExternE numbers can be used for policy preparation. Numbers have indeed already been used in several policy areas, such as economic evaluations of the draft directive on non-hazardous waste incineration, the Large Combustion Plant Directive, the EU strategy to combat acidification, the National Air Quality Strategy, the Emission Ceilings Directive, proposals under the UN-ECE multi-pollutant, multi-effect protocol and many more policies, green accounting research projects, and air quality objectives.

1.4 EUROPEAN CASES (COST ASSESSMENT OF SUSTAINABLE ENERGY) PROJECT

Objective I: To compile detailed estimates of external and internal costs of energy production for different energy sources for the EU-25 Countries and some non-EU Countries (Bulgaria, Turkey, Brazil, India, China) within a coherent dynamic framework, under energy scenarios up to 2030.

Objective2: To evaluate policy options for improving the efficiency of energy use, taking account of the full cost data.

Objective 3: To disseminate research findings to energy sector producers and users and to the policy making community.

Research institutions: 21 European Union and 5 non-European Union research centers.

Work Packages. CASES consists of 13 integrated work packages (WPs**):**

- **WP1** provides electricity demand and primary energy source options scenarios up to 2030 for each of the country studied (25 EU Countries, Bulgaria, Turkey, Brazil, India, China) taking into account different local conditions across countries.

- **WP2** focuses on human health**,** materials and crops external costs. The deliverables are a database on life cycle emissions for electricity and heat generation technologies, a report on methodology for estimating external costs to human health, crops and materials and updated and extended version of ECOSENSE tool.

- **WP3** updates the estimates of non-human health related environmental costs of different energy sources based on life cycle impacts for EU and non-EU countries with specific attention to ‘new impacts’ (acidification, eutrophication and visual intrusion);
- **WP4** investigates private costs of generating electricity and heat by combustible renewables, focusing on heat generation technologies (oil, gas and bio-mass heating systems, heat exchanger, heat pump;
- **WP5** estimates externalities related to energy supply insecurity for EU and other selected countries;
- **WP6** focuses on the consistent set of national level full costs estimates for the 25 EU countries for different energy sources;
- **WP7** focuses on the consistent set of national level full costs estimates for Bulgaria, Turkey, Brazil, India and China;
- **WP8** assesses policy instruments to internalize environment related external costs in EU Member States, excluding renewables;
- **WP9** assesses policy instruments to internalize environment related external costs in EU Member States, via promotion of renewables;
- **WP10** assesses policy instruments to internalize externalities in non EU Member States, via promotion of renewable and consider the social and fiscal implications that these measures have, especially on poor and vulnerable groups;
- **WP11** assists WPs 8-10 by providing the guidelines for the assessment methods, including Cost-Benefit-Analysis (CBA) and Multi-Criteria Decision Analysis (MCDA);
- **WP12** is devoted to dissemination**.**
- **WP13** encompasses the running of the project co-ordination and management activities.

CASES is an ambitious project towards more profound knowledge on energy-environment-society interactions and internalization of externalities in the energy market and policy.

1.5. SUSTAINABILITY ISSUES

1.5.1 ENERGY INDICATORS AND ENERGY POLICY STATUS

Since the publication of the Brundtland Report in 1987, various international and national organizations have been developing sets of indicators to measure and assess one or more aspects of sustainable development. These efforts received a major boost following the adoption of Agenda 21 at the Earth Summit in 1992, which (in Chapter 40) specifically asks countries and international governmental and nongovernmental organizations to develop the concept of indicators of sustainable development and to harmonize them at the national, regional and global levels. Some of them are:

1.5.1.1 THE UNITED NATIONS EFFORT ON INDICATORS OF SUSTAINABLE DEVELOPMENT.

In response to decisions taken by the United Nations (UN) Commission on Sustainable Development (CSD) and to Chapter 40 of Agenda 21, in 1995 the UN Department of Economic and Social Affairs (UNDESA) began working to produce a set of indicators for sustainable development. Four dimensions of sustainable development are included as indicator, such as social, economic, environmental and institutional.

1.5.1.2 ENERGY INDICATORS AND SUSTAINABLE DEVELOPMENT: THE COMMISSION ON SUSTAINABLE DEVELOPMENT AND THE JOHANNESBURG PLAN OF IMPLEMENTATION.

The initial work on energy indicators undertaken by the International Atomic Energy Agency (IAEA) with contributions from UNDESA, the International Energy Agency (IEA) and other international and national organizations was presented at the ninth session of the Commission on Sustainable Development (CSD-9) in 2001, under the name 'Indicators for Sustainable Energy Development' (ISED). Improving affordability of and accessibility to modern energy services for the rural and urban poor as well as promoting less wasteful use of energy resources by the rich were among the most pressing issues identified at CSD-9.

1.5.1.3 ENERGY INDICATOR EFFORTS IN PARTICIPATING AGENCIES

This report is the result of an interagency effort led by the IAEA in cooperation with UNDESA, the IEA, the Statistical Office of the European Communities (Eurostat) and the European Environment Agency (EEA). It is a joint endeavour intended to eliminate duplication and provide users with a single set of energy indicators applicable in every country. In addition to the interagency cooperative work on EISD, each of these agencies has ongoing programmes on energy or energy/environmental indicators, which are to some extent interlinked.

1.5.1.4 THE INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA) AND THE ISED/EISD EFFORT

The IAEA initiated this indicator project in 1999 in cooperation with various international organizations, including the IEA and UNDESA, and some Member States of the IAEA. This name was later modified to Energy Indicators for Sustainable Development (EISD) to reflect the view held by some users that 'sustainable energy development' refers only to renewable energy. The project was conceived to (i) fill the need for a consistent set of energy indicators applicable worldwide, (ii) assist countries in the energy and statistical capacity building necessary to promote energy sustainability and (iii) supplement the work on general indicators being undertaken by the CSD.

1.5.1.5 INTERNATIONAL ENERGY AGENCY (IEA)

The IEA project was established in 1996 where analytical framework and data developed have become important tools for IEA analysis of energy-use developments. The focus of the energy indicator project is to assist IEA Member countries in analyzing factors behind changes in energy use and emissions of carbon dioxide (CO_2). The indicators help to reveal key couplings between energy use, energy prices and economic activity. The IEA is also assisting non–Organisation for

Economic Co-operation and Development (OECD) countries to improve their energy statistics and to establish energy indicators. This includes work with international organizations such as the Energy Charter Secretariat, Eurostat, the Asia Pacific Energy Research Centre (APERC) and the IAEA.

1.5.1.6 EUROSTAT

Eurostat has collaborated with the IEA on energy-data collection for more than 25 years, and more recently has collaborated on indicator development. As in most IEA Member countries, since the oil crises of the 1970s, energy policy in the European Union (EU) has traditionally concentrated on security and diversity of supply, energy efficiency, prices and competitiveness.

Eurostat publishes annually, in pocketbook format, integration indicators for energy based on data collected by Eurostat and the EEA.

1.5.1.7 EUROPEAN ENVIRONMENT AGENCY (EEA)

The EEA is the EU body dedicated to providing sound, independent information on the environment. It is a main information source for those involved in developing, adopting, implementing and evaluating environmental policy, and for the general public. Indicators are an important tool in the EEA's work for assessing progress towards environmental protection and sustainable development. The EEA's indicator work covers the environmental aspect of sustainable development and is based on the so called DPSIR assessment framework (Driving forces, Pressures, State of the environment, Impacts, and societal Responses).

Achieving sustainable economic development on a global scale will require the judicious use of resources, technology, appropriate economic incentives and strategic policy planning at the local and national levels. It will also require regular monitoring of the impacts of selected policies and strategies to see if they are furthering sustainable development or if they should be adjusted. It is important to be able to measure a country's state of development and to monitor its progress or lack of progress towards sustainability. Policymakers need to know their country's current status concerning energy and economic sustainability, what needs to be improved and how these improvements can be achieved.

2. FUTURE ENERGY SYSTEMS AND CLEAN ENERGY TECHNOLOGIES

2.1 Introduction

For over a century cheap, plentiful fossil energy has been supporting the industrialization of many countries, and the increasingly higher standards of living of their inhabitants. Today 85% of our country's energy comes from the combustion of dead fossils, a dirty fuel that is forcing the world's atmosphere to overheat. However, new 21st century energy sources that produce no carbon emissions and do not contribute to global warming are now emerging. Beyond the realm of fuel cells and hydrogen is the non-conventional world of "future energy." However, a number of separate major issues and challenges, and their concerted effects in particular, are likely to change the way energy is used and supplied over the next century. While consciousness about environmental issues has grown, energy use continues to cause environmental degradation, including air, water and soil pollution. Rapidly developing countries, such as China, have severe environmental problems linked to the rapid increase in energy use and its supply from polluting sources and technologies. The global environmental effect of energy use, in the form of climate change, is a serious environmental threat with no easy solution, with emissions from countries already responsible for the bulk of the emissions expected to continue its growth. In addition to these problems, a number of political (*e.g.,* war in Iraq) and climatic (*e.g.,* hurricane Katrina) destabilizing factors, as well as constraints in supply capacity, have led to record oil prices above $70 per barrel, not far in real terms from the prices reached during the first oil shock in 1973. Sustained energy demand, uncertainty over future fossil fuel reserves, and increasing dependency on a few geopolitically unstable regions for the known reserves of oil, cause serious concerns over energy security, and are directing even greater political priority to this issue. However, several clean energy options are viable today and several others are likely to be so in the future, as technologies improve, costs are reduced, and the competitive landscape for energy technologies evolves. Tackling climate change and energy security requires the simultaneous deployment of available commercial clean technologies, demonstration and commercialization of technologies at the advanced research, development and demonstration stage, and research into new technologies. Clean technologies are a diverse range of products, services and processes that harness renewable materials and energy sources, dramatically reduce the use of natural resources, and cut or eliminate emissions and wastes. Clean technologies are competitive with, if not superior to, their conventional counterparts. Clean technology includes recycling, energy (Wind power, solar power, biomass, hydropower, biofuels), information technology, green transportation, electric motors, green chemistry, lighting, Greywater, and many other appliances that are now more energy efficient. It is a means to create electricity and fuels, with a smaller environmental footprint and minimize pollution. To make green buildings, transport and infrastructure both more energy efficient and environmentally benign [10, 11].

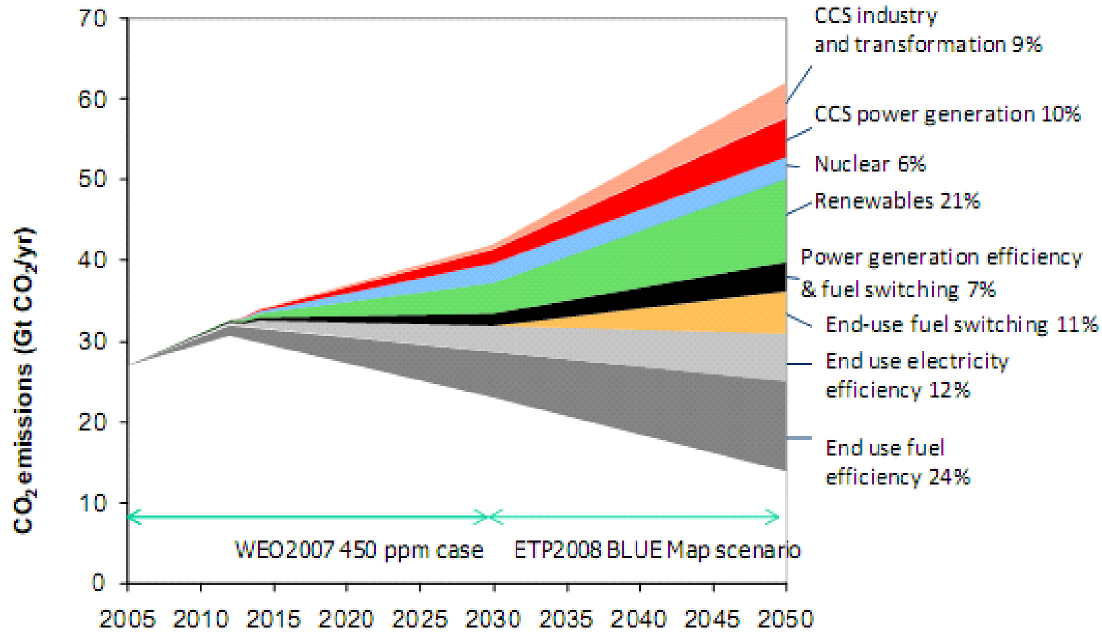


Fig 1. Projected CO_2 emission in different sector [12]

