1. ENERGY SCENARIO

Commercial and non-commercial energy, Primary energy resources, Commercial energy production, Final energy consumption, Indian energy scenario, Sectoral energy consumption, Energy needs of growing economy, Energy intensity on purchasing power parity (PPP) basis, Long term energy scenario, Energy pricing, Energy security, Energy strategy for the future, Energy conservation and its importance

1.1 Introduction

Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes critical importance in view of the ever-increasing energy needs, requiring huge investments to meet them.

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.

Energy consumption also has a significant impact on our natural environment. There is clear evidence that climate change is caused by human activity, mostly related to the use of energy.

Energy, that we use, can be classified into several types based on the following criteria:

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

1.2 Primary and Secondary Energy

Primary energy refers to all types of energy extracted or captured directly from natural resources. Primary energy can be further divided into two distinctive groups:

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

The primary energy content of all fuels is generally expressed in terms of toe (tonne of oil equivalent) and is based the following conversion factor.

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

Primary energy sources are mostly converted in industrial utilities into secondary energy sources; for example coal, oil or gas converted into steam and electricity. Primary energy can also be used directly. Some energy sources have non-energy uses, for example coal or natural gas can be used as a feedstock in fertiliser plants. Primary energy is transformed in energy conversion process to more convenient forms of energy such as electricity, steam etc. These forms of energy are called secondary energy. The major primary and secondary energy sources are shown in Figure 1.1.

