# INTRODUCTION TO ENERGY CONSERVATION

Principles - Past and present energy scenario of world – Energy consumption in India – resource availability – Demand supply gap - Environmental aspects–Energy Conservation act – Standards and labeling – designated consumers.

## ENERGY SCENERIO



INTRODUCTION

**What is Energy Conservation?**

Energy Conservation and Energy Efficiency are separate, but related concepts. Energy conservation is achieved when growth of energy consumption is reduced in physical terms. Energy Conservation can, therefore, is the result of several processes or developments, such as productivity increase or technological progress. On the other hand Energy efficiency is achieved when energy intensity in a specific product, process or area of production or consumption is reduced without affecting output, consumption or comfort levels. Promotion of energy efficiency will contribute to energy conservation and is therefore an integral part of energy conservation promotional policies.

The consumption of energy is increasing at a fast pace while available resources remain limited. The global need for energy is increasing on an average by about 2.4% every year. Out of the total amount of primary energy, over 85% comes from fossil fuels. The current consumption of fossil fuels, particularly oil, is not sustainable in the long term.

- Primary energy and secondary energy
- Commercial and non commercial energy
- Renewable and non-renewable energy

PRIMARY AND SECONDARY ENERGY

Primary fuels are directly or indirectly. Primary energy are converted in to another form of energy needed . For example, coal is fired to get steam and electricity is generated. These steam or electricity is called secondary energy. Primary energy can be classified further as

- Renewable (solar, wind, geothermal, tidal, biomass, hydel etc.)
- Non-renewable (fossil fuels: crude oil and its products, coal, natural gas, nuclear, etc.)

Renewable energy does not pollute the environment.

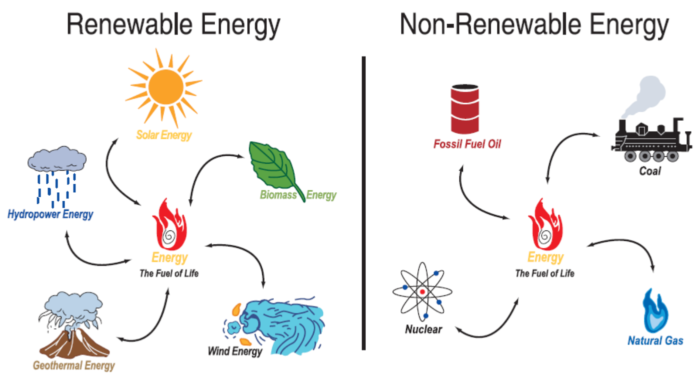



**Figure 1.2 Renewable and Non-Renewable Energy**

Commercial energy is a energy which is available for fixed price. Best example is electricity, gas etc. Non-commercial energy (traditional fuel)are available locally at the community and it is not meant for trading. For example fire wood, agriculture waste etc.

**One tonne of oil equivalent (toe) = 1 x $10^7$ kcal = 11630 kWh = 41868 MJ**

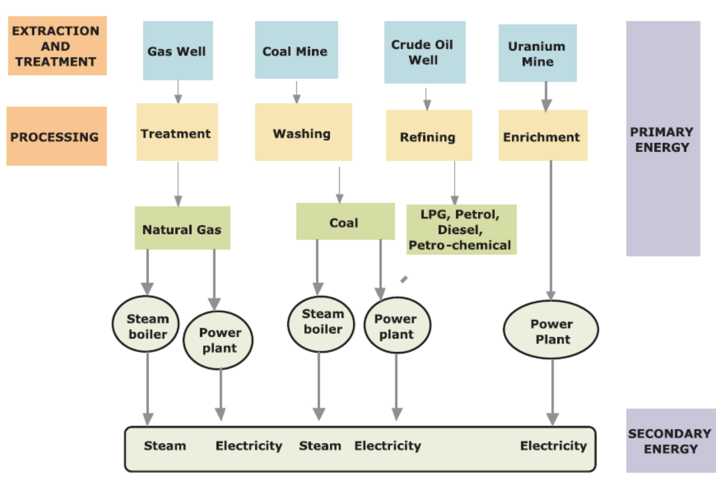



**Figure 1.1 Major Primary and Secondary Energy Sources**

COMMERCIAL AND NON-COMERCIAL ENERGY

## Commercial Energy

Energy that is available in the market for a definite price is known as commercial energy. No matter what the method of energy production is, whether it is from fossil fuels, nuclear or renewable sources, any form of energy used for commercial purposes constitutes commercial energy.

By far, the most important forms of commercial energy are electricity, coal, refined petroleum products and natural gas. Commercial energy forms the basis of industrial, agricultural, transport and commercial development in the modern world. In the industrialized countries, commercial fuels are predominant sources of energy not only for industrial use, but also for many household needs.

*Examples: Electricity, lignite, coal, oil, natural gas etc.*

## Non-Commercial Energy

Any kind of energy which is sourced within a community and its surrounding area, and which is not normally traded in the commercial market is termed as non-commercial energy.

Non-commercial energy sources include fuels such as firewood, cattle dung and agricultural wastes, which are traditionally gathered, and used mostly in rural households. These are also called as traditional fuels. Non-commercial energy is often ignored in compiling a country's energy statistics.

Examples: Firewood and agro waste in rural areas, solar energy for water heating, electricity generation, and for drying grain, fish and fruits; animal power for transport, threshing, lifting water for irrigation, crushing sugarcane etc.; wind energy for lifting water and electricity generation.

RNEWABLE AND NON-RENEWABLE ENERGY

Renewable energy is the energy obtained from natural sources which are essentially inexhaustible. Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power (see Figure 1.2). The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants.

A non-renewable resource is a natural resource which cannot be produced, grown, replenished, or used on a scale which can sustain its consumption rate. These resources often exist in a fixed amount, or are consumed much faster than nature can create them. Natural resources such as coal, oil and natural gas take millions of years to form and cannot be replaced as fast as they are being consumed now. These resources will deplete with time.

**GLOBAL PRIMARY EBERGY**

**i. COAL**

It has been estimated that there are around 892 billion tonnes of proven coal reserves worldwide. Proved coal reserves are shown for anthracite and bituminous (including brown coal) and sub-bituminous and lignite. There is enough coal to last around 113 years at current rates of production

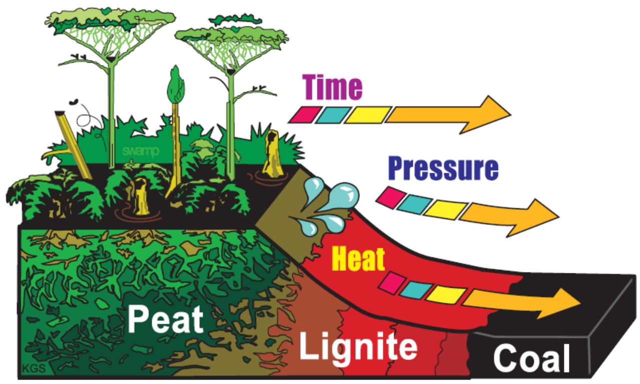



**Figure 1.3 Formation of Coal**

**Table 1.1 Proven Coal Reserves by Country by end of 2013**

| Country | Million tonnes | Share of total, % | Reserve / Production (R/P in years) |
|---|---|---|---|
| US | 237295 | 26.6 | 266 |
| Russian Federation | 157010 | 17.6 | 452 |
| China | 114500 | 12.8 | 31 |
| Australia | 76400 | 8.6 | 160 |
| India | 60600 | 6.8 | 100 |
| Others | 245726 | 27.6 | |
| **World** | **891531** | 100 | **113** |

*Source: BP Statistical Review of World Energy June 2014*

**ii. OIL**

The global proven oil (crude oil) reserve was estimated to be 1687.9 billion barrels by the end of 2013. Almost, 48 % of the proven oil reserves are in the Middle East. Saudi Arabia has the largest share of the reserve with 15.8%. Top proven world oil reserves (in billion barrels) are given in Table 1.3.

**Table 1.3 Proven World Oil Reserves by end of 2013**

| Country | Billion tonnes | Billion barrels | Share of total, % | R/P years |
|---|---|---|---|---|
| **Venezuela** | 56.6 | 298.3 | 17.7 | > 100 |
| **Saudi Arabia** | 36.5 | 265.9 | 15.8 | 63.2 |
| **Canada** | 28.1 | 174.3 | 10.3 | > 100 |
| **Iran** | 21.6 | 157 | 9.3 | > 100 |
| **Iraq** | 20.2 | 150.0 | 8.9 | > 100 |
| **India** | 0.8 | 5.7 | 0.3 | 17.5 |
| **Others** | 74.4 | 636.7 | 37.7 | - |
| **World** | **238.2** | **1687.9** | **100** | **53.3** |

*Source: BP Statistical Review of World Energy June 2014*

**(1 barrel ≈ 160 litres)**

As against the top producing countries (end of 2013), India's share is 42 million tonnes and share of total is 1%.

**Table 1.4 Top Oil Producing Countries by End of 2013**

| Region | Million tonnes per year | Share of total, % |
|---|---|---|
| **Saudi Arabia** | 542.3 | 13.1 |
| **Russia** | 531.3 | 12.9 |
| **US** | 446.2 | 10.8 |
| **China** | 208.1 | 5.0 |
| **Canada** | 193 | 4.7 |
| **Iran** | 166.1 | 4.0 |
| **Iraq** | 153.2 | 3.7 |
| **Nigeria** | 111.3 | 2.7 |
| **Others** | 2351.5 | 43.1 |
| **World** | **4130.2** | **100** |

*Source: BP Statistical Review of World Energy June 2014*

### iii. NATURAL GAS

Natural gas is a gaseous fossil fuel consisting primarily of methane but also includes small quantities of ethane, propane, butane and pentane. Before natural gas can be used as a fuel, it undergoes extensive processing for removing almost all constituents except methane. It ranks third after crude oil and coal in terms of usage but has clearly gained in usage. Natural gas has been making a very significant contribution to world energy basket during the past three decades.