3. PREREQUISITES FOR FUTURE ENERGY SYSTEMS

V. Effectively accommodate large amounts of varying renewable energy

VI. Integrate the transport sector through the use of plug-in hybrids and electric vehicles.

VII. Maximize the gains from a transition to intelligent, low energy buildings and

VIII. Introduced advanced energy storage facilities in the system

IX. Development of super grids interconnection different regions.

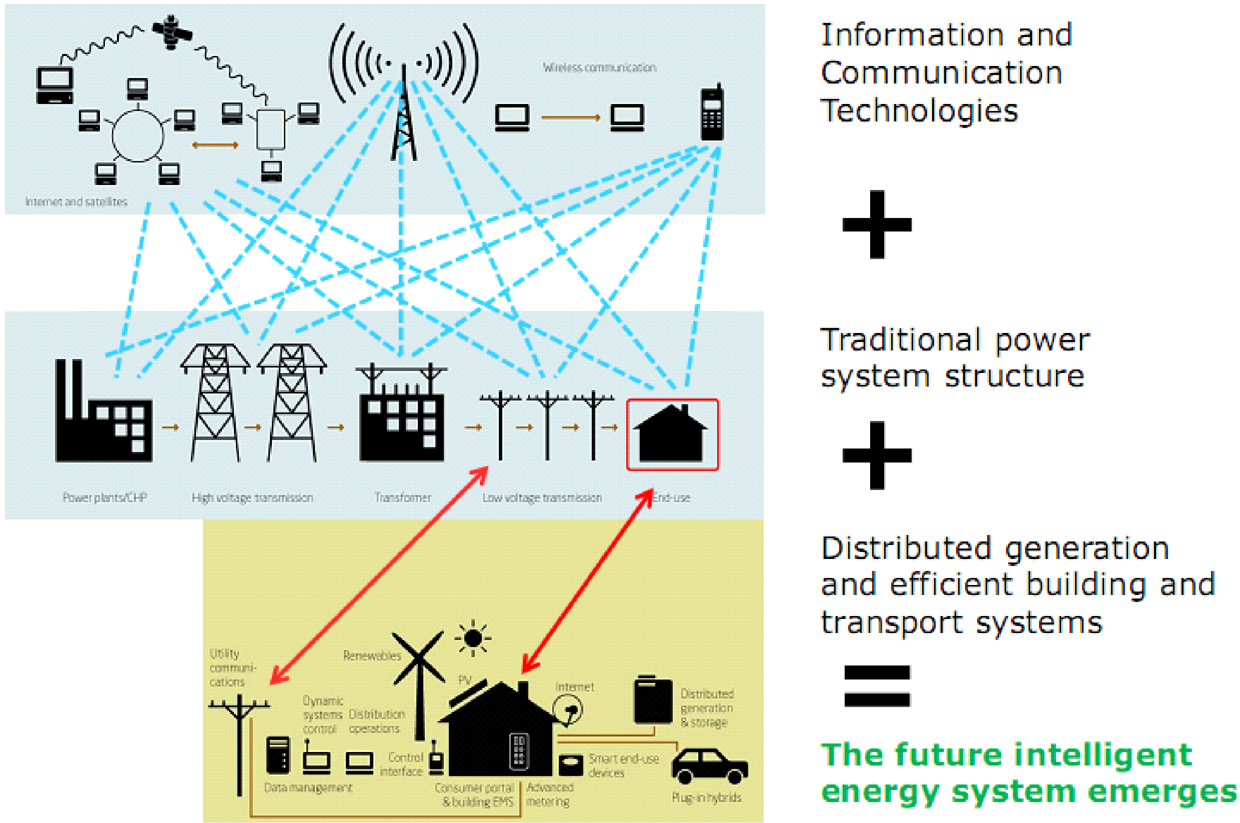


Fig.2. Future intelligent energy system [12]

3.1 INFORMATION AND COMMUNICATIONS TECHNOLOGY

- Increased use of information and communications Technology (ICT).
- The rapidly increasing capabilities and falling costs of ICT open the way to two way communication with end-users and
- Making this one of the most important enabling technologies for the future power system.

3.2 RENEWABLE ENERGY SOURCES

- Renewable energy resources used to occupy an almost insignificant niche, are gradually expanding their role in global energy supply.
- Today largest contributions are traditional biomass and hydropower.
- New renewable such as photovoltaic's, wind power, small-scale hydro, biogas and new biomass plays a minor role, but are expanding rapidly.

3.3 BIO ENERGY

- Production and properties of biomass
- Biomass Conversion and co-production

- The production of two generation bio-fuel from straw by means of an internationally unique method.

3.4 PHOTOVOLTAIC

- The market for photovoltaic's has grown at an average of more than 30% annually over the last 10 years.
- Crystalline silicon remains the standard PV technology with a market share above 90%
- Although efficiencies of solar cells continue to rise, high cost remains the principal barrier to PV as a large scale energy producers
- Polymer solar cells may succeed where silicon has failed because they are cheap to make

3.5 Storage

- Energy storage is needed in a future energy system dominated by fluctuating renewable energy depends on many factors:
  –the mix of energy sources,
  –the ability to shift demand
  –the links between different energy vectors, and
  –the specific use of the Energy
- Storage costs and energy losses need to be considered.

4. EVOLUTION TO FUTURE ENERGY SYSTEM AND CLEAN TECHNOLOGIES

There are plentiful of demand and supply options for addressing climate change and energy security issues. However, the extent to which these will be adopted will depend on different drivers and constraints. No single option will provide a solution to all energy problems, but solutions will consist of a range of options that will evolve over time. The main drivers behind change in the energy sector are climate change, air quality and energy security. The priority of these drivers is likely to vary geographically and with time. The changes instigated will be constrained by technical, economic, infrastructure, geographic and socio-political factors. Managing transitions in resources, technologies and end uses will be crucial in effectively addressing the problems facing energy supply and end use [13].

A. Heat and electricity

Coal, oil and natural gas are the main fuels used for heating, with natural gas increasingly used for heating in the commercial and domestic sectors. While the direct use of fuels for heating is generally efficient (efficiencies of modern heating systems easily exceed 80%), there are different ways in which emission savings can be achieved. Energy savings can be achieved through the diffusion of more efficient heating appliances, *e.g.*, condensing boilers, and through more energy efficient buildings. The use of combined heat and power plants result in energy savings compared to heat-only or electricity-only systems providing the same service. In particular, fuel cells present emissions benefits compared to alternatives. Finally, renewable sources such as biomass and solar energy could substitute fossil fuels in many heat applications. Heating is possibly where the lowest cost CO_2 emission reductions can be achieved, through efficiency measures and fuel substitution. CO_2 abatement costs could be very low and even negative when using efficiency measures and substituting wood chips and pellets or natural gas for higher carbon content fossil fuels.

The electricity sector presents a wide range of options for reducing carbon emissions. For countries where the sector has been reliant on coal, a switch to gas provides a relatively low cost route to reducing emissions. However, rising gas prices and concerns over security of gas supplies could act increasingly as a constraint on the share of gas used for electricity. Efficiency gains can play an important role in electricity generation. For example, combined cycles with natural gas (CCGT) or coal gasification (IGCC) could increase generation efficienciesto65% (gas) and55% (coal) by2020. Also, fuel cells could provide efficiency gains in decentralized generation applications compared to engines and turbines. System efficiencies will depend on the fuel used, fuel cell type and its potential integration with other devices such as micro-turbines. For example, the electrical efficiency of a solid oxide fuel cell (SOFC) system fuelled with natural gas is estimated at 55% and that of a SOFC coupled with a small gas turbine is estimated at 70%. However, fuel cell technology requires further development, demonstration and cost reductions.

Nuclear represents an important share of global electricity generation (16%). Nuclear fuels could contribute large CO_2 emissions reductions in the electricity sector, but significant nuclear expansion requires a solution to the problems of radioactive waste disposal and nuclear proliferation, and the restoration of public confidence in the technology. Carbon capture and storage (CCS) can be applied post combustion of the fuel, where fossil fuel is used in combustion systems to generate electricity, or pre-combustion, where the fossil fuel is used to produce a lower carbon content synfuel or decarbonizes hydrogen. Renewables have benefited the most from the limited driver to produce cleaner energy and desire to increase reliance on domestic energy sources. Significant cost improvements have been made in wind, biomass and solar electricity as a result of technological improvements and increased penetration rates and costs are continuing to decrease. Marine technologies hold good technical promise but are still at the demonstration stage.

Renewables are at present the only truly sustainable source of energy. However, their contribution to electricity generation remains low, except for hydroelectricity in some countries. This is due to the generally higher costs of renewable electricity compared to conventional grid-based generation and difficulties resulting from its smaller scale and more decentralized nature. Although estimates of the exploitable renewable energy potential may vary, most studies concur that it is very large (the technical potential being many times larger than current primary energy supply), in particular when the diversity of renewable options is considered. Renewables are also likely to the route to sustainable hydrogen, and hydrogen could act valuable means of storing intermittent renewable electricity. The interest and value, in terms of carbon abatement in particular, of using renewable to produce hydrogen should grow as low carbon sources of energy are more widely adopted for electricity generation. [14, 15]

4 Transport

Transport is heavily reliant on oil and accounts for most of the projected CO_2 emissions growth in industrialized countries. Vehicle efficiency improvements and vehicle standards have provided and will continue to provide important emissions reductions per unit distance travelled. Average vehicle fuel efficiency could double compared to current values, and assuring that technical efficiency improvements are converted into fuel economy gains, and not offset by increased power and size, represents an important policy challenge. Nevertheless, atmospheric stabilisation of CO_2 will ultimately require transport fuels with near-zero ‘well-to-wheels’ CO_2 emissions. The options are biofuels, electricity, and hydrogen, the last two can only help if produced from very low net CO_2 energy sources. Ethanol and biodiesel are already produced commercially in some countries and blended with petrol and diesel, respectively. They provide only a small fraction of transport fuels in most countries where they are used, with the notable exception of Brazil where bioethanol represents around 40% of road transport fuel in gasoline vehicles. However, biofuels are not strictly carbon neutral, and the carbon emissions from biofuel chains can vary significantly depending on the biomass feedstock and conversion process, and related materials and fuel inputs. For example, the associated CO_2 reductions compared to gasoline and diesel are only about 20–50% for ethanol produced from grains, 40–60% for biodiesel from rapeseed, but up to 90% for ethanol from sugarcane in Brazil, largely because bio gasses is used for Process Energy. Fuel cell vehicles fuelled with hydrogen from a variety of sources could provide significant CO_2 reductions and zero tailpipe emission. The CO_2 emissions reductions strongly depend on the source of hydrogen. An evolutionary route towards sustainable hydrogen might start with the use of surplus hydrogen produced at chemical or petrochemical sites, as well as the re-fuelling of fleet vehicles and gradually expand to other uses [14, 15].

Conclusion

There are visible paths to low carbon and more secure energy systems, with both short and long-term options for emissions reductions and improved energy security in the heat, electricity and transport sectors. Addressing climate change requires the simultaneous deployment of available commercial low carbon technologies, demonstration and commercialization of technologies at the advanced research, development and demonstration stage, and research into new low carbon technologies. Innovation in the energy sector needs to recognize that the evolution of technologies is intrinsically linked with the evolution of the institutional aspects that regulate the energy sector *i.e.*, technical, market and environmental regulations. Also, it needs to recognize the timescales and effort that are required in replacing or building energy infrastructure *e.g.*, in the case of the development of a hydrogen infrastructure. Achieving low concentrations of CO_2 in the atmosphere over the next century could also require changes in consumer behaviour. For example, ever increasing demand for larger and more powerful vehicles and for air travel may offset gains achieved by low carbon technology and fuels, besides exerting increasing pressure on finite energy resources and ecological capacity.