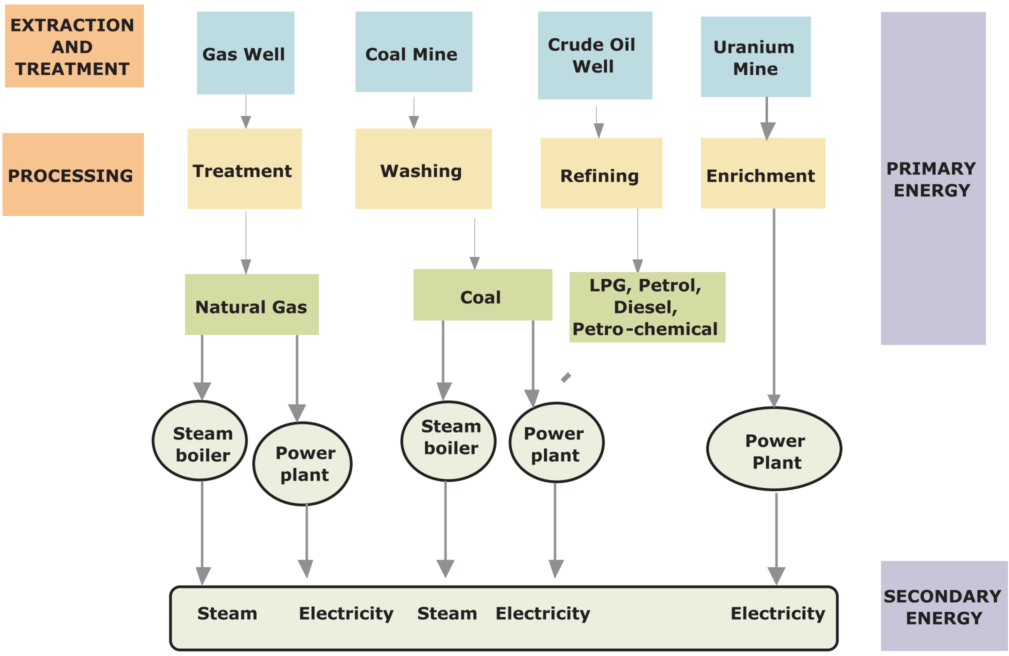


Figure 1.1 Major Primary and Secondary Energy Sources

1.3 Commercial Energy and Non Commercial 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.

1.4 Renewable 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.

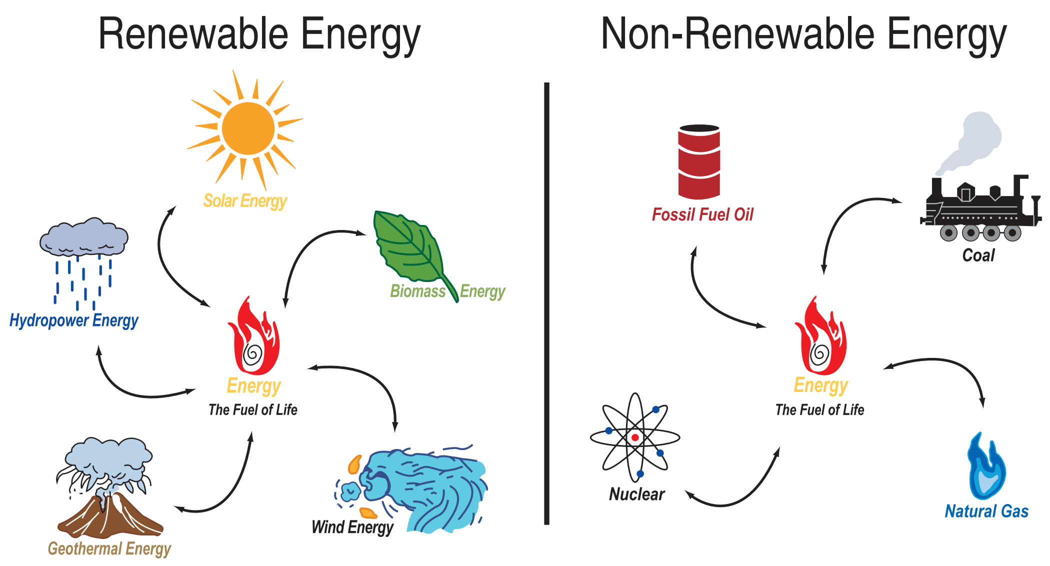


Figure 1.2 Renewable and Non-Renewable Energy

1.5 Global Primary Energy Reserves and Commercial Energy Production

Coal

Coal is the most abundant and geographically dispersed fossil fuel and exists as peat, brown coal (lignite), sub-bituminous, bituminous and anthracite (see Figure 1.3).

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 (Source: BP Statistical Review of World Energy, 2014).

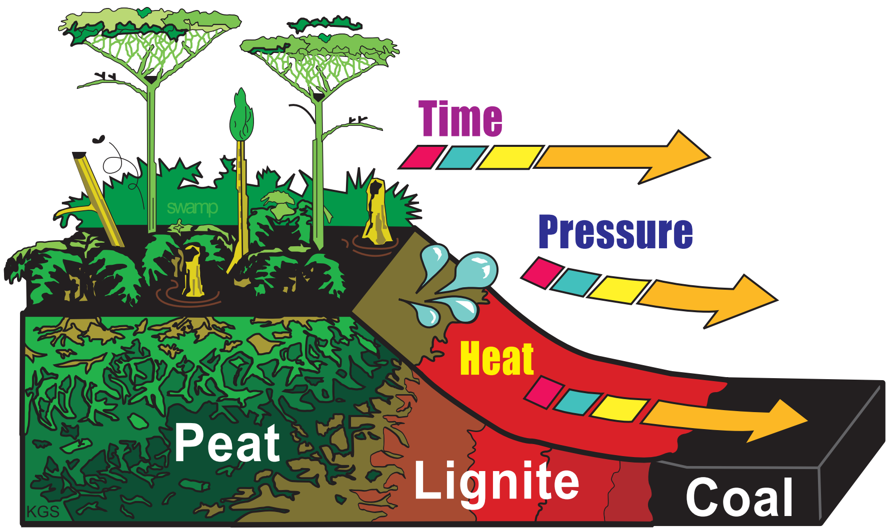


Figure 1.3 Formation of Coal

Reserves/Production (R/P) - If the reserves remaining at the end of the year are divided by the production in that year, the result is the length of time that the remaining reserves would last if production were to continue at that level.

Coal reserves are available in almost every country worldwide with recoverable reserves in around 75 countries. The largest coal reserves are available in the USA, followed by Russia, China, Australia and India (see Table 1.1).

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

Despite its poor environmental credentials, coal remains a crucial contributor to energy supply in many countries. Although countries in Europe, and to some extent North America, are trying to shift their consumption to alternative sources of energy, any reductions are more than offset by the large developing economies, primarily in Asia, which are powered by coal and have significant coal reserves. China alone now uses as much coal as the rest of the world.

The top coal producers are given in Table 1.2. Most of the demand for coal comes from power sector.