**Table 1.5 Natural Gas Proven Reserves: Top Countries (by end of 2013)**

| Country | Trillion cubic metres | Share of total, % | R/P (years) |
|---|---|---|---|
| **Iran** | 33.8 | 18.2 | > 100 |
| **Russia** | 31.3 | 16.8 | 51.7 |
| **Qatar** | 24.7 | 13.3 | > 100 |
| **Turkmenistan** | 17.5 | 9.4 | > 100 |
| **US** | 9.3 | 5 | 13.6 |
| **Others** | 69.1 | 37.3 | - |
| **World** | **185.7** | **100** | **55.1** |

*Source: BP Statistical Review of World Energy June 2014*

***At current R/P ratio, World oil and gas reserves are estimated at just 53 years and 55 years respectively. Coal is likely to last for 113 years.***

GLOBAL ENERGY CONSUMPTION

**Table 1.6 Global Primary Energy Consumption by Energy Source**

| Oil | Natural gas | Coal | Nuclear Energy | Hydro-Power | Renewable Energy | Total, Mmtoe |
|---|---|---|---|---|---|---|
| 4185.1 | 3020.4 | 3826.7 | 563.2 | 855.8 | 279.3 | 12730.4 |
| 33% | 24% | 30% | 4% | 7% | 2% | |

*Source: BP Statistical Review of World Energy June 2014*

| Table-1.7 Primary Energy consumption at the end of 2013 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Million tonnes of oil equivalent ( Mtoe ) | | | | | | | % of Share |
| **Country** | **Oil** | **Natural gas** | **Coal** | **Nuclear Energy** | **Hydro-Power** | **Renewable Energy** | **Total** | |
| China | 507.4 | 145.5 | 1925.3 | 25 | 206.3 | 42.9 | 2852.4 | 22.4 |
| US | 831.0 | 671.0 | 455.7 | 187.9 | 61.5 | 58.6 | 2265.8 | 17.8 |
| Russia | 153.1 | 372.1 | 93.5 | 39.1 | 41 | 0.1 | 699 | 5.5 |
| India | 175.2 | 46.3 | 324.3 | 7.5 | 29.8 | 11.7 | 595.0 | 4.7 |
| Japan | 208.9 | 105.2 | 128.6 | 3.3 | 18.6 | 9.4 | 474.0 | 3.7 |
| Germany | 112.1 | 75.3 | 81.3 | 22.0 | 4.6 | 29.7 | 325.0 | 2.6 |
| Others | 2197.4 | 1198.3 | 818 | 278.4 | 494 | 126.9 | 5519.2 | 43.3 |
| **World** | **4185.1** | **3030.4** | **3826.7** | **563.2** | **855.8** | **279.3** | **12730.4** | **100** |

*Source: BP Statistical Review of World Energy, June 2014*

FINAL ENERGY CONSUMPTION

Final energy is the form of energy available to the end user following conversion from primary energy. Final Energy consumption, measured in Million tonnes of oil equivalent (Mtoe) is the sum of the consumers. Globally, industry consumes almost 50 % of final consumption, followed by Transportation (20 %), Residential (18%), and Commercial (12%) (Source: U.S. Energy Information Administration).

## 1.7 Indian Energy Scenario

The annual energy consumption in India is 595 Million tonnes oil equivalent compared with the world energy consumption of 12,730 Million tonnes oil equivalent in 2013.

Coal dominates the energy production mix in India, contributing to about 55% of the total primary energy production. Over the years (2008-2013), there has been a gradual increase in the share of natural gas in primary energy production and a small drop in share of oil in primary energy production. The share of commercial energy in total primary energy consumption is about 74% and share of non-commercial energy in total primary energy consumption is 26%. The primary energy consumption mix in India for 2008-09 is given in Table 1.8.

**Table 1.8 Primary Commercial Energy Consumption Mix in India in 2013**

| Energy Type | Mtoe | % share in total primary Energy Consumption |
|---|---|---|
| Oil | 175.2 | 29.5% |
| Natural Gas | 46.3 | 7.8% |
| Coal | 324.3 | 54.5% |
| Nuclear energy | 7.5 | 1.3% |
| Hydro Power | 29.8 | 5.0% |
| Renewable energy | 11.7 | 2.0% |
| Total Primary Energy consumption | 595 | 100.00 |

*Source: BP Statistical Review of World Energy, June 2014*

## ENERGY SUPPLY

i. Coal

India has huge coal reserves of about 60.6 billion tonnes comprising of hard coal 56.10 billion tonnes (Anthracite and bituminous) and soft coal 4.5 billion tonnes (sub-bituminous and lignite). This amount to about 6.8 % of the world reserves and it may last for about **100** years at the current Reserve to Production (R/P) ratio. Indian coal reserves are mainly confined to eastern and south central parts of the country. The State of Jharkhand, and Odisha account for almost 51% of the total coal reserves in the country as on 31st March 2013.

India is one of the largest producers of coal and lignite in the world. Majority of the coal (over 80%) is mined only upto 150 - 300 m depth with open cast mining and balance 20% of coal is mined from underground mines.

**Table 1.9 Total Production of Coal (Qty in Million tonnes)**

| Year | Coking coal | Non-coking coal | Coal Total | Lignite |
|---|---|---|---|---|
| 2012-13 | 51.582 | 504.82 | 556.402 | 46.453 |
| 2011-12 | 51.66 | 488.29 | 539.95 | 42.332 |
| 2010-11 | 49.547 | 483.147 | 532.694 | 48.95 |

*Source: Coal Directory of India, 2012 – 2013: Coal Statistics*

**Table 1.10 Total Import of Coal (Qty in Million tonnes)**

| Year | Coking coal | Non-coking coal | Total |
|---|---|---|---|
| 2012-13 | 35.557 | 110.228 | 145.785 |
| 2011-12 | 31.801 | 71.052 | 102.853 |
| 2010-11 | 19.484 | 49.434 | 68.918 |

ii. Oil

India's oil reserves are estimated at 5.7 billion barrels (800 Million tonnes), which amount to only about 0.3% of the total world reserves. The main oil fields are located in the Bombay High, upper Assam, Cambay, and Krishna-Godavari basin.

Oil accounts for about 29 % of the country's primary energy consumption at the end of 2013. India's crude oil production was about 42 million metric tonnes as against the consumption of about 175.2 million metric tonnes. India's present reserve to production (R/P) ratio is only about 17.5 years.

Currently, India is the fourth largest oil-consuming country in the world. India imports over 75% of its crude oil needs, mainly from Gulf nations. In terms of sector wise petroleum products consumption, transport sector is the largest followed by domestic and industry sector.

| Table:1.11 The import bill of crude and petroleum products | | |
|---|---|---|
| Year | Quantity (Million Metric Tonnes) | Import Bill (Rs Crore) |
| 2010-11 | 163.595 | 4,55,276 |
| 2011-12 | 171.729 | 6,72,220 |
| 2012-13 | 184.795 | 7,84,652 |
| 2013-14 | 189.238 | 8,64,875 |
| *Source: Ministry of Petroleum and Natural Gas* | | |

iii. Natural Gas

Natural gas has become the most preferred fuel due to its inherent environmentally benign nature, greater efficiency and cost effectiveness. It is also termed as the fuel of the 21st century. When natural gas is cooled to -161°C, it is transformed into Liquefied Natural Gas (LNG). This is done for ease of storage and transportation. Since liquefaction reduces the volume occupied by the natural gas by 600 times, LNG is transported in specially built ships with cryogenic tanks. Compressed Natural Gas (CNG) is made by compressing natural gas (which is mainly composed of methane [$CH_4$]) to less than 1% of the volume it occupies at standard atmospheric pressure. It is stored and distributed in hard containers of cylindrical or spherical shapes, at a pressure of 200–248 kg/cm$^2$. CNG can be used in traditional petrol internal combustion engine vehicles that have been converted into bi-fuel vehicles (petrol/CNG).

India's gas reserves are estimated at 1.4 trillion cubic metres by end of 2013 which amounts to about 0.7% of the total World reserves. About 66 per cent of the country's production comes from offshore production, whereas the remaining 34 per cent comes from on-shore production. The bulk of onshore production comes from Assam, Gujarat, Andhra Pradesh. Under production sharing contracts, private parties have also started producing gas in some of the fields. India's present Reserves / Production (R/P) ratio is 40 years.

Natural gas accounts for only about 7.8 per cent of fuel consumption in India compared to the world average of about 24% in 2013. India's consumption of natural gas is 51.4 billion cubic metres as against the production of 33.7 billion cubic metres in 2013. India also imports natural gas in the form of LNG. LNG is received in terminals and regassified and then supplied as natural gas to the consumers. LNG projects are capital intensive.

***India's oil and gas reserves are estimated to last just 17.5 years and 40.2 years respectively at the current R/P ratio. Coal is likely to last for 100 years.***

## ELECTRICAL ENERGY SUPPLY

The installed capacity of electric power stations in India is 2,38,743 MW as on February 2014, out of which 40195 MW is from Hydro-electric power plants, 163305 MW is from Thermal and 5780 MW from Nuclear and 29463 MW from Renewable Energy Sources. Refer Table 1.12.