SUGGESTED READINGS

1. Chen, S., Datt, G., Ravallion, M., 1992. *POVCAL: A Program for Calculating Poverty Measures from Grouped Data.* Washington DC: World Bank, Poverty and Human Resources Division, Policy Research Department.

2. Melentev L. A., Systems Research in Energy, Nauka, Moscow, 1983.

3. Gamm A., Makarov A. and al. Theoretical Grounds of the Systems Research in Energy, Nauka, Moscow, 1986.

4. Tzvetanov P. Systems Analysis of the Energy Development of Bulgaria, Dr.Sciences dissertation, Siberian Energy Institute, Russian Academy of Sciences, 1990.

5. Green Paper: Towards a European Strategy for the Security of Energy Supply, EC, 2001

6. World Energy, Technology and Climate Policy Outlook (WETO), Directorate-General for Research Energy, EC, 2003

7. http://www.feem-project.net/cases

8. ExternE, 1999, *Extern E: Externalities of Energy, Vol XX: National Implementation*, Prepared by CIEMAT, ES, European Commission, 1999, 593p.

9. ExternE, 2005, *ExternE: Externalities of Energy, Methodology 2005 Update, EUR21951*, Edited by Peter Bickel and Rainer Friedrich, Institut fur Energiewirtschaft und Rationelle Energieanwendung — IER Universitat Stuttgart, European Commission, Luxemburg, Germany, 270p.

10. David vo n Hippe, “Energy security and sustainability in Northea st Asia”

11. Dr. M. M. Qurashi, “Renewable Energy Technologies for Developing Countries Now and to 2023,” ci. & Tech. in Islamic World”, 1, 1983, pp. 119-126.

12. “The intelligent energy system infrastructure for the future” Renewable Energy Research Conference Trondheim, 7 June 2010

13. Hans Larsen Systems Analysis, Division Risø DTU Denmark

14. Clean Energy, Bright Future Rebuilding America through Green Infrastructure Environment America Research & Policy Center January 2009

15. Ausilio Bauen “Future energy sources and systems—Acting on climate change and energy security” Journal of Power Sources 157 (2006) 893–901

UNIT-7: SOCIO- ECONOMICAL ASPECTS OF ENERGY RESOURCES

1 GENERAL CONCEPTS OF ENERGY

Energy is the backbone of the modern society and the country. The well-being of our people, industry and economy depends on safe, secure, sustainable and affordable energy. Energy is defined as the ability or the capacity to do work and work is the transfer of energy from one form to another. In practical terms, energy is what we use to manipulate the world around us, whether by exciting our muscles, by using electricity, or by using mechanical devices such as automobiles. Energy comes in different forms - heat (thermal), light (radiant), mechanical, electrical, chemical, and nuclear energy. There are two types of energy-kinetic energy and potential energy. Kinetic energy is the energy that a body possess due to its motion and potential energy is the energy that a body possess by virtue of its position, configuration etc. It is difficult to imagine spending an entire day without using energy.

Energy Resources:

The sources from which we get energy is called energy resources. It can be defined as anything that can be used as a source of energy. Access to energy resources is vital to economic development and prosperity. There are three types of energy resources:

I. RENEWABLE ENERGY:

Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, that are renewable (naturally replenished). Biomass is also renewable source of energy as it can be grown in a short period of time and CO_2 can be recycled. These sources are sustainable in that they can be managed to be used indefinitely without degrading the environment (Renewable Energy Association, 2009) [1]. They can be recycled and are normally free from pollution.

II. NON-RENEWABLE RESOURCES:

A non-renewable resource is a natural resource which cannot be produced, grown, generated, or used on a scale which can sustain its consumption rate; once depleted it is no more available for future use. Also considered non-renewable are resources that are consumed much faster than nature can create them. It includes:

a) Conventional energy sources which includes fossil fuel derived energy like oil, gas and coal

b) Non conventional energy sources includes tar sands, shale oil etc.

III. **NON RENEWABLE BUT TECHNOLOGICALLY EXTENDED RESOURCES**:

a) Nuclear fission with potential (through new technologies of fast breeder reactors and others) of indefinitely extending the life of the available uranium and thorium.

b) Fusion power with indefinite potential.

Energy consumption world-wide has been increasing annually. The World energy forum has predicted that fossil fuel based oil, coal and gas reserves will be exhausted in less than another 10 decades. Fossil fuel account for over 79% of the primary energy consumed in the world and 57.7% of that amount is used in transport sector and are diminishing rapidly. The exhaustion of natural resources and the accelerated demand of conventional energy have forced planners and policy makers to look for alternate sources. In addition to sustainability, climate change is another major issue that has driven the search for clean carbon-neutral fuels. In an effort to meet these goals renewable energy technologies are come into focus. Renewable energy is energy derived from sources that are regenerative and do not deplete over time. Renewable energy offers our planet a chance to reduce carbon emissions, clean air and put our civilisation on a more sustainable footing. It also offers countries around the world the chance to improve their energy security and spur economic development. Renewable energy markets grew robustly in 2008. Among new renewable wind power is the largest addition to renewable energy capacity. Renewable energy sources (RES) that use indigenous resources have the potential to provide energy with negligible emissions of air pollutants and green house gases. Renewable energy technologies produce marketable energy by converting natural phenomena or resources into useful energies. The usage of renewable energy sources is a promising prospect for the future as an alternative to conventional energy.

In 2007, the supply of energy from Renewable sources was 11% of the global energy demand. Biomass is by far the largest energy provider contributing a total of 1,150 million tons of oil equivalent (Mtoe) which translates to a 79% share of the total energy supply sourced out from these renewable sources. In terms of final energy consumption worldwide, biomass ranks fourth with a 10% share after the non-renewable fossil fuels such as oil with 34%, coal with 26%, and natural gas with 22% (Blauvelt, 2007) [2].

1.2 SOCIO-ECONOMIC IMPACTS OF ENERGY RESOURCES:

Socioeconomics or socio-economic (or sometimes social economics) is an umbrella term with different usages. 'Social economics' may refer broadly to the use of economics in the study of society. Socio economic involves the combination of social and economic factors. Socioeconomic status (SES) is an economically and sociologically combined total measure of a person's work experience and of an individual's or family's economic and social position relative to others, based on income, education and occupation. The Socio-economic status (SES) is an important determinant of health and nutritional status as well as of mortality and morbidity. Socio-economic status also influences the accessibility, affordability, acceptability and actual utilization of various available health facilities. The energy resources have both positive and negative socio economical aspect.

As now - a- days the demand of renewable energy resources increases day by day. Here we discuss mostly about the socio economic aspects of the renewable energy resources in different dimensions including rural development, Poverty alleviation, Employment, Security of supply and use and Environmental and ethical concerns.

1.2.1 RURAL DEVELOPMENT

The potential of Renewable Energy Technology (RET) to power rural development has been understood for many decades as the non renewable energy resources are exhausted day by day. The connection between clean energy and rural development has been further reinforced by international commitment to the Johannesburg Plan of Implementation (JPOI) adopted at the 2002 World Summit on Sustainable Development (WSSD) in Johannesburg. The JPOI reiterated support for Agenda 21, the outcome document of the 1992 United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit, as well as the MDGs, specifically noting the importance of modern energy services for rural development. Access to modern energy services and rural development are inextricably linked (Barnes and Floor, 1996; Chaurey *et al.*, 2004) [3, 4].

RETs are energy-providing technologies that utilize energy sources in ways that do not deplete the Earth's natural resources and are as environmentally benign as possible. By exploiting these energy sources, RETs have great potential to meet the energy needs of rural societies in a sustainable way. RETs used to produce energy for domestic use tend to do so by exploiting modern fuels or by utilizing traditional fuels in new and improved ways.

Table 1 Renewable energy sources and corresponding RETs

***RETs* & Energy source**	**Energy for domestic use**	**Electricity**
Environmentally renewable		
Solar	Solar pump, solar cooker	Solar PV (Photovoltaic)
Water (including wave/tidal		Micro and pico-hydroelectric generating plant
Wind	Wind-powered pump	Wind turbine generator
Geotherma		Geothermal generating plant
Biologically renewable		
Energy crops		Biomass generating plant
Standard crops and by-products		Biomass generating plant
Forestry and forestry byproduct	Improved cookstoves	Biomass generating plant
Animal by-products	Biogas digester	Biogas digester

Source: Renewable Energy Association 2009 [1]

Common RET options for providing energy in rural areas utilize wind, solar, small-scale hydropower and biomass resources. Wind energy is used for pumping water and generating electricity. Solar photovoltaic (PV) systems convert sunlight into electricity and solar heaters use sunlight to heat stored water. Small-scale hydropower plants are used to generate electricity. Technologies that utilize biomass include improved cook stoves for efficient burning of traditional energy sources or biogas. Biogas can also be used in small power plants to generate electricity (Alazraque -Cherni, 2008; World Bank, 2004b) [5, 6].

Renewable energy technology has a great impact on livelihoods in rural areas. Cleaner use of traditional fuels can significantly improve health by reducing acute respiratory infection and conjunctivitis, commonly caused by indoor pollution. Wider health benefits can occur too; cooking with more efficient technologies can make dietary choice and boiling of water more affordable. Women and children in particular will have more time for education, leisure and economic activity (Murphy, 2001) [7].

Access to electricity can significantly reduce the time required to devote to household activities. Electric water pumps, for example, can provide clean water, reducing the effort needed for collection. Electricity can make possible the refrigeration of vaccines and operation of medical equipment in rural health clinics. Access to radio and television can improve educational opportunities and provide entertainment. Electric lighting provides higher quality illumination than kerosene lanterns, improving opportunities for extended work and study time as well as better security, comfort and safety (World Bank, 2004b; World Bank, 2001) [6, 8].

Improved health and education, combined with more time to undertake non-energy related activities, are important goals in themselves. However, access to modern energy services also have the added value of helping local populations to engage in income-generating activities. Demand for services associated with RETs can help generate local economic activity based on these technologies, in addition to the means to power local industry. Applications of RETs for productive activities vary from mechanical wind-powered water pumping to motorized milling machines for grinding grain. Radio services can provide farmers and fishermen with weather forecasts and telecommunication services can provide growers with information on crop prices (World Bank, 2004b) [6]. As noted by Geibler (2008) [9], these applications can lead to job creation and improved livelihoods, both of which can contribute to significant increase in productivity in rural areas.

Access to modern energy enables agricultural development and the development of productive economic sectors in rural areas. Agricultural products can be processed and sold at a higher price in urban centres, a key factor for poverty alleviation. Rural households thus benefit from this value addition. Additionally, if people are connected to the national grid, they can benefit from rates that are frequently subsidised. The feasibility of financing rural energy supply, and the financial sustainability of doing so, are closely linked with the potential to promote economic productivity that also benefits poor population groups.

POVERTY ALLEVIATION:

The role of RETs for poverty alleviation is generally found to be important in all countries studied, and contrasts with the low level of development and priority assigned to the area. The role of RETs for poverty alleviation varies among countries, depending on resources, capacities, existing energy infrastructure and population distribution (urban/rural). In some of the countries (*e.g.,* Brazil), large scale renewable energy projects are an option for poverty alleviation through increased economic activity in rural areas and through adequate access to energy. Adequate availability and efficient use of energy are two essential ingredients in the efforts to alleviate poverty. Renewable energy technologies are labour intensive whereas fossil fuels are more capital intensive. Essentially, more jobs per dollar of investment in such technologies rather than conventional electricity generation technologies are created. Renewable energy can create three times as many jobs as the same level of spending on fossil fuels (DoE, 2001) [10].