Table 1.2 Top Coal Producers in Million Tonnes (by end of 2013)

Country	Million tonnes	Share of total, %
China	3680.0	47.4
US	892.6	12.9
Indonesia	421.0	6.7
Russian Federation	374.1	4.3
India	605.1	5.9
South Africa	256.7	3.7
Others	1666.9	19.1
World	**7896.4**	100

Source: BP Statistical Review of World Energy June 2014

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)

Saudi Arabia was the largest oil producer in the world (end of 2013) followed closely by Russian Federation and US. Although the United States ranks third in terms of oil production, it only ranks tenth in terms of proven oil reserves. The top oil producing countries in 2013 are given in Table 1.4. 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

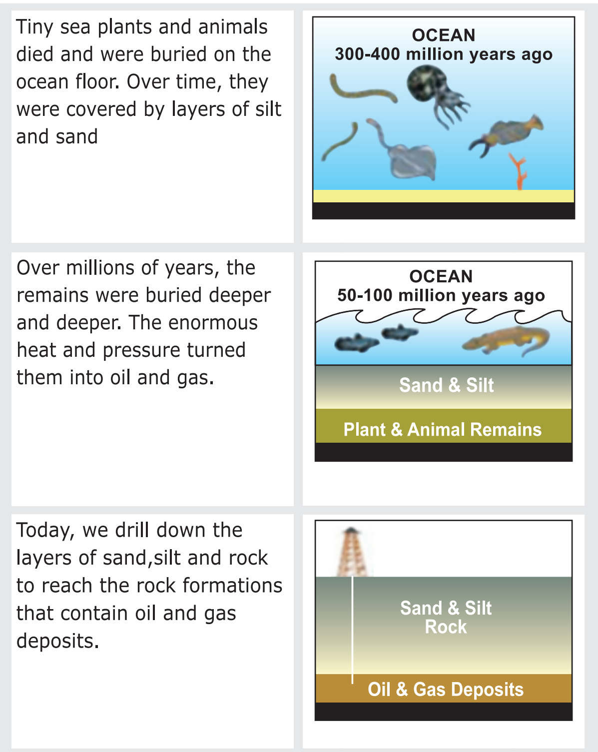
Region	Million tonnes per year	Share of total, %
Saudi Arabia	542.3	13.1
Russia	531.3	12.9
US	446.2	10.8
China	208.1	5.0
Canada	193	4.7
Iran	166.1	4.0
Iraq	153.2	3.7
Nigeria	111.3	2.7
Others	2351.5	43.1
World	**4130.2**	**100**

Source: BP Statistical Review of World Energy June 2014

If production continues at today's rate, many of the major producers such as US, Russia, China will have their oil fields largely depleted within a decade. At that point of time, world may have to depend mostly on Middle East for oil.

The Middle East overall reserves-to-production ratio for conventional oil (average of about 78 years) is much higher than that of non-Middle East countries.

Since unconventional oil resources, including oil shale, oil sands, extra heavy oil and natural bitumen are taken into account as oil, the global oil reserves will be four times larger than the current conventional reserves. Oil still remains the premier energy resource with a wide range of possible applications. Its main use however, will be shifting towards transport and the petrochemical sector. In future oil's position at the top of the energy ladder will face a strong challenge from other fuels such as natural gas.



Oil shale generally refers to any sedimentary rock that contains solid bituminous materials (called **kerogen**) that are released as petroleum-like liquids when the rock is heated in the chemical process of pyrolysis.

Oil sands (also known as Tar sands) are a combination of clay, sand, water, and **bitumen**, a heavy black viscous oil. Tar sands can be mined and processed to extract the oil-rich bitumen, which is then refined into oil.

Natural bitumen is the portion of petroleum that exists in the semi-solid or solid phase in natural deposits. In its natural state it usually contains sulphur, metals and other non-hydrocarbons.

Extra Heavy Oil is the portion of heavy oil having an API gravity of less than 10°.

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.

Natural gas resources are large, but, like oil, they are highly concentrated in a few countries and fields**.** The global proved gas reserve was estimated to be around 186 trillion cubic metres by the end of 2013. This is equal to around 55 years of current production. Iran has the largest share of the reserve followed by Russia and Qatar. India has only about 0.7% of global natural gas reserves. The global distribution of proved natural gas reserves is given in Table 1.5.

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

US is the world's largest natural gas consumer at around 22% followed by Russia at around 12%. Other top gas consuming countries include Iran, China, and Saudi Arabia. Natural gas is extensively used for power generation, transportation and heating buildings in most countries. It would require creation of adequate physical infrastructure to enable mass usage in energy hungry countries like India and China.

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 Primary Energy Consumption

The global primary energy consumption at the end of 2014 was equivalent **to 12730 Million tonnes oil equivalent**. The share of oil is the largest at 33% followed by coal and natural gas with 30% and 24% respectively. The demand for natural gas in future will increase as industrialized countries take strong action to cut CO_2 emissions. The Table 1.6 shows the breakup of various constituents of primary energy consumption (Million Tonnes of Oil Equivalent, Mtoe) worldwide.