The gross generation of power in the year 2013/14 was 881786 million kWh. India faces energy shortage of 3.8 % and peak shortage of 3.3% (Source: Ministry of Power)

**Table 1.12 Breakup of Installed Capacity by Energy Source**

| Power Generation Route | Capacity (MW) | % |
|---|---|---|
| **Total Thermal** | **1,63,304.99** | **68.4** |
| *Coal* | *1,40,723.39* | 58.9 |
| *Gas* | *21,381.85* | 9.0 |
| *Oil* | *1,199.75* | 0.5 |
| **Hydro** | **40,195.40** | **16.84** |
| **Nuclear** | **5,780.00** | **2.42** |
| **Renewable energy sources (small hydro, wind, biomass and others)** | **29,462.55** | **12.34** |
| **Total** | **2,38,742.94** | **100.0** |

## NUCLEAR POWER SUPPLY

India currently operates 21 nuclear power units at seven locations.. The installed capacity of nuclear power plant is 5780 MW which comprises of Boiling Water Reactors and Pressurized Heavy Water Reactors. Projects are underway which can add further 6100 MW to the existing capacity. Currently, Nuclear power contributes to only about 2 per cent of the total installed capacity in India. Department of Atomic Energy plans to put up a total installed nuclear power capacity of 63,000 MW by the year 2032 in the country

India's ability to develop nuclear power is restricted as we do not have adequate supply of Uranium leading to poor operating load factor. The Uranium produced in India is 2-3 times costlier since Indian ores contain only about 0.1% Uranium compared to 12-13% in the Uranium ores mined abroad. The locally available Uranium can meet the requirement of only about 10,000 MW of nuclear power generation.

## HYDRO P[OWER SUPPLY

India is endowed with a vast and viable hydro potential for cleaner power generation. This amounts to economically viable hydro power capacity of over 84,000 MW at 60% load factor. Around 80% of this potential capacity has been identified in the Brahmaputra, Indus and Ganges basins. In addition, another 15,000 MW has been acknowledged as being potentially available in small hydro projects.

In addition to being a benign source of power, hydropower generation has the inherent ability for instantaneous starting, stopping and managing of load variations that will help in improving the reliability of the system. Hydro power also aids utilities in averaging their power procurement cost, as the generation cost reduces over time and most of the low cost power procurement of utilities comes from hydro sources. Unlike generation from fossil fuels, hydropower generation is independent of inflation.

The share of hydropower in the country's total generated units has steadily decreased over time and it stands at about 17% by 2013. In order to maintain a balance between hydro power and thermal power, the Ministry of Power has announced a policy for accelerated development of hydro power in the country. Development of small and mini hydro power at an accelerated pace is one of the tasks in the policy. The small and mini hydro projects have good potential to provide energy in remote and hilly areas where extension of grid system is uneconomical. To accelerate the development of hydro power, projects up to 25 MW have been brought under the domain of the Ministry of New and Renewable Energy (MNRE), while projects beyond 25 MW continue to remain under the  of Ministry of Power.

SECTORWISE ENERGY CONSUMPTION IN DINDIA

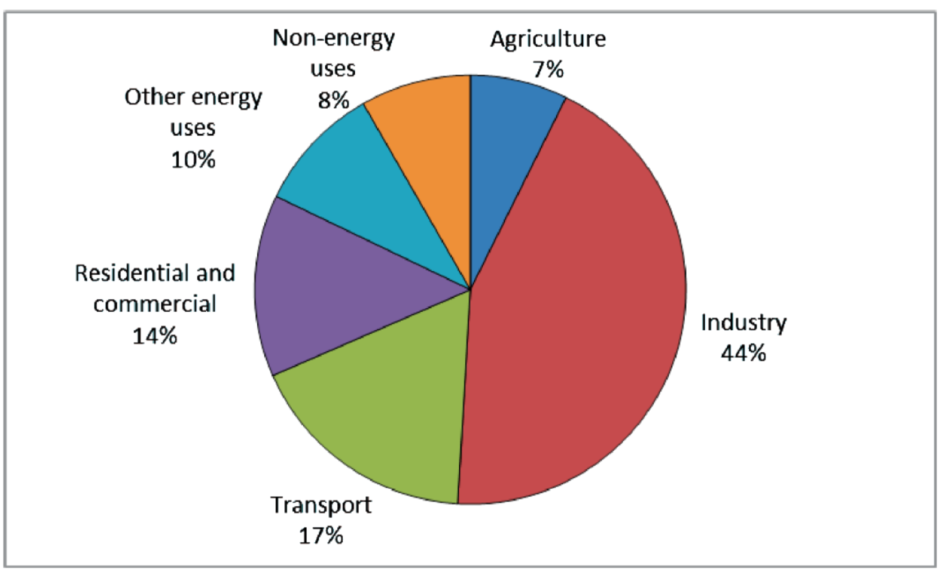



**Figure 1.4 Sectorwise Energy Consumption**
**Source: TERI**

**Table 1.13 SEC in Selected Indian Industries against Global Benchmarks**

| Industry | Specific Energy Consumption (SEC) in GJ/ tonne | |
|---|---|---|
| | India | World |
| Iron & Steel | 25.5 –34.2 | 16.5-18.5 |
| Cement | 3.0-3.4 | 2.9-3.0 |
| Fertilizers( Urea) | 27.2-28.5 | 24.0-25.8 |
| Pulp & Paper | 31.0-51.0 | 25.0-30.0 |
| Chlor Alkali (Caustic Soda) | 7.8-8.6 | 7.1-7.5 |
| Aluminum | 75.6-83.2 | 70.5-73.0 |
| Sugar | 0.7-0.9 | 0.6-0.7 |

*Source: Planning Commission, India Report*

However, the efficiencies of many processes in the Indian cement, steel and aluminium industries have improved over the past 15 years. Continuous improvements in enhancing energy efficiency have helped to lower the country's overall energy intensity to a certain extent. In the cement sector for example, the specific energy consumption of the most efficient plants is now comparable to the best in the world. However, much of the Indian industrial output is derived from small and medium industries operated with inefficient equipment, where it has been difficult to implement efficiency improvements.

**Transport sector**

The energy consumption of this sector is growing at a rapid rate of 16% per annum which is next only to China. This sector almost consumes around 40% of the petroleum products.

By the end of the projection period i.e. 2030, out of the total transport energy demand, road vehicles would account for 86% followed by aviation at 9%. Railways, marine and others are expected to consume 5%.

**Residential, Commercial, Services and Agricultural sector**

There exists a wide difference between the consumption pattern of the rural and urban households. The rural households depend upon biomass to meet 85% of their cooking needs, while the urban households meet 56% of their cooking needs through LPG. Almost 70% of the population in India is rural household, which accounts for only 42% of the demand for oil, gas and electricity. The use of electricity is growing rapidly in the residential sector. Of the total electricity demand in the domestic sector, 70% is used for lighting purpose while the balance 30% is accounted for refrigeration, air conditioning and other electrical gadgets.

The energy consumption especially for commercial and services activities is expected to grow rapidly due to high growth rate in commercial establishments, hotels, shopping malls, IT parks and hospitality industry.

## ENERGY NEEDS OF GROWING ECONOMY

Economic growth is desirable for developing countries, and energy is essential for economic growth. However, the relationship between economic growth and increased energy demand is not always a straightforward linear one.

Massive investment in energy sector is required to deliver a sustained GDP growth rate of 8.0% till the year 2031- 2032. The requirements of energy sector are:

- Growth in primary energy supply by 3-4 times over current consumption
- Increase in electricity installed capacity by 6-7 times
- Increase in annual coal requirement by nearly 3 times over the current demand

**Table 1.14 Growth of Per Capita Consumption (kWh)**

| Particulars | 2010-11 | 2011-12 | 2012-13 |
|---|---|---|---|
| Per Capita Consumption (kWh) | 819 | 884 | 917 |

*Source: Growth of Electricity in India from 1947-2013: CEA Document*

Requirement of coal, the dominant fuel in India's energy mix will need to expand to over 2 billion tonnes/annum based on domestic quality of coal given India's targeted GDP growth.

India's oil requirements also will increase at a significant rate. India already imports about 75% of its crude oil requirements which are likely to go up more than 90% in the near future as production in existing oil and gas fields are declining as a result of years of use.

The share of natural gas in the energy mix is expected to go upto 20-25% by the year 2030-32.

Nuclear power plant capacity targets as envisaged by the Department of Atomic Energy (DAE) are 20,000 MWe by 2020, 50,000 MWe by 2030 and 250,000 MWe of nuclear power by 2050.

## ENERGY INDENSITY ON PURCAHSING POWER PARITY(PPP)

Energy intensity is the ratio between the gross inland consumption of energy and the gross domestic product (GDP) for a given calendar year. It measures the energy consumption of an economy and its overall energy efficiency.

The gross inland consumption of energy is a measure of the energy inputs to the economy, calculated by adding total domestic energy production plus energy imports minus energy exports plus net withdrawals from existing stocks.

The GDP figures are taken at constant prices to avoid the impact of the inflation, in relation to a base year (say 2000). Since gross inland consumption is measured in toe (tons of oil equivalent) and GDP in millions of US $, this ratio is expressed in toe per million US $.

$$EI = \frac{FC}{GDP}$$

Where:

EI = Energy intensity, national level, toe per million US $
FC = Total final consumption, national level, toe
GDP= Gross domestic product, million US $

**What is Purchase Power Parity (PPP)?**

An egg in India costs Rs.3/- whereas it costs 30 Yens/- (equivalent to Rs.15) in Japan. The PPP for an egg between Japan and India is 30 Yens to Rs.3 or 10 Yens to a rupee. In other words, for every rupee spent on egg in India, 10 Yens would have to be spent in Japan to obtain the same quality of egg.