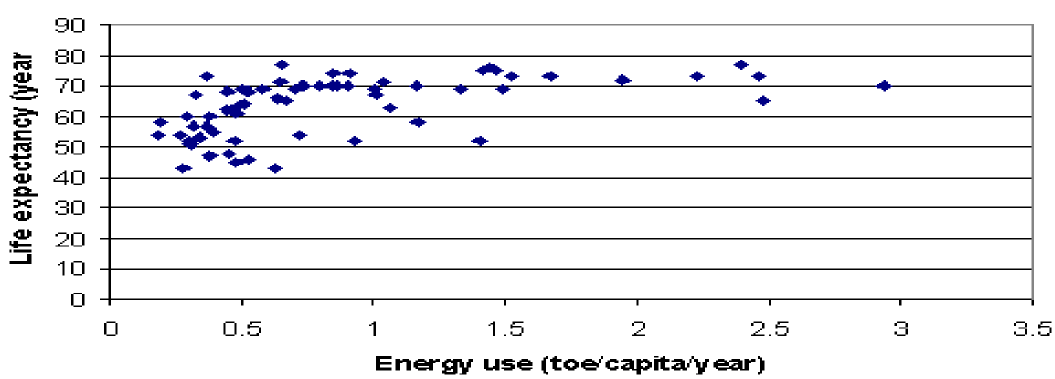
Three case studies on biodiesel, solar water heaters (SWH) and fuel wood, have been selected on the basis of contribution to poverty alleviation and their feasibility.

Biodiesel**:** The major contribution to poverty alleviation of a biodiesel programme would be job creation and economic development in disadvantaged rural areas. Further it would contribute to energy security and reduce greenhouse gas emissions. Biodiesel is produced by the process of transesterification. The by-products are a protein-rich oil cake and glycerol. Four oil crops – sunflower, soy, cotton and groundnuts - are grown for human consumption and are suited to soil and climatic conditions. These crops are often rotated with the staple food maize.

SWH (Solar Water Heaters): Manufacturing and installing SWHs would create jobs and if suitably subsidised, by including the subsidy in the existing housing grant for the poor, SWH would increase the welfare of the poor. SWHs can reduce the peak load of grid electricity and they are GHG emission neutral.

Fuelwood: Fuel wood is the most commonly used energy source of the rural poor. Even after electrification many poor households in South Africa still use fuel wood for cooking because they cannot afford the appliances and the monthly electricity bill. Fuelwood is a valuable national resource and overall fuel wood resources in South Africa are adequate but there are shortfalls in several areas and many wood lands are not sustainably managed. The fuel wood case study has been included because it is the most important energy source of the poor in Southern Africa and Africa for the next 40 years; the deficits in other African countries are apparently huge; and no clear policy has yet emerged to address the situation.

In developing countries, it is widely accepted that poverty will not be reduced without greater use of modern forms of energy. Surpassing the 1 toe/capita per year level of energy use seems to be an important instrument for development and social change. While low energy consumption is not the only cause of poverty and under-development, it does appear to be a close proxy for



many of its causes. For example, environmental degradation, poor health

Figure 1: Life expectancy and energy use per capita (Source: World Bank, 2001) [8].

care, inadequate water supplies and female and child hardship are often related to low energy consumption. As an example of this, Figure 1 shows life expectancy in 70 developing countries as a function of commercial energy use per capita per year (World Bank, 2001) [8].

Empirically it appears that social conditions improve considerably as energy consumption per capita increases. Almost 1.6 billion people in developing countries have no access to electricity. Approximately 85% of these people live in rural areas. Current projections indicate that this number will decline by only 100 million by 2015. 2.5 million People particularly women and children, still die annually of air browse diseases of the airways, because traditional fuels impair the quality of the air in their homes. Electric lights, modern means of communication, and access to new media enhance opportunities for education. Cooking and heating with modern sources of fuel or electricity improves health and reduces workloads particularly for women and children. These examples illustrate how modern energy can significantly improve living conditions and hence help to reduce rural exodus. Access to energy services is an important instrument for empowering poor people and disadvantaged population groups and thus for fostering equity.

An estimated 2.8 billion people worldwide live in poverty, of which 85 percent rely on traditional biomass fuels such as crop waste, charcoal and wood as their primary source of energy and more than 50 percent do not have access to electricity. Empirical evidence shows that energy is highly correlated to human development, as can be seen by comparing a country's human development index (HDI) ranking to per capita energy consumption (see graph below). A publication by the United Nations Development Programme (UNDP), Energizing the Millennium Development Goals, sets a foundation to assess the role of energy in economic and human development (Figure 2).

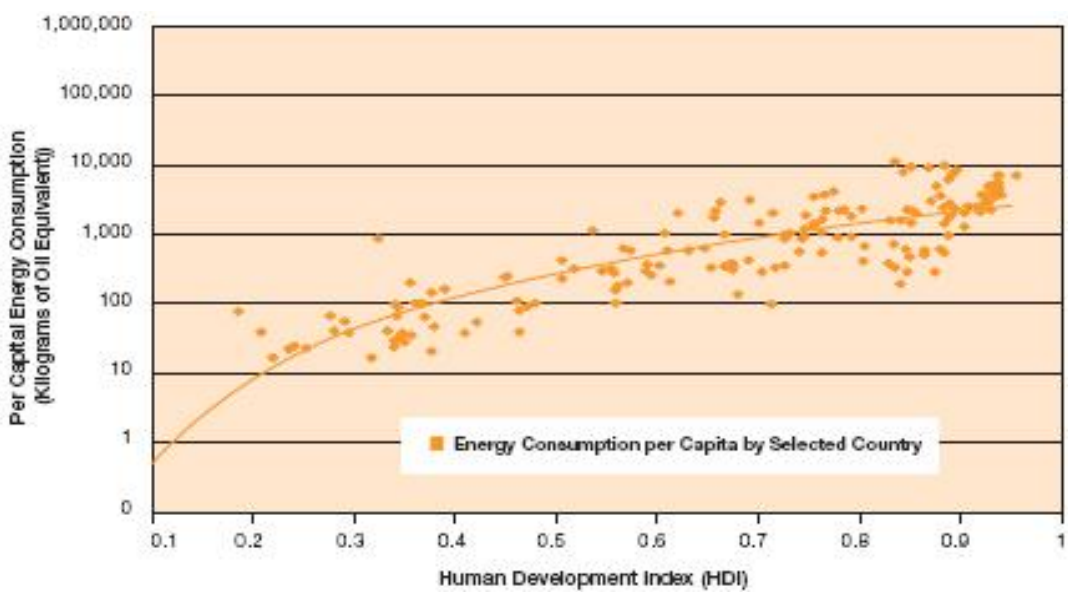


Figure 2: Energy Consumption Per Capita vs. Human Development Index (***Source:*** The Energy Challenge for Achieving the Millennium Development Goals, UN-Energy, 2005) [11]

EMPLOYMENT:

Energy sector is mainly concerned with the large scale production of energy. The companies operating in this sector are mainly involved in the process to extract the energy, manufacture the extracted energy, refine it using the available methods and distribute as per the demand. The functioning of the modern society largely depends on the energy sector and the rate of consumption of energy shows the demand of energy.

The energy industry comprises the following industries namely

- Petroleum industry
- Gas industry
- Electrical power industry
- Coal industry
- Nuclear power industry
- Renewable energy industry
- Traditional energy industry

As the renewable energy sources are more labour intensive than the other industries the employment chances is more in this sector. On the other hand the exhaustion of natural resources and the accelerated demand of conventional energy forced to look us for the renewable energy sources. As it is the clean energy source and produce less pollution, reduce green house gases, it does directly help mitigate climate change.

In order to characterise the employment effects, two terms are used which must be carefully distinguished from one another. Firstly, investments in systems and their operation results in direct employment by manufacturers, operators and service companies. These companies in turn require goods from other economic sectors and thus indirectly provide employment with subcontractors and suppliers. Thus, for example in 2004, “only” one third of the German employment attributed to wind energy is related to the production of wind power stations – the other two thirds are related to the suppliers. The spectrum here ranges from steel production to the manufacture of important components like gearing or generators. There are two types of employments; the so-called gross employment, results from the sum of the direct and indirect employment. While this figure is always positive, a satisfactory macroeconomic analysis must also consider possible negative employment effects. The so-called net employment effect represents the balance of all effects and can therefore be positive or negative. Whereas the gross employment can be determined within one scenario, the net employment must be determined as the difference between two realistic future scenarios. If positive, it represents the true additional employment due to the increase of renewable energy.

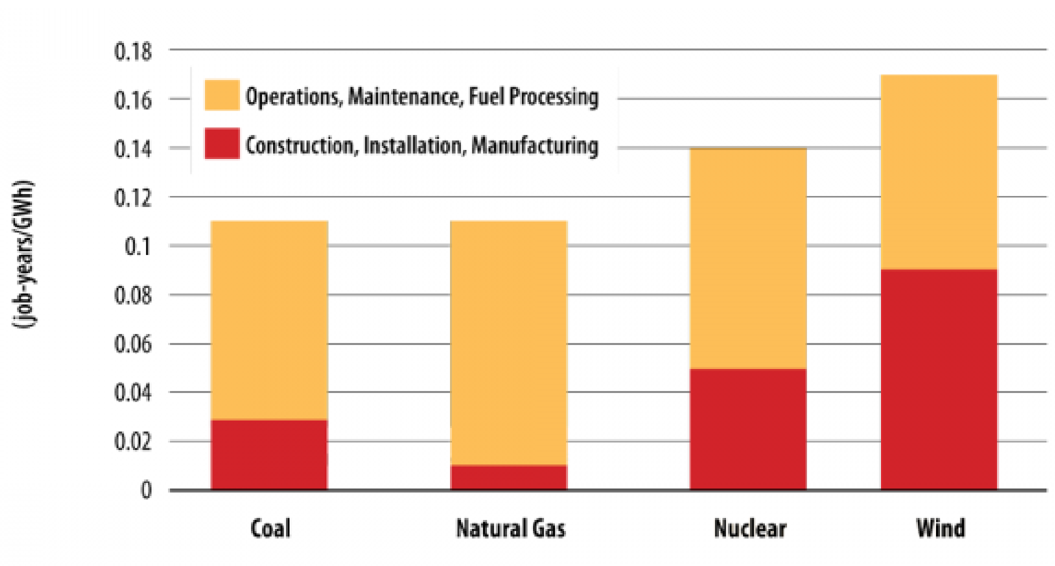


Figure 3: Average total employment for different energy technologies (Source: Wei et al., 2009) [12]

In the above figure we can see that more employment opportunity exists in the wind energy sector compared to that of other non renewable energy sectors, as wind energy has the potential to spur job creation. Several studies show that wind power creates more jobs than power generation from fossil fuels. The nature of wind power is more labour-intensive than traditional energy, and it creates jobs in both manufacturing and skilled scientific, engineering, and service roles.

India is likely to create 10.5 million job opportunities in the clean energy sector in the near future. According to a report by the Climate Group, India [13] the wind sector in India is predicted to be worth Rs 60,000 crore in 2020 and could create between 1,50,000 to 2,50,000 jobs. Similarly, the solar industry is predicted to be worth Rs 32,000 crore, could generate between 1,17,000 to 2,35,000 jobs by 2020 and small hydro and biomass sectors are expected to be worth Rs 27,000 crore and Rs 32,000 crore respectively in 2020.

The Biomass Energy Resource Centre (BERC) [14], an independent, non-profit organisation that assists communities, schools and colleges, state and local governments, businesses, utilities, and others in the development of biomass energy projects, enumerates the positive impacts of biomass energy on local and regional economic development as follows:

1. Creation and perpetuation of jobs in the region's economy since biomass fuel is locally produced, harvested, and processed.
2. Dollars spent on fuel are kept in the local economy compared with fossil fuel systems which generally export fuel dollars.
3. Employment generation in the regional economy through the building and maintenance of biomass energy systems.
4. Growth of the whole regional forest products industry (creation of new local markets) by adopting new ways of utilizing forest by products for fuel.
5. Generation of important local, state, and federal tax revenues due to all the jobs and economic activity created by biomass projects.

SECURITY OF SUPPLY AND USE:

Energy security is a term for an association between national security and the availability of natural resources for energy consumption. Access to cheap energy has become essential to the functioning of modern economies. However, the uneven distribution of energy supplies among countries has led to significant vulnerabilities. Threats to energy security include the political instability of several energy producing countries, the manipulation of energy supplies, the competition over energy sources, attacks on supply infrastructure, as well as accidents, natural disasters, rising terrorism, and dominant countries' reliance to the foreign oil supply. The limited supplies, uneven distribution, and rising costs of fossil fuels, such as oil and gas, create a need to change to more sustainable energy sources in the foreseeable future. Energy security has become one of the leading issues in the world today.