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

The primary energy consumptions for some of the developed and developing countries are shown in Table 1.7. It may be seen that India's absolute primary energy consumption is only about 4.7 % of the world, 26% of USA's and 21% of China's consumption.

Table-1.7 Primary Energy consumption at the end of 2013

	Million tonnes of oil equivalent (Mtoe)							
Country	**Oil**	**Natural gas**	**Coal**	**Nuclear Energy**	**Hydro-Power**	**Renewable Energy**	**Total**	**% of Share**
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

1.6 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 energy consumption in the end-use sectors. Energy used for transformation and for own use by the energy producing industries are excluded. Thus, final consumption reflects energy delivered to 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

Coal Sector

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.

The production of coal (coking and non-coking coal) and lignite is shown in the following Table 1.9.

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

Most of these are high ash content coal (30-45%) and the calorific value in the range of 3000 kcal/kg to 4,500 kcal/kg. The power sector consumes about 75% of the coal produced. Using the high ash coal for the power sector is a challenge in terms of achieving efficiency of consumption and environmental management of the fly ash emissions.

The coal produced in the country is not sufficient to meet the present demand of power, steel and cement sectors which are expanding their capacities. To meet this increasing gap between demand and supply, higher calorific value and low ash content coal are being imported mainly from Australia, Indonesia and South Africa based on quality as well as cost considerations. Coking coal is imported by steel sector and coke manufacturers mainly on availability and quality considerations. Coastal based power stations and cement plants are also importing non-coking coal on considerations of transport logistics and commercial reasons. Main exporter of coal to India was Indonesia followed by Australia and South Africa.

Import of coal is sharply increasing since 2011 and about 145.785 million tonnes of coal (about 20 % of the annual coal requirement) were imported during the year 2012-2013. India's coal import over the period is shown in the Table 1.10.

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

The Government levies Clean Energy Cess or coal tax, on all the coal, peat and lignite mined within the country or imported since July 1, 2010. The Indian Government has announced the coal tax in order to generate funding for the research, development and deployment of cleaner and renewable energy technologies. A tax of Rs. 100 would be levied on every tonne of coal mined in the country as well as that imported from abroad.

However, with India already having committed (domestic commitment) to reduce its carbon intensity by 20 to 25 percent from 2005 levels by 2020, the strategy of using coal for large-scale rural electrification could hamper its efforts to achieve the carbon intensity reduction targets.

Oil Sector

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.

Since the introduction of New Exploration Licensing Policy (NELP), oil and gas sector has been opened to private and foreign investments in order to bring new technologies and international best practices. During the year 2013-14 the import of crude oil was 189.238 MMT valued at Rs. 8,64,875 crores. Table 1.11 gives the crude oil import bill trend over the last few years.

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

Natural Gas Sector

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^{o}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.

Power generation and fertiliser industry dominate the natural gas consumption at 62% . Since gas now finds uses beyond conventional power and fertilizer sectors like automotive fuels, distributed power generation, industrial and domestic fuel, etc., the Indian Government is keen on increasing the availability of gas in the country.

A gas grid is being constructed across the country to meet the consumers' bulk and retail use. City gas supply is now covered only in a few major cities and is set to increase with India's gas infrastructure. More LNG terminals are also being developed to tap the global gas market.

The disadvantages with the use of natural gas are unpredictability in its price and uncertainty in its availability.

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 Power 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.

1.8 Sector wise Energy Consumption in India

The major commercial energy consuming sectors in the country are shown in the Figure 1.4. The industrial sector consumes almost 44 % of the total commercial energy consumption followed by transport.