Applying actual exchange rates of Yen to Rupee in this process would overestimate the GDP of Japan with high price levels relative to India with low price levels. The use of PPPs ensures that the GDP of all countries is valued at a uniform price level and thus reflects only differences in the actual volume of the economy. Adjustments are required to give a better picture than comparing gross domestic products (GDP) using market exchange rates.

A purchasing power parity (PPP) exchange rate equalizes the purchasing power of different currencies in their home countries for a given basket of goods. These special exchange rates are often used to compare the standards of living of two or more countries. In their simplest form, PPPs are price relatives that show the ratio of the prices in national currencies of the same good or service in different countries.

Simply, it means the purchasing power of country, after neutralizing the currency to global standards, thus giving a more correct picture of the country's purchasing power. PPP is a useful measure because, more often than not, the amount of goods a currency can purchase within two nations varies widely based on availability of goods, demand for the goods, and a number of other factors.

Taking into account PPP, the energy intensity is expressed as Energy Intensity (kgoe/US $PPP GDP).

## 1.15 Energy Conservation and its Importance

Coal and other fossil fuels, have taken hundreds of millions of years to form, are likely to deplete soon. In the last two hundred years, we have consumed 60% of all resources. For sustainable development, we need to adopt energy efficiency measures.

Today, 85% of India's primary energy comes from non-renewable and fossil sources (coal, oil, etc.). These reserves are continually diminishing with increasing consumption and will not exist for future generations (see Figure 1.5).

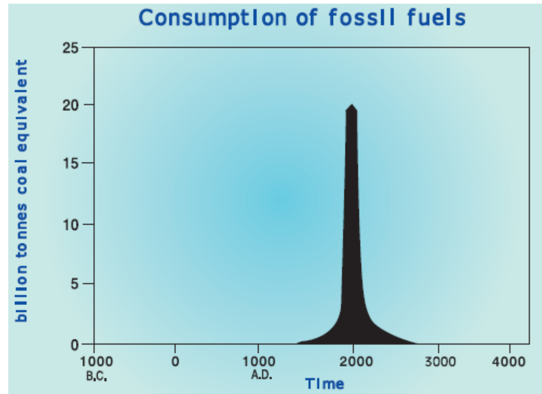



**Figure 1.5 Consumption of Fossil Fuels**

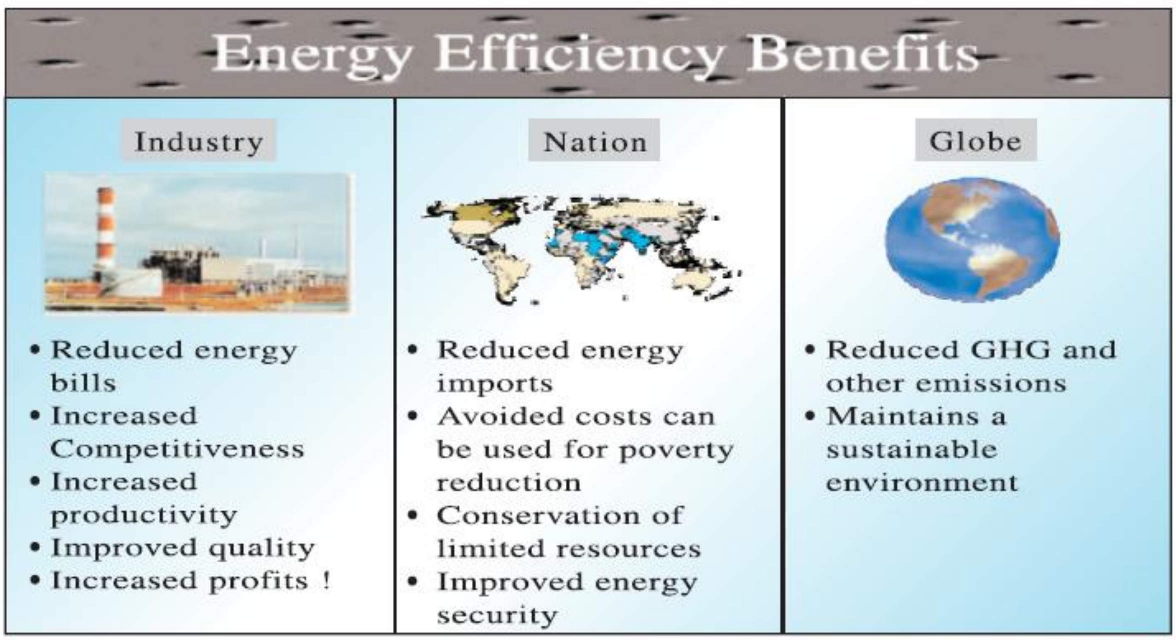



**Figure 1.7 Energy Efficiency Benefits**

# 2 ENERGY CONSERVATION ACT-2001 AND RELATED POLICIES



## INTRODUCTION

Energy Conservation Act (EC Act) was enacted by the Government of India in 2001 to provide legal framework and institutional arrangements for enhancing energy efficiency. This Act led to the creation of Bureau of Energy Efficiency (BEE) as the nodal agency at the center and State Designated Agencies (SDAs) at the State level to implement the provisions of the Act. The Central Government, State Government and Bureau of Energy Efficiency have major roles to play in implementation of the Act. The Mission of BEE is to develop policy and strategies based on self-regulation and market principles with the goal of reducing energy intensity of the Indian economy. This will be achieved with active participation of all stakeholders, resulting in rapid and sustained adoption of energy efficiency in all sectors.

**Designated agency:** Designated agency means an agency which coordinates, regulates and enforce provisions of this act within a State.

**Designated consumer:** Designated consumer means any user or class of users of energy in a energy intensive industries and other establishments specified in the Schedule as designated consumer.

**Energy:** Energy means any form of energy derived from fossil fuels, nuclear substances or materials, hydro-electricity and includes electrical energy or electricity generated from renewable sources of energy or biomass connected to the grid.

**Energy audit:** Energy audit means the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption.

## 13. Powers and Functions of Bureau

13. (1) The Bureau shall, effectively co-ordinate with designated consumers, designated agencies and other agencies, recognize and utilise the existing resources and infrastructure, in performing the functions assigned to it by or under this Act.

(2) The Bureau may perform such functions and exercise such powers as may be assigned to it by or under this Act and in particular, such functions and powers include the function and power to -

(a) recommend to the Central Government the norms for processes and energy consumption standards required to be notified under section 14A;

(aa) recommend to the Central Government for issuing of the energy savings certificate

(b) recommend to the Central Government on display label on equipment or on appliances and manner of display under clause (d) of section 14;

(c) recommend to the Central Government for notifying any user or class of users of energy as a designated consumer under clause (e) of section 14;

(d) take suitable steps to prescribe guidelines for energy conservation building codes under clause (p) of section 14.

(e) take all measures necessary to create awareness and disseminate information for efficient use of energy and its conservation;

(f) arrange and organize training of personnel and specialists in the techniques for efficient use of energy and its conservation;

(g) strengthen consultancy services in the field of energy conservation;

(h) promote research and development in the field of energy conservation;

(i) develop testing and certification procedure and promote testing facilities for certification and testing for energy consumption of equipment and appliances;

(j) formulate and facilitate implementation of pilot projects and demonstration projects for promotion of efficient use of energy and its conservation;

(k) promote use of energy efficient processes, equipment, devices and systems;

(l) promote innovative financing of energy efficiency projects;

(m) give financial assistance to institutions for promoting efficient use of energy and its conservation;

(n) levy fee for services provided for promoting efficient use of energy and its conservation;

(o) maintain a list of accredited energy auditors as may be specified by regulations;

(p) specify, by regulations, the qualifications, criteria and conditions subject to which a person may be accredited as an energy auditor and the procedure for such accreditation;

(q) specify, by regulations, the manner and intervals of time in which the energy audit shall be conducted;

(r) specify, by regulations, certification procedures for energy managers and energy auditors to be designated or appointed by designated consumers;

(s) prepare educational curriculum on efficient use of energy and its conservation for educational institutions, boards, universities or autonomous bodies and coordinate with them for inclusion of such curriculum in their syllabus;

(sa) conduct examination for capacity building and strengthening of services in the field of energy conservation including certification of energy managers and energy auditors.

(t) implement international co-operation programmes relating to efficient use of energy and its conservation as may be assigned to it by the Central Government.

**Power of State Government to facilitate and Enforce Efficient Use of Energy and its Conservation**

15. The State Government may, by notification, in consultation with the Bureau -

(a) amend the energy conservation building codes to suit the regional and local climatic conditions and may, by rules made by it, specify and notify energy conservation building codes with respect to use of energy in the buildings;

(b) direct every owner or occupier of a building or building complex being a designated consumer to comply with the provisions of the energy conservation building codes;

(c) direct, if considered necessary for efficient use of energy and its conservation, any designated consumer to get energy audit conducted by an accredited energy auditor in such manner and at such intervals of time as may be specified by regulations;

**Establishment of Fund by State Government**

16. (1) The State Government shall constitute a Fund to be called the State Energy Conservation Fund for the purposes of promotion of efficient use of energy and its conservation within the State.