The modern world relies on a vast energy supply in order to fuel everything from transportation to communication, to security and health delivery systems. Due to their vital roles energy sources are logical targets for attacks. It is said, threats to energy sources extend beyond basic tactical aggression or terrorism. One of the leading threats to energy security is the significant increase in energy prices, either on the world markets – as has occurred in a number of energy crises over the years. In some cases the threat might come from a single energy superpower – those states able to significantly influence world markets by their action alone. Rather than just manipulating prices, such suppliers might go beyond this by suspending or terminating supplies. This has been done to apply pressure during economic negotiations - such as during the Russia-Belarus energy dispute or to apply political pressure, for example by OPEC in response to Western support for Israel in the Yom Kippur War. New threats to energy security have emerged in the form of the increased world competition for energy resources due to the increased pace of industrialization in countries such as India and China.

Energy shortage and the environmental effects of energy usage are two interlinked issues faced globally by nations. If renewable and alternate fuel sources are invented or discovered in an economically viable manner and scale, detrimental environmental effects and exhaustion of fossil fuels can be avoided. Though alternate energy sources such as wind or solar energy are growing in usage, they are hampered still by lack of portability, low efficiency and unattractive economics.

Energy dependency, such as those of India on imported oil, brings about a global imbalance. Countries that own the energy sources can set prices and hence influence the development of other countries dependent on them. This lead to the real fear of dependent nations, of being exploited or being held to ransom. The European Union (EU) being stranded with no energy supply from its supplier, the Russian owned Gazprom, during January 2009, are good examples of such a situation. Energy insecurity combined with other global issues risks fueling conflict, repeating past mistakes in history.

Recent years and months have seen increasing attention being paid to the issue of energy security. There are a number of concerns and fears such as (though not limited to):

Oil and other fossil fuel depletion (peak oil, etc)

Many fear that the world is quickly using up the vast but finite amount of fossil fuels. Some fear we may have already peaked in fossil fuel extraction and production. So much of the world relies on oil, for example, that if there has been a peak, or if a peak is imminent, or even if a peak is some way off, it is surely environmentally, geopolitically and economically sensible to be efficient in use and invest in alternatives.

Reliance on foreign sources of energy Geopolitics (such as supporting dictatorships, rising terrorism, "stability" of nations that supply energy)

There has certainly been a recognition in recent months and years that energy security is a concern. Even US president George Bush admitted during his 2006 State of the Union speech that, "Keeping America competitive requires affordable energy. And here we have a serious problem: America is addicted to oil, which is often imported from unstable parts of the world. The best way to break this addiction is through technology."

As more and more developing countries industrialize, they will naturally want more energy to quench the growth thirst. Legitimate stability and supply issues are also of concern. For example, places like Nigeria, Iraq, Iran, etc. all produce oil but present problems of varying degree for oil consuming nations, as concerns range from stable supply, to stable government. Others, such as Venezuela, "threaten" to use oil and its related profits to develop their own country and region even more.

Energy needs of poorer countries, and demands from advancing developing countries such as China and India

The western nations form a small percentage of the world population but consume far more resources. Problems such as climate change and energy depletion are thus largely caused by these nations. However, as China and India also grow rapidly there is a fear that these countries' demands for energy and resources will very quickly see the world's natural resources stripped away even more quickly given their large population sizes. Some fear that already we are close to, or are already exceeding, the planet's ability to replenish itself at a quick enough rate.

Economic efficiency versus population growth debate

Another issue is whether it is population growth or economic choices (patterns of consumption, production, etc.) that drive resource depletion and energy needs. The former implies countries like China and India are major causes of problems, and the latter implies that economic policies, perhaps even fundamental economic ideologies may be major problems.

Energy security is the state when a nation has guaranteed supplies of energy, sufficient for its current and future needs. Nations need to have energy security, to provide continuous support for their own development. For example India has large coal reserves that it can exploit for its energy needs, but this step will affect its global image as usage of coal will contribute to environmental degradation. Energy security is essential and countries have used their military strengths and diplomatic involvement to find new energy sources. Energy security involves not merely finding and locking down a source of energy and but also finding a secure and economical method to transport it.

ENVIRONMENTAL AND ETHICAL CONCERNS:

Now-a-days most of the environmental problems are associated mainly with energy sectors. Many environmental problems are associated with both coal and nuclear power generation (Pimentel *et al.*, 1994) [15]. For coal, the problems include the substantial damage to land by mining, air pollution, acid rain, global warming, as well as the safe disposal of large quantities of ash (Wolfson, 1991) [16]. For nuclear power, the environmental hazards consist mainly of radioactive waste that may last for thousands of years, accidents, and the decommissioning of old nuclear plants (Wolfson, 1991) [16]. Fossil-fuel electric utilities account for two-thirds of the sulphur dioxide, one-third of the nitrogen dioxide, and one-third of the carbon dioxide emissions in the United States (Kennedy *et al.*, 1991) [17]. The occupational and public health risks of both coal and nuclear plants are fairly high, due mainly to the hazards of mining, ore transportation and subsequent air pollution during the production of electricity. However, there are 22 times as many deaths per unit of energy related to coal than of nuclear energy production because 90,000 times greater volume of coal than nuclear ore is needed to generate an equivalent amount of electricity. Also, and as important, coal produces more diffuse pollutants than nuclear fuels during normal operation of the generating plant. Coal fired plants produce air pollutants--including sulphur oxides, nitrogen oxides, carbon dioxide, and particulates--that adversely affect air quality and contribute to acid rain.

Fossil fuel combustion especially that based on oil and coal is the major contributor to increasing carbon dioxide concentration in the atmosphere, thereby contributing to probable global warming. This climate change is considered one of the most serious environmental threats throughout the world because of its potential impact on food production and processes vital to a productive environment. Therefore, concerns about carbon dioxide emissions may discourage widespread dependence on coal use and encourage the development and use of renewable energy technologies.

A concern about global warming in recent decades has stimulated interest in using biomass for energy. Energy crops currently contribute a relatively small proportion to the total energy produced from biomass energy each year. At present there are few ethical or environmental issues associated with energy crops, but widespread use of bio energy may raise concerns in the future. Examples include the impact of monocultures of often non-native energy crops grown on large areas of land, pesticides application, use of harvesting machinery etc. There are potential implications for biodiversity and perception by public of what rural landscapes should look like.

In some regions there may be ethical issues and public opposition to energy crops if genetically modified and if using land when there are likely to be food shortages elsewhere in the world.

The environmental and social impacts of bio fuel production, which continues to grow throughout the world, vary depending on the context. Substitution of bio fuels for fossil fuels will have positive impacts, primarily in relation to reduction of greenhouse gases and possible recultivation of degraded areas. As a cash crop, bio fuels also represent a new source of agricultural income. But there are many questions about the extent to which smallholders will be able to profit from this new market. At the same time, there is a great risk that cultivation to produce bio fuels will accelerate soil degradation, overexploitation of water, and loss of biodiversity, and also compete with food production, thereby endangering food security.

Public and industrial investment in biofuels began to accelerate in the 1990s to reduce our dependence on fossil fuels. But this positive vision has a downside and early attempts to increase global production of biofuels have had serious negative impacts on the livelihoods of some of those who cultivate the land, on the sustainability of cultivation systems and on biodiversity. There are well-documented claims that there can be serious harmful environmental and social consequences of agro fuel production and that these have been grossly underestimated. It also appears that the alleged benefits of agro fuels have been exaggerated. This debate has received increasing attention owing to the food crisis caused by a steep increase in prices without a corresponding increase in income for the food-insecure. One cause of this crisis arises from the production of agro fuel, which competes with food production for the use of land and water.
Monoculture production of feedstock for agro fuel can harm the environment in a number of ways. With the possible exception of sugar-cane production for ethanol, there is increasing evidence that when the whole life cycle of the production, distribution and use of agro fuel is taken into account, and when direct and indirect effects are counted, agro fuel production actually increases GHG emissions and thereby intensifies rather than mitigates global warming. Compounding these negative environmental effects of agro fuel production is the claim by critics that monoculture production is harmful to biodiversity, which in turn has considerable consequences for the necessary food diversity required for adequate diets. Furthermore, the production of agro fuel causes both competition for water and the pollution of remaining water resources. Palm oil for biodiesel is heavily dependent on water. The *Jatropha* bush is less dependent on water and can grow in marginal and dry areas, but its yield is low compared with when it is grown in more fertile land or with more access to water.

Impact on food security

The second issue with large-scale production of agro fuel is the impact on food security. Concentration, eviction and the transformation of living conditions in rural areas are among the results of liquid agro fuel production and these have serious consequences for food security. Production of feedstock for agro fuel is, by its very nature, best suited for large tracts of land, and it is a monoculture production, with all its negative implications. Large-scale monoculture production opens the land for foreign and outside investors on an unprecedented scale. Traditional, small-scale agriculture in developing countries is not attractive for investors, but agro fuel is, as long as there is a guaranteed market. The implication of this is ominous – it may lead to a process of marginalization or eviction of smallholders to an unprecedented degree, either transforming them into badly paid workers or adding them to the swelling number of urban poor.

Liquid bio-fuel produced for other purposes can have clearly positive consequences under certain specified conditions. It can provide improved access to modern forms of energy (electricity and other forms) in rural areas, and have positive impacts on food security (e.g. fewer health problems through reducing the use of fuel wood, access to water through bio energy-propelled water pumps, and simple drying devices that reduce crop losses).

It is also not excluded that larger agro fuel projects can have a beneficial impact when organized in a proper way and provide safeguards to protect the poor and food-insecure, avoid harmful displacement of water resources, and ensure environmental sustainability by avoiding pollution and net increases in GHG emissions.

CONCLUSION

Secure energy supplies, an efficient use of resources, affordable prices and innovative solutions are crucial to our long-term sustainable growth, job creation and quality of life. Renewable energy technologies will introduce new conflicts. For example, a basic parameter controlling renewable energy supplies is the availability of land. Relatively little land available for other uses, such as biomass production and solar technologies. Population growth is expected to further exacerbate the demands for land. Therefore, future land conflicts could be intense.

Everyone hopes that his or her own activities cause no harm to others and, indeed, may help; however, energy supply has very considerable impacts. Negative impacts are the most worrying. For instance use of fossil fuels cause local pollution and damage health, but most importantly increase climate change. In addition, nuclear power adds to the legacy of radioactive waste and, by default, to the politics of nuclear warfare. Renewable energy has less environmental impact and may have beneficial impacts on employment, security and environment.

As individuals, we have a duty to consider the energy we use and its impacts. Thus we may: change electricity supplier to have ‘green (renewable) electricity’, insulate buildings, have solar water heating, install biomass heating (e.g. wood-pellet stoves), change to a low-energy car (perhaps hybrid or multi/bio fuel), offset air-travel fuel, lobby officials and exercise our vote for environmental policies. There is hardly any action using energy that cannot be reduced, so decreasing the impact (e.g. changing thermostats, turning devices off, low-energy lighting, ‘A class’ white-goods, and travel reduction).

Energy is the prime mover of economic growth. Availability of energy with required quality of supply is not only key to sustainable development, but also the commercial energy has a direct impact and influence on the quality of service in the fields of education, health and, in fact, even food security. Inadequacy of energy supply would obviously affect very adversely these vital and essential requirements of any society. There is, therefore, an urgent need to enhance substantially the energy availability at a rapid pace so that aspirations of those who have remained insulated from such important inputs and services are fulfilled and they are enabled to have a reasonable access.

REFERENCES:

[1] Renewable Energy Association (2009) *Energy and environment*. At http://www.r-ea.net/info/energy-info (accessed 14 April 2010).

[2] Blauvelt, E. 2007. Biomass – The largest source of renewable energy. Retrieved from the World Energy Discussion on-line database on the World Wide Web: www. worldenergydiscussion.blogspot.com/2007/08/biomass-largest-source-of-renewable.html

[3] Barnes D and Floor W (1996). Rural Energy in Developing Countries: A Challenge for Economic Development. *Annual Review of Energy and Environment*, No. 21.

[4] Chaurey A, Ranganathana M and Mohanty P (2004). Electricity access for geographically disadvantaged rural communities — technology and policy insights. *Energy Policy*, No.32.