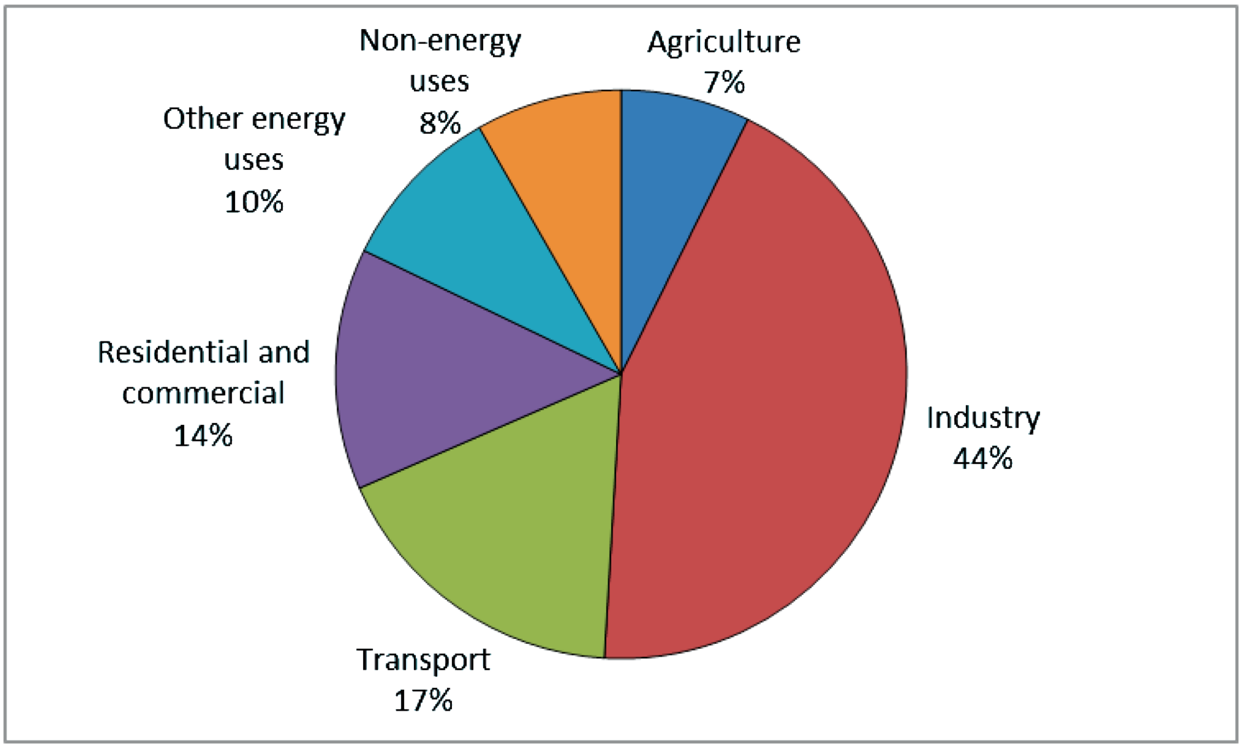


Figure 1.4 Sectorwise Energy Consumption
Source: TERI

Specific Energy Consumption (SEC) of the major industry sectors in India is much higher compared to global benchmarks (see Table 1.13). With ever increasing energy costs, it is more important to improve the energy efficiency of manufacturing processes in major industries and small enterprises.

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.

Gradual shift to mechanized farming has lead to a steep rise in agricultural energy consumption, both electricity and diesel. The electricity consumption in agriculture sector has increased at a much faster rate compared to other sectors during the last four decades

1.9 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

As far as electricity consumption is concerned, India has reached a level of about 917 kiloWatt hour (kWh) per person per year (2012-13) as shown in Table 1.14. The comparable figure for Japan is 7848, for China 3298, for USA 13,246, for UK 6206, for Canada 16,473 and the world average is 2430 (Source: World Bank). Thus, India's per capita electricity consumption is much less than that of many countries and much less than the World average

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.

1.10 Integrated Energy Policy

The power supply position prevailing in the country is characterized by persistent power shortages, unreliability and also high prices for industrial consumer. India depends on imported oil to an extent of about 75% and this raises energy security concerns.

Also consistency in policies governing each sector and consistency in pricing of different types of energy is lacking. There is a need for clarity in the direction which we must follow in aspects like energy security, addressing environmental concerns, energy conservation and Research and Development.

To achieve these objectives, Expert Committee has made a comprehensive review to make recommendations for integrated energy policy. The integrated energy policy is briefly covered in Chapter-2 of this book.

1.11 Energy Intensity on Purchasing 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 $

A low energy intensity would indicate that the country has the right mix of industries sector wise. An economy dominated by heavy industrial production, for instance, is more likely to have higher energy intensity than the one where the service sector is dominant, even if the energy efficiencies of the two countries are identical. Likewise, a country that relies on trade to acquire (import) carbon-intensive goods will—when all other factors are equal—have lower energy intensity than the countries that manufacture the same goods for export.

Although, energy use generally increases as the economy grows, continuing improvement in the energy efficiency of the nation's economy and a shift to less energy-intensive activities are projected to keep the rate of energy consumption growth lower than the rate of GDP growth

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).

1.12 Long Term Energy Scenario for India

Coal

Apart from meeting the energy needs of the industry, coal is the predominant energy source for power production in India accounting for about 60% of the installed capacity. Energy demand in India is expected to increase heavily over the next 10-15 years. Coal will continue to remain the dominant fuel in the Indian economy.