(2) To the Fund shall be credited all grants and loans that may be made by the State Government or, Central Government or any other organization or individual for the purposes of this Act.

(3) The Fund shall be applied for meeting the expenses incurred for implementing the provisions of this Act.

(4) The Fund created shall be administered by such persons or any authority and in such manner as may be specified in the rules made by the State Government.

**Power of Central Government or State Government to issue directions**

18. The Central Government or the State Government may, in the exercise of its powers and performance of its functions under this Act and for efficient use of energy and its conservation, issue such directions in writing as it deems fit for the purposes of this Act to any person, officer, authority or any designated consumer and such person, officer or authority or any designated consumer shall be bound to comply with such directions.

Explanation – For the avoidance of doubts, it is hereby declared that the power to issue directions under this section includes the power to direct –

(a) Regulation of norms for process and energy consumption standards in any industry or building or building complex; or

(b) Regulation of the energy consumption standards for equipment and appliances.

## PENALTIES AND ADJUDICATION

26. Penalty

(1) If any person fails to comply with the provisions of clause (c) or clause (d) or clause (h) or clause (i) or clause (k) or clause (l) [xxx] or clause (r) or clause (s) of section 14 or clause (b) or clause (c) or clause (h) of section 15, he shall be liable to a penalty which shall not exceed ten lakh rupees for each such failure and, in the case of continuing failure, with an additional penalty which may extend to ten thousand rupees for every day during which such failure continues:

PROVIDED that no person shall be liable to pay penalty within five years from the date of commencement of this Act.

(1A) If any person fails to comply with the provisions of clause (n) of section 14, he shall be liable to a penalty which shall not exceed ten lakh rupees and, in the case of continuing failure, with an additional penalty which shall not be less than the price of every metric ton of oil equivalent of energy, prescribed under this Act, that is in excess of the prescribed norms.

(2) Any amount payable under this section, if not paid, may be recovered as if it were an arrear of land revenue.

## Role of State Designated Agencies

As per Energy Conservation Act 2001, State Governments have been empowered to designate agencies (State Designated Agency, i.e. SDA) in consultation with Bureau of Energy Efficiency. Designated Agencies will have the responsibility to implement the Act within the State.

***Responsibilities***

- Spread awareness on EC Act
- Undertake voluntary initiatives to promote energy conservation
- Liaison and coordinate with BEE, State Government Departments dealing with energy, industry, planning, regulators, consumer affairs, municipal bodies etc.
- Capacity building of staff employed
- Launch and maintain state specific website addressing the voluntary and mandatory provisions of EC Act
- Undertake energy conservation awareness program for consumers, industrial & commercial sector, school children, farmers etc.
- Arrange interactive meets between energy managers, energy auditors, designated consumers and other experts

***Duties***

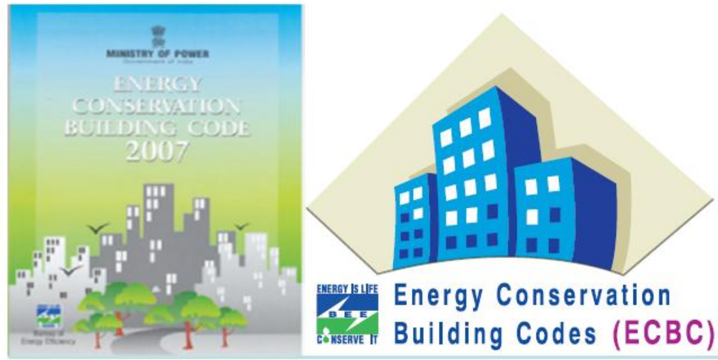
- Prepare a list of designated consumers
- Compile information received from designated consumers through annual statements on energy consumption, energy audit reports, and action taken on the report of energy audit
- Prepare a state and sectoral energy data base and provide the feed back to designated consumers
- Take all measures necessary to create awareness and disseminate information for efficient use of energy and its conservation
- Arrange and organize training of personnel and specialists in the techniques for efficient use of energy and its conservation
- Take steps to encourage preferential treatment for use of energy efficient equipment or appliances
- Appoint or designate inspecting officer with specified powers as necessary for the purpose of ensuring compliance with energy consumption standards
- Assist State Government in the preparation of Rules under Section 57 of the Energy Conservation Act.
- Establish Energy Conservation Fund for the purposes of promotion of efficient use of energy and its conservation within the State.

## 2.3 Schemes of BEE under the Energy Conservation Act-2001

- Energy Conservation Building Codes (ECBC)
- Standards and Labeling (S & L)
- Demand Side Management (DSM)
- Bachat Lamp Yojana (BLY)
- Promoting Energy Efficiency in Small and Medium Enterprises (SMEs)
- Designated Consumers
- Certification of energy auditors and energy managers

### 2.3.1 Energy Conservation Building Codes (ECBC)

Energy Conservation Building Codes (ECBC) was developed to deal with rapidly increasing energy consumption in commercial buildings. ECBC sets minimum energy efficiency standards for design and construction of commercial buildings.




ECBC encourages energy efficient design or retrofit of buildings so that

- Building funciton, comfort, health and the productivity of the occupants is considered
- Life cycle costs (i.e. construction and energy cost are minimized)

### 2.3.2 Standards and Labeling (S&L)

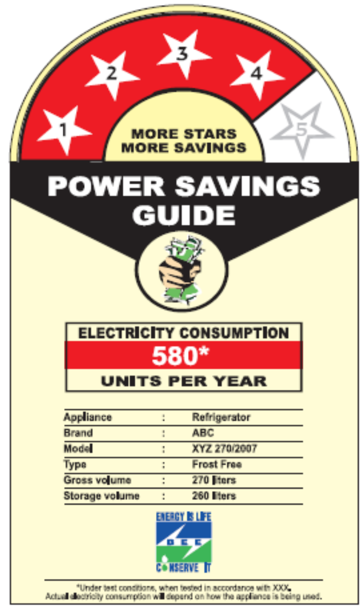
There is a wide variation in energy consumption of similar products by various manufacturers. Also information on energy consumption is often not easily available. This leads to continued manufacture and purchase of inefficient equipment and appliances.

The objectives of Standards & Labeling Program is to provide the consumer an informed choice about the energy saving and thereby the cost saving potential of the marketed household and other equipment. This is expected to impact the energy savings in the medium and long run while at the same time it will position domestic industry to compete in such markets where norms for energy efficiency are mandatory.

The main provision of EC act on Standards and Labeling are:

- Recommend to the Central Government, the norms for processes & energy consumption
- standards for any equipment which consumes, generates, transmits or supplies energy.

**Standard:** Energy-efficiency standards are procedures and regulations prescribing the energy performance of manufactured/ commercially sold products sometimes prohibiting the sale of products that are less efficient than a minimum level. The term "standards" commonly encompasses two possible meanings:




a) well-defined test protocols (or test procedures) to obtain a sufficiently accurate estimate of the energy performance of a product, or at least a relative ranking of its energy performance compared to that of other models; and

b) target limits on energy performance (usually maximum use or minimum efficiency) based on a specified test protocol.

**Labels:** Energy-efficiency labels are informative labels affixed to manufactured products to describe the product's energy performance (usually in the form of energy use, efficiency). These labels give consumers the data necessary to make informed purchases. Mainly there are two types of labels namely,

a) Comparative label: allow consumers to compare efficiency of all the models of a product in order to make an informed choice. It shows the relative energy use of a product compared to other models available in the market.

b) Endorsement label: define a group of products as efficient when they meet minimum energy performance criteria specified in the respective product schedule/regulation/statutory order.

**Minimum Energy Performance Standards (MEPS):** MEPS prescribe minimum efficiencies (or maximum energy consumption) that manufacturers must achieve in each product, specifying the energy performance(or output) but not the technology or design details of the product. The MEPS will be reviewed and upgraded periodically to enhance & ensure the availability of energy efficiency product in the market.

**Star Ratings:** A ranking system based on energy efficiency of an appliance declared by manufacturer. Depending upon the performance of an appliance, they are rated on a scale of star 1 to star 5. The number of stars depends on the highest pre-set threshold for energy performance that the appliance is able to meet. Therefore, Star 1 is the least energy efficient (and hence the least money saved) and star 5 is the most energy efficient (and hence more money saved ).

**Label period:** The validity period of the energy efficiency label under the energy consumption standard specified by the Central Government under clause (a) of Section 14 and in case the end period of the energy efficiency label is not specified, it shall be deemed to be valid until a new energy efficiency level is announced by the Central Government.

**Appliances/equipment covered under S&L program:**

In the 11th plan, S&L Programme has been expanded to 18 equipment out of which 4 equipment are introduced for mandatory S&L scheme from 7th January 2010. The equipment under the mandatory labeling program are:

1. Household Frost Free Refrigerators
2. Room Air Conditioners
3. Tubular Fluorescent Lamps
4. Distribution Transformers (up to 200 KVA)

| | | | |
|---|---|---|---|
|  |  |  |  |
| Frost-free Refrigerator | TFL | AC | Distribution Transformer |

The following equipment have been introduced under voluntary labeling scheme:

1. Direct Cool Refrigerators
2. Induction Motors
3. Ceiling Fans
4. Agricultural pump Sets
5. Color Televisions
6. Electric Water Geysers
7. Laptop & Notebook
8. Office equipments
9. LPG Stoves
10. Cassette/Floor standing ACs
11. Solid State Inverters
12. Diesel Generators
13. Ballast
14. Diesel Engine driven moonset pumps for agricultural purpose
15. Washing Machine

(Note: More Details are available at www.beestarlabel.com)

### 2.3.3 Demand Side Management (DSM)

Demand Side Management (DSM) means managing of the demand for power, by utilities / Distribution companies, among some or all its customers to meet current or future needs. DSM programs result in energy and / or demand reduction. For example, under this process, the demand can be shifted from peak to off peak hours thereby reducing the need for buying expensive imported power during peak hours. DSM also enables end-users to better manage their load curve and thus improves the profitability. Potential energy saving through DSM is treated same as new additions on the supply side in MWs. DSM can reduce the capital needs for power capacity expansion.