[5] Alazraque-Cherni J (2008). Renewable Energy for Rural Sustainability in Developing Countries. *Bulletin of Science, Technology & Society*. Vol. **28**, No. 2 (April).

[6] World Bank (2004b). Renewable Energy for Development: the role of the World Bank Group. Washington DC: World Bank.

[7] Murphy JT (2001). Making the energy transition in rural East Africa: Is leapfrogging an alternative?" *Technological Forecasting and Social Change*, No. 68.

[8] World Bank (2001). The World Bank Group’s Energy Program: Poverty Reduction, Sustainability and Selectivity. Washington DC: World Bank.

[9] Geibler JV, Bringezu S, Schutz H. Integrating land-use implications of biomass trade in national policies: Towards a sustainable biomass strategy, Paper published in Conference on “Impact Assessment of Land use change”, Berlin, 6-9 April, 2008.

[10] http://www.eren.doe.gov/consumerinfo/

[11] http://www.unhabitat.org/downloads/docs/920_88725_The Energy challenge for achieving the millennium development goals.pdf.

[12] Wei, M., Patadia, S., & Kammen, D. M. (2010). Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US? *Energy Policy*, *38*(2), 919-931.

[13] www.theclimategroup.org/programs/**india**/

[14] www.biomasscenter.org

[15] Pimentel, D., M. Herdendorf, S. Eisenfeld, L. Olanden M. Carroquino, C. Corson, J. McDade Y. Chung, W. Cannon, J. Roberts, L. Bluman, and J. Gregg. (1994). Achieving a secure energy future: environmental and economic issues. Ecological Economics, **9**: 201-219.

[16] Wolfson, R. 1991. Nuclear Choices. MIT Press, Cambridge, MA.

[17] Kennedy, T., J. Finnell, and D. Kumor. (l991). Considering environmental costs in energy planning: alternative approaches and implementation. Pages 145-150 in T. R. Mancini, K. Watanabe and D. E. Klett, eds. Solar Engineering 1991. American Society of Mechanical Engineering, New York.

UNIT 8: INTERNATIONAL TREATIES & CONVENTION ON ENVIRONMENTAL MITIGATION

UNIT STRUCTURE

8.1 INTRODUCTION

A treaty is a compact, or contract, made between or among sovereign nations, involving matters of each country's public interest. It has the force of law within each signing nation. Treaties are the formal conclusion of the negotiating process rather than an intermediate step. Ideally, they include both the formal commitment of nations and mechanisms for enforcement, although many international environmental treaties fall short on the adequacy of enforcement mechanisms. A convention is also an international agreement, although it often has a narrower scope and is less politically motivated than a treaty. In addition, a convention may consist of agreed-upon arrangements that precede a formal treaty or that serve as the basis for an anticipated treaty. International environmental agreements are generally multilateral (or sometimes bilateral) treaties. The majority of such conventions deal directly with specific environmental issues. There are also some general treaties with one or two clauses referring to environmental issues but these are rarer. There are about 1000 environmental law treaties in existence today where UNFCCC occupies a handsome amount of space; no other area of law has generated such a large body of conventions on a specific topic.

8.2 UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) is an international environmental treaty with the goal of achieving stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system– commonly believed to be around 2°C above the pre-industrial global average temperature. It is informally known as the Earth Summit which was held in Rio de Janeiro from June 3 to 14, 1992. On June 12, 1992, 154 nations signed the UNFCCC. The Convention on Climate Change sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases. Under the Convention, governments:

- gather and share information on greenhouse gas emissions, national policies and best practices
- national strategies for addressing greenhouse launch gas emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries
- cooperate in preparing for adaptation to the impacts of climate change

The UNFCCC was opened for signature on May 9, 1992, after an Intergovernmental Negotiating Committee produced the text of the Framework Convention as a report following its meeting in New York from April 30 to May 9, 1992. It entered into force on March 21, 1994. UNFCCC has 194 parties, as of May 2011. The treaty itself set no mandatory limits on greenhouse gas emissions for individual countries and contains no enforcement mechanisms. In that sense, the treaty is considered legally non-binding. Instead, the treaty provides for updates which are called "protocols" that would set mandatory emission limits. The parties to the convention have met annually from 1995 in Conferences of the Parties (COP) to assess progress in dealing with climate change. In 1997, the Kyoto Protocol was concluded and established legally binding obligations for developed countries to reduce their greenhouse gas emissions. The Kyoto Protocol has become much better known than the UNFCCC itself.

Parties to UNFCCC are classified as:

- Annex I countries – industrialized countries and economies in transition
- Annex II countries – developed countries which pay for costs of developing countries
- None Annex I countries - Developing countries.

Annex I countries which have ratified the Protocol have committed to reduce their emission levels of greenhouse gasses to targets that are mainly set below their 1990 levels. They may do this by allocating reduced annual allowances to the major operators within their borders. These operators can only exceed their allocations if they buy emission allowances, or offset their excesses through a mechanism that is agreed by all the parties to UNFCCC.

There are **40 Annex I countries plus the European Union**. These countries are classified as industrialized countries and countries in transition:

Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom, United States of America

Annex II countries are a sub-group of the Annex I countries. There are **23 Annex II countries plus the European Union**. These countries are classified as developed countries which pay for costs of developing countries:

Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States of America

Developing countries are not required to reduce emission levels unless developed countries supply enough funding and technology. Provision for keeping the developing countries out of the emission restrictions mechanisms, is intended to serve **three purposes**:

- it avoids restrictions on their development, because emissions are strongly linked to industrial capacity
- developing countries can sell emissions credits to nations whose operators have difficulty meeting their emissions targets
- developing countries get monetary benefit and green technologies for low-carbon investments from Annex II countries.

A key element of the UNFCCC is that parties should act to protect the climate system "on the basis of equality and in accordance with their **common but differentiated responsibilities** and respective capabilities." The principle of 'common but differentiated responsibility' includes two fundamental elements. The first is the common responsibility of Parties to protect the environment, or parts of it, at the national, regional and global levels. The second is the need to take into account the different circumstances, particularly each Party's contribution to the problem and its ability to prevent, reduce and control the threat. Another element underpinning the UNFCCC is the **polluter pays principle**. This means that the party responsible for producing pollution is responsible for paying for the damage done to the natural environment.

CONFERENCE OF THE PARTIES

Since the UNFCCC entered into force, the parties have been meeting annually in Conferences of the Parties (COP) to assess progress in dealing with climate change, and beginning in the mid-1990s, to negotiate the Kyoto Protocol to establish legally binding obligations for developed countries to reduce their greenhouse gas emissions. From 2005 the Conferences have met in conjunction with Meetings of Parties of the Kyoto Protocol (MOP), and parties to the Convention that are not parties to the Protocol can participate in Protocol-related meetings as observers.

1995 – COP 1, The Berlin Mandate

The first UNFCCC Conference of Parties took place in March 1995 in Berlin, Germany. It voiced concerns about the adequacy of countries' abilities to meet commitments under the Body for Scientific and Technological Advice (SBSTA) and the Subsidiary Body for Implementation (SBI).

1996 – COP 2, Geneva, Switzerland

COP 2 took place in July 1996 in Geneva, Switzerland. Its Ministerial Declaration was noted (but not adopted) July 18, 1996, and reflected a U.S. position statement presented by Timothy Wirth, former Under Secretary for Global Affairs for the U.S. State Department at that meeting, which

- Accepted the scientific findings on climate change proffered by the Intergovernmental Panel on Climate Change (IPCC) in its second assessment (1995);
- Rejected uniform "harmonized policies" in favor of flexibility;
- Called for "legally binding mid-term targets."

1997 – COP 3, The Kyoto Protocol on Climate Change

After intensive negotiations, it adopted the Kyoto Protocol, which outlined the greenhouse gas emissions reduction obligation for Annex I countries, along with what came to be known as Kyoto mechanisms such as emissions trading, clean development mechanism and joint implementation. Most industrialized countries and some central European economies in transition agreed to legally binding reductions in greenhouse gas emissions of an average of 6 to 8% below

1990 levels between the years 2008–2012, defined as the first emissions budget period. COP 3 took place in December 1997 in Kyoto, Japan.

1998 – COP 4, Buenos Aires, Argentina

COP 4 took place in November 1998 in Buenos Aires. It had been expected that the remaining issues unresolved in Kyoto would be finalized at this meeting. However, the complexity and difficulty of finding agreement on these issues proved insurmountable, and instead the parties adopted a 2-year "Plan of Action" to advance efforts and to devise mechanisms for implementing the Kyoto Protocol, to be completed by 2000. During COP4, Argentina and Kazakhstan expressed their commitment to take on the greenhouse gas emissions reduction obligation, the first two non-Annex countries to do so.

1999 – COP 5, Bonn, Germany

COP 5 was primarily a technical meeting, and did not reach major conclusions. It took place between October 25 and November 5, 1999, in Bonn, Germany.

2000 – COP 6, The Hague, Netherlands

The discussions evolved rapidly into a high-level negotiation over the major political issues. These included major controversy over the United States' proposal to allow credit for carbon "sinks" in forests and agricultural lands, satisfying a major proportion of the U.S. emissions reductions in this way; disagreements over consequences for non-compliance by countries that did not meet their emission reduction targets; and difficulties in resolving how developing countries could obtain financial assistance to deal with adverse effects of climate change and meet their obligations to plan for measuring and possibly reducing greenhouse gas emissions.

2001 – COP 6, Bonn, Germany

COP 6 negotiations resumed July 17–27, 2001, in Bonn, Germany. The agreements included:

- **Flexible Mechanisms**: The "flexibility" mechanisms which the United States had strongly favored when the Protocol was initially put together, including emissions trading; Joint Implementation (JI); and the Clean Development Mechanism (CDM) which allow industrialized countries to fund emissions reduction activities in developing countries as an alternative to domestic emission reductions.
- **Carbon sinks**: It was agreed that credit would be granted for broad activities that absorb carbon from the atmosphere or store it, including forest and cropland management, and

re-vegetation, with no over-all cap on the amount of credit that a country could claim for sinks activities.

- **Compliance**: Final action on compliance procedures and mechanisms that would address non-compliance with Protocol provisions was deferred to COP 7, but included broad outlines of consequences for failing to meet emissions targets that would include a requirement to "make up" shortfalls at 1.3 tons to 1, suspension of the right to sell credits for surplus emissions reductions, and a required compliance action plan for those not meeting their targets.
- **Financing**: There was agreement on the establishment of three new funds to provide assistance for needs associated with climate change: (1) a fund for climate change that supports a series of climate measures; (2) a least-developed-country fund to support National Adaptation Programs of Action; and (3) a Kyoto Protocol adaptation fund supported by a CDM levy and voluntary contributions.

2001 – COP 7, Marrakech, Morocco

At the COP 7 meeting in Marrakech, Morocco from October 29 to November 10, 2001, negotiators wrapped up the work on the Buenos Aires Plan of Action, finalizing most of the operational details and setting the stage for nations to ratify the Kyoto Protocol.

The main decisions at COP 7 included:

- Operational rules for international emissions trading among parties to the Protocol and for the CDM and joint implementation;
- A compliance regime that outlined consequences for failure to meet emissions targets but deferred to the parties to the Protocol, once it came into force, the decision on whether those consequences would be legally binding;
- Accounting procedures for the flexibility mechanisms;
- A decision to consider at COP 8 how to achieve a review of the adequacy of commitments that might lead to discussions on future commitments by developing countries.

2002 – COP 8, New Delhi, India

COP8 adopted the Delhi Ministerial Declaration that, amongst others, called for efforts by developed countries to transfer technology and minimize the impact of climate change on developing countries. It is also approved the New Delhi work programme on Article 6 of the Convention. It took place from October 23, – November 1, 2002.

2003 – COP 9, Milan, Italy

At COP9 (December 1 – 12, 2003), the parties agreed to review the first national reports submitted by 110 non-Annex I countries. The parties also agreed to use the Adaptation Fund established at COP7 in 2001 primarily in supporting developing countries better adapt to climate change.

2004 – COP 10, Buenos Aires, Argentina

COP10 discussed the progress made since the first Conference of the Parties 10 years ago and its future challenges, with special emphasis on climate change mitigation and adaptation. In this convention, the Buenos Aires Plan of Action was adopted to promote developing countries better adapt to climate change. The parties also began discussing the post-Kyoto mechanism, on how to allocate emission reduction obligation following 2012, when the first commitment period ends. It took place from December 6 – 17, 2004.