Despite significant increases in the total installed generation capacity during the last decade, the gap between the electricity supply and demand continues to increase. The resulting shortfall has had a negative impact on the industrial output and economic growth.

The coal production stood at around 551.71 Million tonnes by the end of 2013. Indian coal is typically of poor quality and as such requires beneficiation to improve the quality. As domestic coal production is very unlikely to cope with increasing demand, coal imports are expected to increase drastically in future to satisfy the industrial and power generation requirements.

Oil

India's demand for petroleum products rose from 97.7 million tonnes in 2001-02 to around 175.2 million tonnes by 2013. Domestic crude oil production was 37.788 million metric tonnes (MMT) for the year 2013-14.

India's self sufficiency in oil has consistently declined from 60% in the 1950s to 25% currently. Same is expected to go down to 8% by 2020. About 90% of India's total oil demand by 2020 would have to be met by imports.

Natural Gas

In keeping with the world wide trend, the demand for natural gas in India has been on the increase. The production of natural gas which was negligible at the time of independence is now at the level of 35.407 Billion Cubic Meters. To meet the future requirements of natural gas, trans-national gas pipelines are being planned.

While gas pipeline projects would yield results only in long term, immediate relief can come in the form of LNG. Import of LNG will require special terminals to handle them at the ports. The constructions of such terminals have already started and some of them have been commissioned. The world trade in LNG is around 150 Billion Cubic Metres (BCM). Geographically, India is strategically located and is flanked by large gas reserves on both East and West. India is located relatively near to four of top five countries in terms of proven gas reserves viz. Iran, Qatar, Saudi Arabia and Abu Dhabi. The large natural gas market of India is a major attraction to the LNG exporting countries. In order to encourage gas imports, Government has kept import of LNG under Open General License (OGL) and permitted 100% Foreign Direct Investment (FDI)

Electricity

With India already reeling under peak demand and energy shortage, increasing economic growth is expected to put heavy pressure on the power sector. For sustaining the current economic growth rate, the capacity will have to be doubled every 10 years.

Accelerated Power Development & Reforms Programme was introduced by the Ministry of Power in 2002-03 in order to improve the power reliability at the distribution level and to achieve commercial viability of State Electricity Boards. The strategies include technical, commercial, financial and IT interventions to achieve the following objectives

- Targets towards the commercial viability of the utilities by reducing their Aggregate Technical & Commercial (AT&C) losses to 15%
- Improvement in quality, supply and reliability of supply
- Improved revenue collection and customer satisfaction

APDRP was later restructured as R-APDRP, the focus of which is on actual, demonstrable performance in terms of loss reduction.

1.13 Electricity Pricing in India

In terms of purchasing power parity, power tariffs in India for industries and commercial establishments are among the highest in the world. The average tariff on PPP basis in India is 30.8 cents/kWh, while it is 7.7 in US, 15.3 in Japan and 20.6 in China.

Consumer prices for electricity are currently set by State Electricity Regulatory Commissions on cost plus basis. Power tariffs are structured on the basis of industrial and commercial users cross subsidizing agricultural and domestic power consumption.

Electricity tariffs in India are structured in a relatively simple manner. While high tension consumers are charged based on both demand (kVA) and energy (kWh), the low-tension (LT) consumer pays only for the energy consumed (kWh) as per tariff system in most of the distribution companies. The price per kWh varies significantly across States as well as customer segments within a State.

The agricultural sector is supplied un-metered power in almost all states and the farmers pay a highly subsidized lump sum amount based on the declared horse power of their pumps. This leads to a zero marginal cost of power which promotes inefficient use and over exploitation of ground water. The domestic sector also has a range of subsidies based on the level of consumption including heavily subsidised power for the poorest segment wherein households pay a low lump sum monthly charge. With the rising cost of supply, the burden of these cross-subsidies has increased and is disproportionately loaded on the paying industrial, commercial and large household consumers.

Introduction of Availability Based Tariffs (ABT) and unscheduled interchange charges for power, introduced in 2003 for inter-state sale of power, have reduced voltage and frequency fluctuations.

What is ABT?

- It is a performance-based tariff system for the supply of electricity by generators owned and controlled by the central government
- It is also a new system of scheduling and dispatch, which requires both generators and beneficiaries to commit to day-ahead schedules.
- It is a system of rewards and penalties seeking to enforce day ahead pre-committed schedules, though variations are permitted if notified one and half hours in advance.
- The order emphasises prompt payment of dues. Non-payment of prescribed charges will be liable for appropriate action.