### 2.3.4 Bachat Lamp Yojana (BLY)


The “Bachat Lamp Yojana”, which literally means “Save Lamp Scheme”, aims at the large scale replacement of inefficient incandescent bulbs in households by Compact Fluorescent Lamps (CFLs). It seeks to provide CFLs to households at the price similar to that of incandescent bulbs and plans to use the Clean Development Mechanism (CDM) to recover the cost difference between the market price of the CFLs and the price at which they are sold to households.

The Bachat Lamp Yojana is designed as a public-private partnership between the Government of India, Investors/ private sector CFL suppliers and State level Electricity Distribution Companies (DISCOMs). The CFL suppliers would sell high quality CFLs to households at a price of Rs. 15 per CFL within a designated project area in a DISCOM region of operation.

### 2.3.5 Promoting Energy Efficiency in Small and Medium Enterprises (SMEs)

Energy Efficiency in the SME sector assumes importance because of the prevailing high costs of energy and supply related concerns. It will be useful to build their energy efficiency awareness by funding/subsidizing need based studies in large number of units in the SMEs and giving energy conservation recommendations including technology upgradation opportunities. It is envisaged that such interventions supported by diagnostic studies and pilot projects at cluster level focusing on energy/ resource efficiency, energy conservation and technology upgradation would be helpful in addressing the cluster specific problems and enhancing energy efficiency in SMEs.

### 2.3.6 Designated Consumers (DC)

The Central Government has notified the following 9 energy intensive industries as designated consumers under The EC Act 2001:

| No. | Industry | Energy consumption |
|---|---|---|
| 1. | Thermal Power Stations | 30,000 metric tonne of oil equivalent (MTOE) per year and above |
| 2. | Fertilizer | 30,000 metric tonne of oil equivalent (MTOE) per year and above |
| 3. | Cement | 30,000 metric tonne of oil equivalent (MTOE) pe*r year and above |
| 4. | Iron & Steel | 30,000 metric tonne of oil equivalent (MTOE) per year and above |
| 5. | Chlor-Alkali | 12,000 metric tonne of oil equivalent (MTOE) per year and above |
| 6. | Aluminium | 7,500 metric tonne of oil equivalent (MTOE) per year and above |
| 7. | Railways | Electric traction Sub-Section (TSS), diesel loco shed, Production units and Workshops of Indian Railways having total annual energy consumption of 30,000 MTOE or more under Ministry of Railways |
| 8. | Textile | 3,000 metric tonne of oil equivalent (MTOE) per year and above |
| 9. | Pulp & Paper | 30,000 metric tonne of oil equivalent (MTOE) per year and above |

Energy Conversion values used for working out annual energy consumption in terms of metric tonne of oil equivalent For the purpose of this table

i) 1 kg of Oil Equivalent: 10000 kcal

ii) I Metric Tonne of Oil Equivalent (MTOE): 1 x $10^7$ kcal

iii) In case of coal, petroleum products and other fuels in absence of supplier certificate. GCV of the above fuel (fuel sample) will be considered as per the test Certificate from a NABL Accredited Lab or State Government Laboratory or Government recognized Laboratory

As per the Act, Designated consumers have to fulfill the following criteria:

- Designated consumers have to appoint Energy managers with prescribed qualifications.
- The designated consumer has to get an energy audit conducted by an accredited energy auditor. Designated consumers would comply with prescribed norms and standards of energy consumption for the industrial sectors.
- Designated Consumers are required to adhere to energy efficient consumption norms stipulated.
- Designated Consumers are required to submit the status of energy consumption information every financial year as prescribed.

**Perform, Achieve and Trade (PAT) Scheme** is a market based mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded. The genesis of the PAT mechanism flows out of the provision of the Energy Conservation Act, 2001 (amended in 2010).

**National Mission for Enhanced Energy Efficiency:** The Energy Conservation Act of 2001 provides a legal mandate for the implementation of the energy efficiency measures through the institutional mechanism of Bureau of Energy Efficiency (BEE) in the Central Government and designated agencies in each state. A number of schemes and programmes have been initiated under the Act and implemented by BEE has resulted in avoided capacity addition of 10836 MW the XI Plan.

The National Mission for Enhanced Energy Efficiency (NMEEE) aims to strengthen the market for energy efficiency by creating conducive regulatory and policy regime and has envisaged fostering innovative and sustainable business models to the energy efficiency sector.

The mission was approved for two years of the 11th Plan period (2010 -11 and 2011-12) with an outlay of Rs.235.50 crore and continuation of the mission for XII Plan was approved with an outlay of Rs. 775 crores.

The NMEEE spelt out four initiatives to enhance energy efficiency in energy intensive industries which are as follows:

1. **Perform Achieve and Trade Scheme (PAT)**, a market based mechanism to enhance the cost effectiveness in improving the Energy Efficiency in Energy Intensive industries through certification of energy saving which can be traded.
2. **Market Transformation for Energy Efficiency (MTEE)**, for accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable.
3. **Energy Efficiency Financing Platform (EEFP)**, for creation of mechanisms that would help finance demand side management programmes in all sectors by capturing future energy savings.
4. **Framework for Energy Efficient Economic Development (FEEED)**, for development of fiscal instruments to promote energy efficiency.

**Eight National Missions**

There are eight National Missions which form the core of the National Action Plan are:

- National Solar Mission
- National Mission for Enhanced Energy Efficiency
- National Mission on Sustainable Habitat
- National Water Mission
- National Mission for Sustaining the Himalayan Ecosystem
- National Mission for Green India
- National Mission for Sustainable Agriculture
- National Mission for Strategic Knowledge on Climatic Change

## 10.1 Energy and Environment

The combustion of hydrocarbon based fuels in industrial activity generates by-product materials, many of which are considered to be air pollutants (Figure 10.1). The principal emissions which impact on the air environment are carbon dioxide, particulate matter (dust), sulphur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide.

**Figure 10.1 Emissions Due to Energy Use**

Particulate matter is predominantly generated during the combustion of solid fuels such as coal, lignite, biomass etc mostly from ash content in the fuel. Sulphur oxide (SOx) emissions mainly occur from combustion of oil and coal due to sulphur content in the fuel. Nitrogen oxides (NOx) emissions are also associated with fuel combustion, both from fuel as well as combustion air. Both SOx and NOx emissions have been identified as major air pollutants globally as they lead to acid rain which is a trans-boundary environmental issue. The main sources of carbon monoxide emissions are due to incomplete combustion of fuels.

Carbon dioxide resulting from the oxidation of carbon in fuels during combustion dominates the total emissions. Although, carbon dioxide is not considered as a pollutant, it is considered as a major contributor to global warming and climatic change.

## 10.2 Global Environmental Issues

One of the most important characteristics of global environmental issues is that it affects all mankind on a global scale without regard to any particular country or region. These environmental issues have global significance and need to be addressed through international efforts. The whole world is a stakeholder and this raises issues on who should do what to combat environmental problems.

Some of the key environmental issues of global significance are

- ✓ Acid rain
- ✓ Ozone layer depletion
- ✓ Global warming and climatic change
- ✓ Loss of biodiversity

## 10.3 Acid Rain

Acid rain is caused by release of sulphur oxides and nitrogen oxides from combustion of fossil fuels, which then mix with water vapour in atmosphere to form sulphuric acids and nitric acids respectively (Refer Figure 10.2).

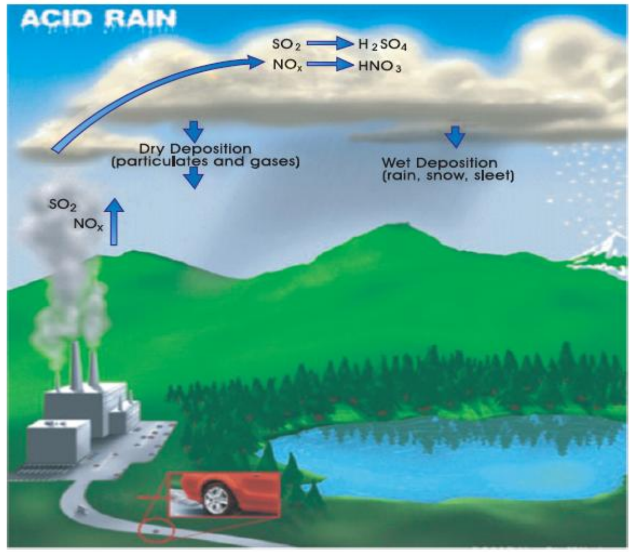



Figure 10.2 Acid Rain Formation

The effects of acid rain are as follows:

- ✓ Acidification of lakes, streams, and soils
- ✓ Direct and indirect effects (release of metals, for example: Aluminum which washes away plant nutrients)
- ✓ Killing of wildlife (trees, crops, aquatic plants, and animals)
- ✓ Decay of building materials and paints, statues, and sculptures
- ✓ Health problems (respiratory, burning- skin and eyes)

## 10.4 Ozone Layer Depletion

Ozone layer is a thin layer of ozone ($O_3$) present in stratosphere which extends from 10-50 km from the earth (Figure 10.3). The ozone layer is highly beneficial to life on earth as it blocks the sun's Ultraviolet radiations (UV-B) from reaching the earth. Any disturbance or depletion of ozone layer would result in an increase of harmful radiation reaching the earth's surface leading to dangerous consequences.