2005 – COP 11/MOP 1, Montreal, Canada

COP 11 was the first *Meeting of the Parties* (MOP-1) to the Kyoto Protocol since their initial meeting in Kyoto in 1997 which took place between November 28 and December 9, 2005, in Montreal, Quebec, Canada. It was the first *Meeting of the Parties* (MOP-1) to the Kyoto Protocol since their initial meeting in Kyoto in 1997. The **Montreal Action Plan** is an agreement hammered out at the end of the conference to "extend the life of the Kyoto Protocol beyond its 2012 expiration date and negotiate deeper cuts in greenhouse-gas emissions.

2006 – COP 12/MOP 2, Nairobi, Kenya

It took place between November 6 and 17, 2006 in Nairobi, Kenya where the parties adopted a five-year plan of work to support climate change adaptation by developing countries, and agreed on the procedures and modalities for the Adaptation Fund. They also agreed to improve the projects for clean development mechanism.

2007 – COP 13/MOP 3, Bali, Indonesia

Agreement on a timeline and structured negotiation on the post-2012 framework (the end of the first commitment period of the Kyoto Protocol) was achieved with the adoption of the Bali Action Plan in this convention that took place between December 3 and December 15, 2007, at Nusa Dua, in Bali, Indonesia.

2008 – COP 14/MOP 4, Poznan, Poland

The convention took place from December 1 to12, 2008 in Poland. Delegates agreed on principles for the financing of a fund to help the poorest nations cope with the effects of climate change and they approved a mechanism to incorporate forest protection into the efforts of the international community to combat climate change.

2009 – COP 15/MOP 5, Copenhagen, Denmark

The overall goal for the COP 15/MOP 5 was to establish an ambitious global climate agreement for the period from 2012 when the first commitment period under the Kyoto Protocol expires that took place in Copenhagen, Denmark, from December 7 to December 18, 2009.

2010 – COP 16/MOP 6, Cancun, Mexico

COP 16 was held in Cancun, Mexico, from November 29 to December 10, 2010.

2011 – COP 17/MOP 7, Durban, South Africa

The 2011 COP 17 is to be hosted by Durban, South Africa, from November 28 to December 9, 2011.

2012 – COP 18/MOP 8

Two countries, Qatar and South Korea, are currently bidding to host the 2012 COP 18.

INDIA AND UNFCCC

India signed the UNFCCC on 10 June 1992 and ratified it on 1 November 1993. Under the UNFCCC, developing countries such as India do not have binding GHG mitigation commitments in recognition of their small contribution to the greenhouse problem as well as low financial and technical capacities. The Ministry of Environment and Forests is the nodal agency for climate change issues in India. It has constituted Working Groups on the UNFCCC and Kyoto Protocol. Work is currently in progress on India's initial National Communication (NATCOM) to the UNFCCC.

The Kyoto Protocol to the UNFCCC was adopted in 1997 and requires developed countries and economies in transition listed in Annex B of the Protocol, to reduce their GHG emissions by an average of 5.2% below 1990 levels. Article 12 of the Kyoto Protocol provides for the Clean Development Mechanism (CDM). India acceded to the Kyoto Protocol on 26 August 2002.

Current initiatives in India to improve understanding of climate change, and comply with the requirements of the UNFCCC include:

- Preparation of the country's initial National Communication to the UNFCCC by the Government of India. All Parties are required to communicate a national inventory of GHGs, and a general description of steps taken for the implementation of the Convention. The GHG inventory for the country is being prepared for the base year 1994, and will cover five sectors: energy, industrial processes, agriculture, forestry, and waste. This exercise involved detailed work on estimation of sectoral GHG emissions and identification of country-specific emission factors. Vulnerability and adaptation assessment is also part of the National Communication project.
- An extensive methane measurement campaign coordinated by the National Physical Laboratory in 1991. Measurements were undertaken in major paddy growing regions of the country under different rice environs for the whole cropping period. Emissions from paddy cultivation in India were estimated to be about 4 Tg/year (a tenth of United States Environmental Protection Agency estimates obtained by extrapolating European and American data to India).
- Several measures being undertaken in the country, which contribute to GHG mitigation.
- Establishment of the Technology Information, Forecasting and Assessment Council under the Department of Science and Technology, which facilitates the transfer of environmentally sound technology.
- Extensive efforts in conservation of forests and biodiversity. The Participatory Forest Management Strategy of the Government of India secures rehabilitation of degraded areas, conservation of biodiversity, along with sharing of benefits with local people. In situ conservation is undertaken through a system of protected areas, including 75 national parks and 421 wildlife sanctuaries, covering 146,000 square km.
- Support of the Asian Least-cost Greenhouse Gas Abatement Strategy (ALGAS) study, by the Government of India. The study developed a national inventory of GHG sources and sinks, and identified potential mitigation options. Country-specific emission factors have been developed for methane emissions from paddy cultivation, carbon dioxide emissions from Indian coal, etc.
- Coastal zone management plans by all coastal states and Union Territories as per the Coastal Zone Regulation Notification of 1991by all coastal states and Union Territories. The Government of India has set up Standing Committees for monitoring development in such fragile ecosystems as islands.

- Generation of much-needed information about the vulnerability to climate change under the ongoing Indo-UK Climate Change Impacts Programme supported by the Ministry of Environment and Forests, Government of India. Several research organizations and academic institutions in the country are also engaged in research on climate change impacts. The Indian Institute of Tropical Meteorology, Pune, and the Indian Institute of Technology, Delhi are engaged in developing climate change scenarios for India.
- Replacement of the existing cyclone detection radars with state-of-art Doppler Weather Radars in a phased manner. The cities of Calcutta and Chennai have been the first ones to witness their use. Indigenous Doppler weather radar is being developed under a collaborative Programme of the IMD with the Indian Space Research Organization (IMD, 2001).
- Involvement of a number of governmental and independent agencies in climate change research in India. The India Meteorological Department (IMD) observes climatic parameters at surface and upper air observatories throughout the country. IMD's network includes 559 surface observatories, more than 8000 rainfall monitoring stations, 100 satellite-based data collection platforms in remote areas, 203 voluntary observing ships, 10 cyclone detection radars, and 17 storm detection radars. Since 1983, IMD has maintained a meteorological observatory at the Indian Antarctic station. This data is scrutinized and archived at the National Data Centre, Pune, and used to study, predict, and determine the effects of climate change.
- Using satellite data received from INSAT to provide cloud imageries in the visible and infrared channels, which in turn, are used to derive cloud motion vectors, sea surface temperatures, and outgoing long wave radiation.
- Key role played by Indian scientists in national and international climate research efforts such as the IIOE (International Indian Ocean Expedition), MONEX (Monsoon Experiment), INDOEX (Indian Ocean Experiment), World Climate Research Programme, Global Observing System, and International Geosphere-Biosphere Programme.

New approaches to enhance mitigation action are currently being discussed in the context of the UNFCCC, in order to set the stage for the future of the Kyoto Protocol and for a larger involvement of all countries in emissions reduction policies. But most project activities remain concentrated in few countries and few sectors, with the complexity of the project cycle and related transaction costs acting as a barrier to environmentally friendly investments. The challenge is to set up methodologies applicable to multiple projects, regardless of project specific conditions. This may contribute to reduce transaction costs, increase transparency, ensure better predictability of emission reductions and allow a faster project cycle. Following the recent Cancun decision on "further guidance relating to the clean development mechanism", there is a stronger mandate for the clean development mechanism (CDM). Executive Board to work on standardization. Yet, considering limited availability of financial resources, work needs to be concentrated on clear priorities. In this regard, the challenge of standardization should be considered within the wider exercise of streamlining methodologies and facilitating their applicability in under-represented regions, thus enhancing geographical distribution of the CDM. The Executive Board has a challenging work ahead and next UNFCCC sessions, including Durban, are expected to further pave the way to the improvement of the CDM. While being also a political issue, with potential effects on the carbon market, standardization should remain a tool to overcome current weaknesses of the CDM and improve investment in clean technologies.

INTERNATIONAL TREATIES AND CONVENTIONS ON ENVIRONMENTAL MITIGATION

The number and range of international agreements on environmental practices and policies have grown tremendously since the 1970s. Some estimates suggest that there were around 900 agreements in force in 1992, including regional and bilateral treaties. Major accords reached on issues related to global environmental change include the Montreal Protocol on Substances that Deplete the Ozone Layer (1987), the United Nations Framework Convention on Climate Change (1992), the Convention on Biological Diversity (1992), and the various agreements forged as part of the United Nations Conference on Environment and Development in 1992.

Responding to concerns that human activities were increasing concentrations of greenhouse gases (such as carbon dioxide and methane) in the atmosphere, most nations of the world joined together in 1992 to sign the United Nations Framework Convention on Climate Change (UNFCCC). The United Nations Conference on Environment and Development (UNCED) was held in Rio de Janeiro in June 1992 and was the world's most comprehensive organized response to international environmental degradation. UNCED delegates sought to adopt conventions on greenhouse gases and biodiversity; to enunciate in an Earth Charter the principles by which human should conduct them in relation to the environment; to adopt a program of action, called Agenda 21, to implement the Earth Charter; and to develop a set of institutional and financial arrangements to support such measures.

The Framework Convention on Climate Change was one of two binding treaties opened for signature at UNCED in 1992. The treaty, also known as the Climate Convention, addressed potential human-induced global warming by pledging countries to seek "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." Although stated only in general terms, the Climate Convention parties agreed to attempt to limit emissions of greenhouse gases, mainly carbon dioxide and methane.

Although signed at UNCED, the Climate Convention was negotiated through a separate process under the Intergovernmental Negotiating Committee for the Framework Convention on Climate Change. The text was adopted at New York on 9 May 1992 and opened for signature at Rio de Janeiro from 4 to 14 June 1992 and thereafter at United Nations Headquarters from 20 June 1992 to 19 June 1993. By that date the convention had received 166 signatures.

The United States was one of the first nations to ratify this treaty. It included a legally nonbinding, voluntary pledge that the major industrialized, developed nations would reduce their greenhouse gas emissions to 1990 levels by the year 2000. However, as it became apparent that major nations such as the United States and Japan would not meet the voluntary stabilization target by 2000, parties to the treaty decided in 1995 to enter into negotiations on a protocol to establish legally binding limitations or reductions in greenhouse gas emissions. These negotiations were completed at a meeting held in Kyoto, Japan, 1–10 December 1997. There was wide disparity among key players especially on three items: (1) the amounts of binding reductions in greenhouse gases to be required, and the gases to be included in these requirements; (2) whether developing countries should be part of the requirements for greenhouse gas limitations; and (3) whether to allow emissions trading and joint implementation, which allow credit to be given for emissions reductions to a country that provides funding or investments in other countries that bring about the actual reductions in those other countries or locations where they may be cheaper to attain.

8.3 VARIOUS CONVENTION AND TREATIES AT INTERNATIONAL LEVEL AIMING AT CO_2 MITIGATION

The various treaties and conventions at international level aiming at CO_2 mitigation are discussed below-

Kyoto Protocol

Under the Climate Change Convention agreed at the Rio Earth Summit in 1992, industrialised countries agreed to stabilise their emissions of CO_2 at 1990 levels by the year 2000. But by 1996 most of these countries had accepted the scientific case for significant reductions in their emissions and promised to set reductions target by the end of 1997. It then became very obvious that most countries wouldn't be able to meet the 2000 target, and many countries abandoned the 1992 agreements. President Clinton postponed the stabilisation of US emission to 2012 and ruled out real cuts before 2017. The European Union called for a 15% cut by all industrialised countries by 2010.

In December 1997, scientists and diplomats from 160 countries gathered in Kyoto, Japan, for the UN Climate Convention. The aim was to find acceptable ways forward. Many countries, including the US, demanded 'flexibility measures' which would allow them to bank, borrow or trade spare emission 'permissions'. It was also argued that flexibility would allow countries to emit more greenhouse gases if they plant more trees. The European Union negotiators were against flexibility measures and wanted to implement its targets collectively. The Kyoto Conference eventually settled for stability targets rather than cuts, and it adopted flexibility measures.