1.14 Energy Security

The basic aim of energy security for a nation is to reduce its dependency on the imported energy sources for its economic growth. Energy security is defined as **“The continuous availability of energy in varied forms in sufficient quantities at reasonable prices”.**

World Energy Assessment (UNDP 1999)

Energy security is a serious concern because India's energy needs are growing with rising income levels and a fast growing population. The dependence on imported energy is also increasing rapidly due to increasing energy needs. A special concern is that the import of oil is about 75% of total oil consumption. The domestic oil wells are all over 30 years old and the yield from these wells have started reducing. Oil demand is rising at a rate of about 5% every year leading to huge oil import bills. By 2020, it is projected that our oil imports would exceed 90% of the total consumption if the economic growth continues at the same pace as now.

Any disruption in energy supplies would be harmful to the country's economic growth, human survival and well being. For example, disruption in oil supply or increase in price of oil will force the farmers to reduce the use of pumps and tractors and this will lead to lower agricultural output which in turn may lead to lower employment.

India is dependent on Middle East- a region prone to disturbances and disruptions of oil supplies- for most of our oil imports. This calls for diversification of sources of oil imports. The need to deal with oil price fluctuations also necessitates measures to be taken to reduce the oil dependence of the economy, possibly through fiscal measures to reduce demand, and by developing alternatives to oil, such as natural gas and renewable energy.

Poor coal quality and high prices of domestic coal will drive the increase in coal imports from present level of 25%. The imports of gas and LNG (liquefied natural gas) are likely to increase in the coming years. Thus the energy import dependence implies vulnerability to external price shocks and supply fluctuations, which in turn threaten the energy security of the country.

Some of the strategies that can be used to meet future energy requirements include:

- Reducing energy requirements
  - Improving the efficiency of extraction of fossil fuels
  - Improving fuel efficiency of new coal-fired power plants by adopting new technology (i.e. super critical pulverized fuel fired boilers)
  - Adopting energy efficiency and demand side management
  - Promotion of public transport / mass transport (e.g. metro rail, light rail, monorail etc.) in urban areas
  - Developing renewable energy sources especially solar and wind
- Substituting imported oil/gas with domestic alternatives
  - Ethanol / Biodiesl as substitute for petrol / diesel
  - Biomass gasification for heat or power as alternative to gas / coal
  - Coal-to-oil technology as done in South Africa

- Diversifying energy supply sources
  - Mix of fuel comprising of coal, gas, nuclear, hydro and renewables with no dependence on any particular fuel
  - Sourcing oil / LNG from different countries
  - Importing gas through pipelines passing through countries who also benefit
- Expanding energy resource and developing alternative energy sources
  - Improved Oil Recovery (IOR) and Enhanced Oil Recovery (EOR) for improving exploitation of reserves
  - Recovery of oil and gas from abandoned or marginal fields
  - In-situ coal gasification
  - Capturing Coal Bed Methane (CBM) which escapes from coal seams during mining
  - Conversion of coal to oil
  - Gas to Liquid (GTL)
  - Stepping up exploration to find new reserves (only one-third of oil bearing area explored so far)
  - Equity oil, gas, coal from other countries
  - Setting up energy intensive units (i.e. fertilizer plants) abroad
  - New domestic sources (nuclear –fast breeder reactor, thorium reactors, gas hydrates etc.)
  - Promoting Community Biogas Plants
  - Energy plantations

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).

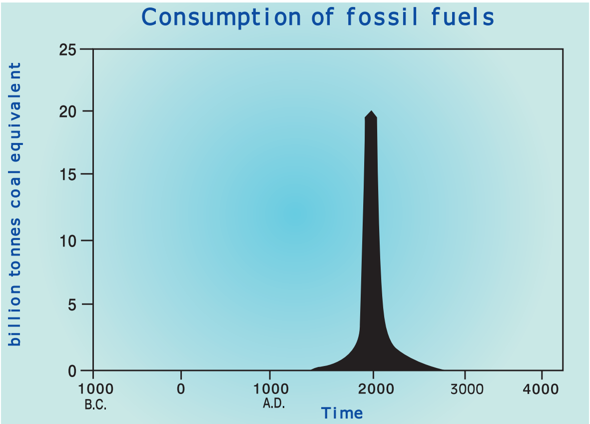


Figure 1.5 Consumption of Fossil Fuels

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.

Energy efficiency is often viewed as a resource option like coal, oil or natural gas. It provides additional economic value by preserving the resource base and reducing pollution. For example, replacing Incandescent lamps with LED's means will require $1/8^{th}$ of the energy to light a room. Pollution levels also reduce by the same amount (refer Figure 1.6).