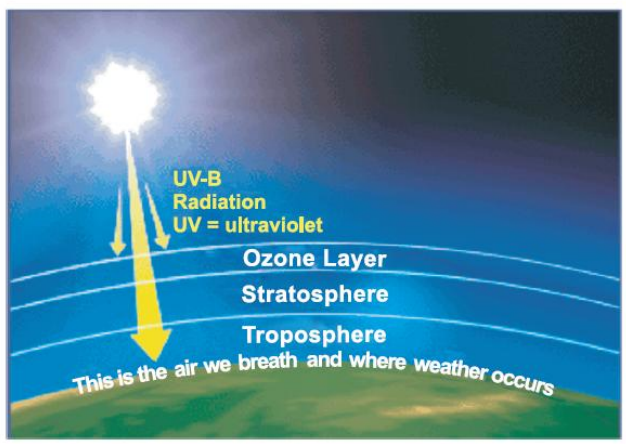



Figure 10.3 Ozone Layer

Ozone, which is highly unstable, is produced and destroyed naturally in the stratosphere and until recently, this resulted in a well-balanced equilibrium (see Figure 10.4). Ozone is formed when oxygen molecules absorb ultraviolet radiation with wavelengths less than 240 nanometres and is destroyed when it absorbs ultraviolet radiation with wavelengths greater than 290 nanometres.

**Effects of Ozone Layer Depletion**

***Effects on Human and Animal Health:*** Increased penetration of solar UV-B radiation is likely to have high impact on human health with potential risks of eye diseases, skin cancer and infectious diseases.

***Effects on Terrestrial Plants:*** Increased radiation is likely to change species composition in forest and grassland thus altering the bio-diversity in different ecosystems. It could also affect the plant community indirectly resulting in changes in plant form, secondary metabolism, etc.

***Effects on Aquatic Ecosystems:*** High levels of radiation exposure in tropics and subtropics may affect the distribution of phytoplanktons, which form the foundation of aquatic food webs. It can also cause damage to early development stages of fish, shrimp, crab, amphibians and other animals, the most severe effects being decreased reproductive capacity and impaired larval development.

***Effects on Bio-geo-chemical Cycles:*** Increased solar UV radiation could affect terrestrial and aquatic bio-geo-chemical cycles thus altering both sources and sinks of greenhouse and important trace gases, e.g. carbon dioxide ($CO_2$), carbon monoxide (CO), carbonyl sulfide (COS), etc. These changes would contribute to biosphere-atmosphere feedbacks responsible for the atmosphere build-up of these greenhouse gases.

***Effects on Air Quality:*** Reduction of stratospheric ozone and increased penetration of UV-B radiation result in higher photo dissociation rates of key trace gases that control the chemical reactivity of the troposphere. This can increase both production and destruction of ozone and related oxidants such as hydrogen peroxide, which are known to have adverse effects on human health, terrestrial plants and outdoor materials.

## 10.5 Global Warming and Climatic Change

The atmosphere is a thin layer of gas which surrounds the Earth. The two most important layers in the atmosphere are known as the troposphere and the stratosphere. The air layer gets thinner and thinner with altitude. 90% of all the molecules in the atmosphere are in the troposphere.

The atmosphere is composed mainly of 21% Oxygen, 78% Nitrogen, 0.04% carbon dioxide, and Argon 0.04% by volume. In addition, water vapour and several gases are present in very small amounts.

**The Greenhouse Effect**

The earth is surrounded by a blanket of gases including greenhouse gases. The greenhouse gases are those gases in the atmosphere which by absorbing thermal radiation emitted by the earth's surface have a blanketing effect over the surface keeping it warmer than it would otherwise be. This results in build up of energy, and the overall warming of the atmosphere. This blanket traps energy in the atmosphere, much the same way as glass traps heat inside a greenhouse. Without naturally occurring greenhouse gases such as water vapour, carbon dioxide, methane and nitrous oxide, the earth's average surface temperature would be a cold -18°C rather than the tolerable 15°C. This warming of the earth called the greenhouse effect (Figure 10.6) is a natural process which made life on Earth possible.

The Earth's atmosphere allows short-wave solar radiation from sun to pass relatively unimpeded. The long-wave infrared radiation emitted from the warm earth's surface is partially trapped and re-emitted downwards by greenhouse gases such as water vapour, carbon dioxide, methane, Nitrous oxide, in the upper atmosphere. In this way an energy balance is set up, which ensures that the Earth is warmer than it would be without it.

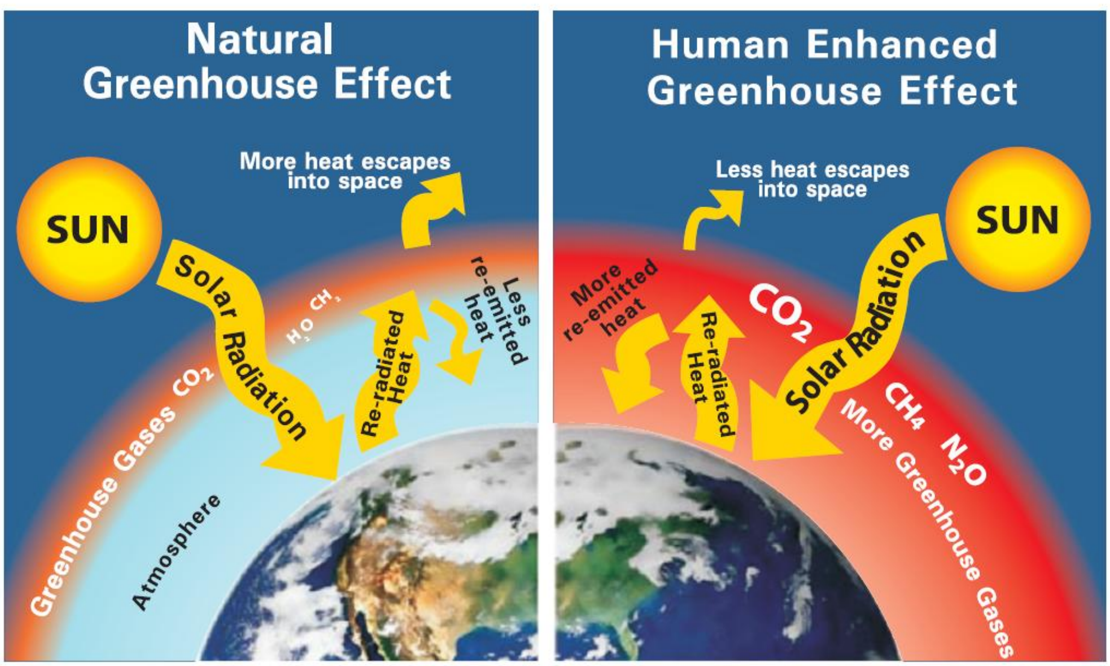



**Figure 10.6 Greenhouse Effect**

### Enhanced Greenhouse Effect

The natural greenhouse effect is enhanced (Figure 10.6) by the increase of greenhouse gases in the atmosphere especially carbon dioxide from burning of fossil fuels, coal, oil and gas, together with wide deforestation over the past 200 years and more substantially over the past 50 years.

Although, water vapour is also considered as greenhouse gas, its amount in the atmosphere is not changing directly because of human activities. The other important greenhouse gases that are directly influenced by human activities leading to enhanced greenhouse effect are carbon dioxide, methane, nitrous oxide, the chlorofluorocarbons (CFCs) and ozone.

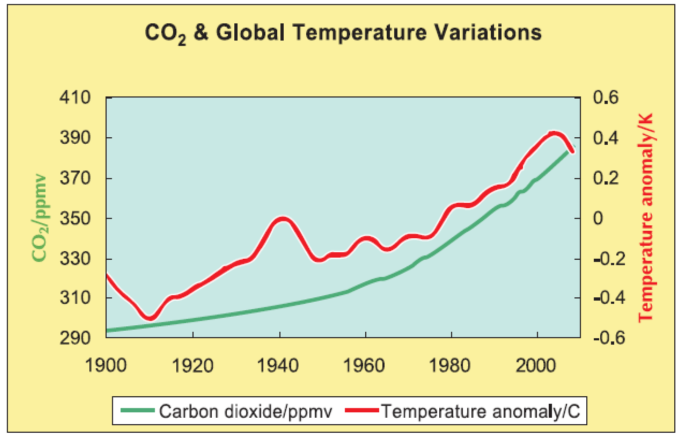



**Figure 10.7 Rising Global Temperatures**

There is now overwhelming evidence that enhanced greenhouse effect from human activities is changing the global climate. It is estimated that the earth's average temperature has risen by 0.75°C since 1880 because of emissions of greenhouse gases from human activity. The relation between $CO_2$ and global temperature variations is shown in Figure 10.7.

**Greenhouse Gases**

***Carbon Dioxide:*** Carbon dioxide is the most important of the greenhouse gases because of its abundance in the atmosphere. The increase in carbon dioxide has contributed to about 60% of the enhanced greenhouse effect as its concentration of 397 ppm (Mauna Loa Observatory: November, 2014 data) is much higher than other greenhouse gases. It is also persistent with atmospheric lifetime of over 100 years.