Under the Kyoto Protocol, rich industrial countries agreed to reduce their emissions of greenhouse gases by an average of 5.2% by 2010. Developing countries were not set formal emission limits, partly because to do so would unfairly inhibit their persuit of economic growth. But the political debate between countries continues, and the US has insisted that some developing countries accept emission targets before it is willing to reduce its own greenhouse gas emissions. Most other industrialised countries (including the European Union and Japan) have promised to bring the Kyoto Protocol into law.

A new proposal, unveiled in June 1999, is designed to break this deadlock. The new plan requires developing countries to improve the carbon efficiency of their economies rather than requiring them to accept absolute limits on emission. Some developing countries are already making great progress in this direction. China, for example, has increased the carbon efficiency of its economy by 47% over the past 20 years, mainly as a result of measures designed to reduce urban air pollution. Supporters of the new plan point out that it reduces the scope for trading in rights to emit greenhouse gases.

Trading of rights to emit greenhouse gases is a controversial theme. But one had taken seriously under the Kyoto Protocol. Under current plans, developing countries would receive fixed targets above the current emission levels to allow for economic growth. Rich countries could buy the excess capacity and thus avoid the need to reduce their own output. Critics of the trading approach argue that it could well serve to increase overall emissions of greenhouse gases.

An alternative approach is the so-called clean development mechanism (CDM), an incentive scheme proposed at the 1998 Buenos Aires Climate summit. The CDM approach seeks to give 'carbon credits' (credit to industrialised countries towards the emission targets agreed in the Kyoto Protocol) in developing countries by investing in renewable energy projects or by enlarging carbon sinks such as forests. But countries are divided over the question of which energy technologies should count and the tendency to promote coal-fired power stations at the expense of renewable energy technologies.

The five principal concepts of the Kyoto Protocol are

- Commitments to the Annex-countries. The heart of the Protocol lies in establishing commitments for the reduction of greenhouse gases that are legally binding for Annex I countries. Dividing the countries in different groups is one of the key concepts in making commitments possible, where only the Annex I countries in 1997, were seen as having the economic capacity to commit themselves and their industry. Making only the few nations in the Annex 1 group committed to the protocols limitations.
- Implementation. In order to meet the objectives of the Protocol, Annex I countries are required to prepare policies and measures for the reduction of greenhouse gases in their respective countries. In addition, they are required to increase the absorption of these gases and utilize all mechanisms available, such as joint implementation, the clean development mechanism and emissions trading, in order to be rewarded with credits that would allow more greenhouse gas emissions at home.
- Minimizing Impacts on Developing Countries by establishing an adaptation fund for climate change.
- Accounting, Reporting and Review in order to ensure the integrity of the Protocol.
- Compliance. Establishing a Compliance Committee to enforce compliance with the commitments under the Protocol.

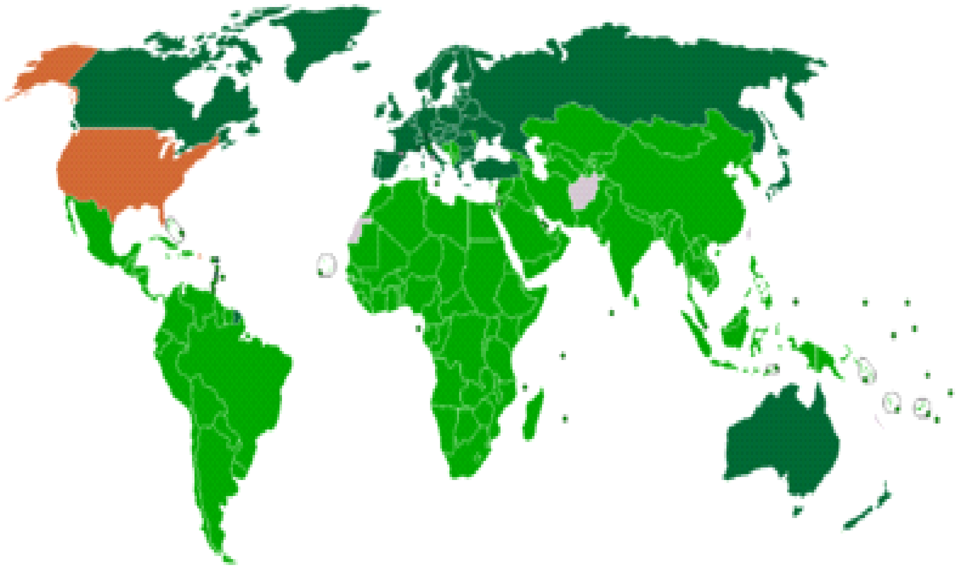


Fig. 1: Participation of Countries in the Kyoto Protocol, as of December 2010

Green : Countries that have signed and ratified the treaty, (Annex I & II countries in dark green)

Grey : Countries that have not yet decided, *Brown* : No intention to ratify at this stage.

Copenhagen Accord

The first phase of the Kyoto Protocol expires in 2012. The United Nations Climate Change Conference in Copenhagen in December 2009 was the next in an annual series of UN meetings that followed the 1992 Earth Summit in Rio. In 1997 the talks led to the Kyoto Protocol, Copenhagen was considered the world's chance to agree a successor to Kyoto that would bring about meaningful carbon cuts.

The Accord

- Endorses the continuation of the Kyoto Protocol.
- Underlines that climate change is one of the greatest challenges of our time and emphasises a "strong political will to urgently combat climate change in accordance with the principle of common but differentiated responsibilities and respective capabilities"
- To prevent dangerous anthropogenic interference with the climate system, recognizes "the scientific view that the increase in global temperature should be below 2 degrees Celsius", in a context of sustainable development, to combat climate change.
- Recognizes "the critical impacts of climate change and the potential impacts of response measures on countries particularly vulnerable to its adverse effects" and stresses "the need to establish a comprehensive adaptation programme including international support"

- Recognizes that "deep cuts in global emissions are required according to science" (IPCC AR4) and agrees cooperation in peaking (stopping from rising) global and national greenhouse gas emissions "as soon as possible" and that "a low-emission development strategy is indispensable to sustainable development"
- States that "enhanced action and international cooperation on adaptation is urgently required to... reduce vulnerability and build resilience in developing countries, especially in those that are particularly vulnerable, especially least developed countries (LDCs), small island developing states (SIDS) and Africa" and agrees that "developed countries shall provide adequate, predictable and sustainable financial resources, technology and capacity-building to support the implementation of adaptation action in developing countries"
- About mitigation agrees that developed countries (Annex I Parties) would "commit to economy-wide emissions targets for 2020" to be submitted by 31 January 2010 and agrees that these Parties to the Kyoto Protocol would strengthen their existing targets. Delivery of reductions and finance by developed countries will be measured, reported and verified (MRV) in accordance with COP guidelines.
- Agrees that developing nations (non-Annex I Parties) would "implement mitigation actions" (Nationally Appropriate Mitigation Actions) to slow growth in their carbon emissions, submitting these by 31 January 2010. LDS and SIDS may undertake actions voluntarily and on the basis of (international) support.
- Agrees that developing countries would report those actions once every two years via the U.N. climate change secretariat, subjected to their domestic MRV. NAMAs seeking international support will be subject to international MRV
- Recognizes "the crucial role of reducing emission from deforestation and forest degradation and the need to enhance removals of greenhouse gas emission by forests", and the need to establish a mechanism (including REDD-plus) to enable the mobilization of financial resources from developed countries to help achieve this
- Decides pursue opportunities to use markets to enhance the cost-effectiveness of, and to promote mitigation actions.
- Developing countries, specially these with low-emitting economies should be provided incentives to continue to develop on a low-emission pathway
- States that "scaled up, new and additional, predictable and adequate funding as well as improved access shall be provided to developing countries... to enable and support enhanced action"

- Agrees that developed countries would raise funds of $30 billion from 2010-2012 of new and additional resources
- Agrees a "goal" for the world to raise $100 billion per year by 2020, from "a wide variety of sources", to help developing countries cut carbon emissions (mitigation). New multilateral funding for adaptation will be delivered, with a governance structure.
- Establishes a Copenhagen Green Climate Fund, as an operating entity of the financial mechanism, "to support projects, programme, policies and other activities in developing countries related to mitigation". To this end, creates a High Level Panel
- Establishes a Technology Mechanism "to accelerate technology development and transfer...guided by a country-driven approach"
- Calls for "an assessment of the implementation of this Accord to be completed by 2015... This would include consideration of strengthening the long-term goal", for example to limit temperature rises to 1.5 C

CONCLUSION

One of the issues often discussed in relation to climate change mitigation is the stabilization of greenhouse gas concentrations in the atmosphere. The United Nations Framework Convention on Climate Change (UNFCCC) has the ultimate objective of preventing "dangerous" anthropogenic (i.e., human) interference of the climate system. As is stated in Article 2 of the Convention, this requires that greenhouse gas (GHG) concentrations are stabilized in the atmosphere at a level where ecosystems can adapt naturally to climate change, food production is not threatened, and economic development can proceed in a sustainable fashion. A distinction needs to be made between stabilizing GHG emissions and GHG concentrations. The two are not the same. The most important GHG emitted by human activities is carbon dioxide. Stabilizing emissions of CO_2 at current levels would not lead to stabilization in the atmospheric concentration of CO_2. In fact, stabilizing emissions at current levels would result in the atmospheric concentration of CO_2 continuing to rise over the 21st century and beyond. The reason for this is that human activities are adding CO_2 to the atmosphere far faster than natural processes can remove it. This is analogous to a flow of water into a bathtub. So long as the tap runs water (analogous to the emission of carbon dioxide) into the tub faster than water escapes through the plughole (the natural removal of carbon dioxide from the atmosphere), then the level of water in the tub (analogous to the concentration of carbon dioxide in the atmosphere) will continue to rise. Stabilizing the atmospheric concentration of the other greenhouse gases humans emit also depends on how fast their emissions are added to the atmosphere, and how fast the GHGs are removed.

Bibliography

1. www.unfccc.int/ (assessed on 10 Jan, 2012)
2. **B. Metz *et. al*.** *Climate Change 2001: Mitigation*. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, U.K., and New York, N.Y., U.S.A.
3. **Carnahan, K**. (2009). Multi-Project, Standardized Baselines: Explaining a Key Issue in the Reform of the Clean Development Mechanism. International Emissions Trading Association (IETA)
4. **Easterling, W. et al**. (2007). Food, fibre, and forest products. *In: Climate Change 2007: Climate Change Impacts, Adaptation, and Vulnerability*. IPCC. Cambridge: Cambridge University Press.
5. **Fischer, C.** (2005)– Project-Based Mechanisms for Emissions Reductions: Balancing Trade-Offs with Baselines – Energy Policy, Vol. 33, pp. 1807-1823,
6. http://en.wikipedia.org/wiki/United_Nations_Framework_Convention_on_Climate_Change - cite_ref-8#cite_ref-8**Fisher, B.S., *et al.*** (2007). In B. Metz, *et al.*, (eds.). *Chapter 3: Issues related to mitigation in the long-term context*. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Inter-governmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
7. **Forner, C., J. Blaser, F. Jotzo, C. Robledo**. (2006). *keeping the forest for the climate's sake: avoiding deforestation in developing countries under the UNFCCC.* Climate Policy 6, 2006.
8. GEF (Global Environment Facility). (2004). Programming to implement the guidance for the Special Climate Change Fund adopted by the Conference of the Parties to the United Nations Framework Convention on Climate Change at its Ninth Session. GEF/C.24/12.
9. **Rana, S.V.S**., (2007). Essentials of Ecology and Environmental Science, Third Edition, Prentice-Hall of India Private Limited, New Delhi.
10. **Smith, B.; Schneider, H.; Oppenheimer, M.; Yohe, W.; Hare, W**.; Mastrandrea, D.; Patwardhan, A.; Burton, I. et al. (Mar 2009). "Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) "reasons for concern"". *Proceedings of the National Academy of Sciences of the United States of America* **106** (11): 4133–4137.
11. **Sterman, J.D. and L.B. Sweeney** (2007). "Understanding public complacency about climate change: adults' mental models of climate change violate conservation of matter" . *Climatic Change* **80**: 221–222.