***Man-made Carbon Dioxide Emissions*:** The major source of $CO_2$ is fossil-fuel combustion (coal, petroleum, and natural gas). For the same amount of heat released, natural gas emits the least $CO_2$. Coal-based power plants are the major $CO_2$ sources in many countries in the world. Among the industrial processes, cement is a major contributor of $CO_2$ as emissions occur from both fuel combustion and calcination of limestone.

Petroleum-burning motor vehicles are another major contributor of $CO_2$ emissions. Deforestation contributes too because when felled trees are burned, their stored carbon is released as $CO_2$. At the same time, deforestation leaves fewer trees to take up atmospheric $CO_2$.

***Carbon Sequestration:*** It is the term given to the process of removing $CO_2$ from large point sources such as power plant, oil refineries, industrial process etc. The $CO_2$ is then stored in geologic formations such as depleted oil and gas reservoirs, deep coal seams or saline reservoirs. Oceans are a major $CO_2$ sink, containing about 50 times more carbon than the atmosphere. Terrestrial biomass including trees and grasses store about three times more $CO_2$ than the atmosphere. Together, ocean and terrestrial ecosystems absorb about half the excess $CO_2$ generated by human activities.

***Methane:*** The main natural source of methane is from wetlands. Methane is also created when organic matter such as food and vegetables decompose without presence of oxygen- a process called anaerobic decomposition.

Anthropogenic sources include leakage during coal mining, leakage from natural gas pipelines and from petroleum wells, rice cultivation, belching from cattle and other livestock, decay of municipal solid wastes dumped in landfill sites and from wood burning.

Methane is a naturally occurring inflammable gas. Methane is produced by geological coal formations and by the decomposition of organic matter. Leading anthropogenic sources of methane are landfills, livestock digestive processes and wastes, especially ruminants (cud-chewing animals) and wetland rice cultivation.

***Nitrous Oxide:*** The emissions to the atmosphere that are associated with human activities are from use of nitrogen fertilizer, manure, biomass combustion, fossil fuel combustion in power plant and the chemical industry (for example. nylon production). Also, $N_2O$ is contained in soil by bacteria. When farmers plow the soil and disturb the surface layer, $N_2O$ is released into the atmosphere. It is also released from catalytic converters in cars. It has an atmospheric lifetime of about 120 years.

***Ozone:*** Ground-level ozone is a greenhouse gas. It can absorb infrared radiation and contribute to warming. Ground-level ozone forms from Volatile Organic Compounds (VOCs) and nitrogen oxides in the presence of heat and the sun's ultraviolet radiation.

***Chlorofluorocarbons (CFCs):*** The CFCs are man-made chemicals which vaporise just below room temperature and are non-toxic and non-flammable. CFC contains chlorine atoms and has been used in industry as refrigerants, cleaning solvents, manufacturing of insulation and propellants in spray cans.

They are so chemically unreactive and once released into the atmosphere, they remain for a long time of about 100 or 200 years before being destroyed.

As an outcome of Montreal Protocol, CFCs are phased out, being replaced by other halocarbons-hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). While HCFC and HFC are less destructive to ozone than the CFCs, they are still considered as greenhouse gases.

***Perflurocarbons:*** Perfluorcarbons is also considered as an important greenhouse gas as it has a long atmospheric life, more than several thousand years. All emissions of these gases accumulate in the atmosphere and will continue to influence climate for thousands of years.

Primary aluminum production and semiconductor manufacture are the largest known man-made sources of perfluorocarbons.

***Sulphur Hexafluoride ($SF_6$):*** Sulfur hexafluoride is the most potent greenhouse gas. It is used in insulation, electric power transmission equipment, the magnesium industry, semiconductor manufacturing to create circuitry patterns on silicon wafers, and as a tracer gas for leak detection.

**Global Warming Potential (GWP)**

The different types of greenhouse gases all have different properties. For example, the amount of time they reside in the atmosphere and the amount of heat that they trap can vary widely. Many of the greenhouse gases are extremely potent—some greenhouse gases such as sulphur hexafluoride can continue to reside in the atmosphere for thousands of years after they have been emitted.


**Figure 10.8 Global $CO_2$ Emissions (Source: http://co2now.org/)**

**India's Greenhouse Gas Emissions**

India contributed to almost 7% of global emissions and is now third largest contributor in terms of $CO_2$ emissions behind China and USA. Although, India' emitted about 2.5 Giga tonnes of carbon dioxide in 2013, the per capita emissions is still low at 1.6 tonnes per annum. Coal-based power production, accounted for almost 70% of all of India's coal-related $CO_2$ emissions.

## 10.6 Global Warming and Climatic Change Impacts

There is strong evidence now that most of the observed warming over the last 50 years is caused by human activities. Climate models predict that the global temperature will rise by about 6 °C by the year 2100. The major impacts of global warming are as follows:

**Increasing Ocean Temperature and Rising Sea Levels**

During the twentieth century, observations show that the average sea level increased by about 20 cm. The largest contribution to this rise is from thermal expansion of ocean water as the oceans warm the water expands and the sea level rises. A further increase in average sea level of 10 to 20 cm by 2030 and up to 1 m by 2100 is predicted. The coastal flooding will increasingly occur with rising sea level.

People, who are already poor and overcrowded, may be forced from homes in low-lying countries such as Bangladesh. Even developed countries such as the Netherlands may lose land. Since half of the world populations live near the coastal zones, their vulnerability to rising sea levels are very high.

**Snow and Ice Melting**

Ice is already melting worldwide, especially at the earth's poles. This includes mountain glaciers, ice sheets covering West Antarctica and Greenland, and Arctic sea ice. Snow and ice melting would also lead to rising sea levels. Also melting ice caps will disturb the ocean ecosystem. Fresh water from melting ice caps would desalinate the oceans and eco systems will be put out of balance and ocean currents which regulate the temperatures will be disturbed. Also cooling property of white ice caps which reflect heat back into space is lost further warming the earth.

Over the past 150 years, the majority of mountain glaciers monitored have been shrinking. Many glaciers at lower latitudes are now disappearing, and scientists predict that the majority of glaciers will be gone by the year 2100. As glaciers continue to shrink, summer water flows will drop sharply, disrupting an important source of water for irrigation and power in many areas that rely on mountain watersheds. Monitoring of Himalayan glaciers indicates that recession of some glaciers has occurred in some regions though not consistently across entire mountain chain.

**Altered Rainfall Patterns**

Rainfall patterns would be altered, with some areas getting more rainfall and others suffering more droughts. On warmer days, more water evaporates from soil and trees into the air leading to more clouds and rainfall. But moisture can also evaporate from dry soils, depriving them of already limited moisture.

A trend of increasing rainfall has been found along the west coast, northern Andhra Pradesh while decreasing monsoon rainfall trend has been observed over north-eastern India and some parts of Gujarat and Kerala.

### Extreme Weather Events

Already, cyclones, storm, hurricanes are occurring more frequently and floods and draughts are more intense than before. This increase in extreme weather events are not considered as random events. Computer models predict this trend towards more powerful storms and hotter, longer dry periods. States of West Bengal, Gujarat and Kerala have reported increasing extreme weather trends.

### More Severe Heat Waves

Heat waves and periods of unusually warm weather are already happening and are expected to increase with global warming. Already many cities in India are experiencing increasing heat waves due to global warming.

### Loss of Biodiversity

Ecosystems will change - some species will move farther north or become more successful; others would not be able to move and could become extinct. Most of the world's endangered species (some 25 per cent of mammals and 12 per cent of birds) may become extinct over the next few decades as warmer conditions alter the forests, wetlands, and rangelands they depend on, and human development blocks them from migrating elsewhere. The oceans, which are source of great biodiversity, would also be affected. For example the coral reefs, which have limited tolerance for warm waters would be severely affected.

### Increased Diseases

Diseases currently restricted to existing hot regions may move into the newly warming regions. Malaria is one such disease, spread by mosquito vectors, infecting and killing millions each year in warm climates. As temperature increases in currently temperate regions, mosquitoes and other insects are expected to move in, spreading diseases as they go. In addition, indigenous disease organisms previously killed by winter cold will be better able to survive milder winters.

### Dwindling Freshwater Supply

A higher sea level also means salty water can infiltrate fresh groundwater in coastal areas reducing the supply and also making it undrinkable. This is a major concern, since billions of people on earth already lack access to freshwater. Higher ocean levels already are contaminating underground water sources in many parts of the world. Climate change is projected to decrease water availability in many arid- and semi-arid regions. One third of the world's population is now subject to water scarcity

### Food Shortages

Food production needs to double to meet the needs of an additional 3 billion people in the next 30 years. Water resources will be affected as precipitation and evaporation patterns change around the world. This will affect agricultural output. Climate change is projected to decrease potential crop yields in the tropics and sub-tropics for almost any amount of warming. Food security is likely to be threatened and some regions are likely to experience food shortages and hunger.

## 10.10 The Kyoto Protocol

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change. The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions. This amounts to an average of five per cent against 1990 levels over the five-year period 2008-2012.

> The major difference between the Protocol and the Convention is that while the convention encouraged industrialized countries to stabilize GHG emissions, the protocol commits them to do so.

**Targets**

The targets cover emissions of the six main greenhouse gases, namely:

- ✓ Carbon dioxide ($CO_2$)
- ✓ Methane ($CH_4$)
- ✓ Nitrous oxide ($N_2O$)
- ✓ Hydrofluorocarbons (HFCs)
- ✓ Perfluorocarbons (PFCs)
- ✓ Sulphur hexafluoride ($SF_6$)