Nature sets some basic limits on how efficiently energy can be used, but in most cases our products and manufacturing processes are still a long way from operating at this theoretical limit. Very simply, energy efficiency means using less energy to perform the same function.

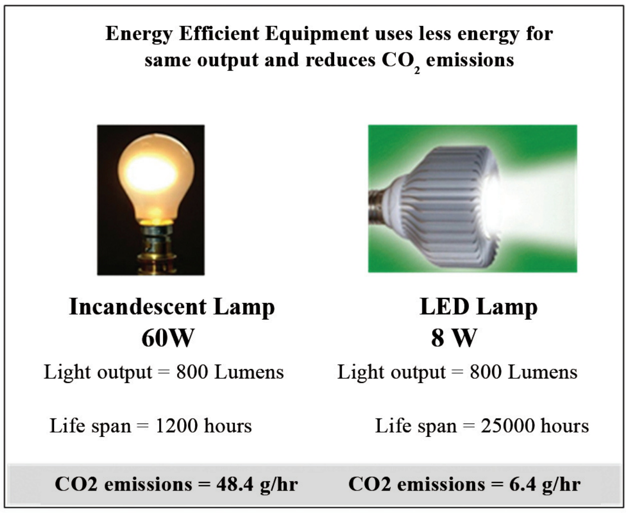


Figure 1.6 Energy Efficient Equipment

Although, energy efficiency has been in practice ever since the first oil crisis in 1973, it has today assumed even more importance because of being the most cost-effective and reliable means of mitigating the global climatic change. Recognition of that potential has led to high expectations for the reduction of future CO_2 emissions through more energy efficiency improvements than that achieved in the past. The industrial sector accounts for about 41 per cent of global primary energy demand and approximately the same share of CO_2 emissions. The benefits of Energy conservation for various players are given in Figure 1.7.

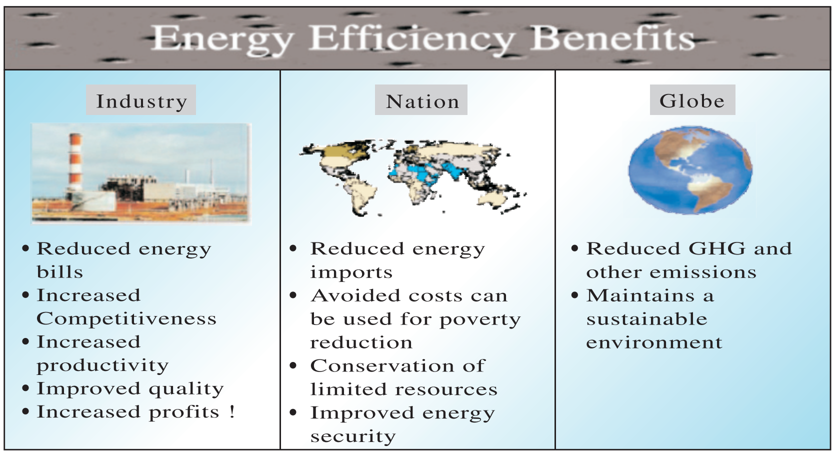


Figure 1.7 Energy Efficiency Benefits

QUESTIONS	
Objective Type Questions	
1.	The Government of India levies Clean Energy Cess on which of the following: a) Electricity b) Coal c) Diesel d) Biodiesel
2.	One tonne of oil equivalent is a) 10,000 kcal b) 1000 kcal c) 1000 kg of oil d) 10 Mcal
3	Which of the following is not a national mission under the Prime Minister's National Action Plan on Climatic Change a) National solar mission b) National mission for enhanced energy efficiency c) National mission on CFC alternatives d) National mission for green India
4	The country that accounts for largest energy consumption is a) USA b) Russia c) China d) India
5.	Coal in our planet is expected to last for about a) 45 years b) 65 years c) 200 years d) 113 years
6.	The major source of electrical power generation in India is a) thermal b) hydel c) nuclear d) wind
7.	Which of the following with respect to fossil fuels is true? a) R/P ratio is a constant once established b) R/P varies every year with only changes in production c) R/P ratio varies with only changes in reserves d) R/P ratio varies every year with changes in both production and reserves
8.	Nuclear energy development in India is constrained by a) low % of Uranium in the ore b) inadequate supply of Uranium c) constraints in import of Uranium d) all of the above
9.	Availability based tariff is applicable to a) oil b) coal c) natural gas d) electricity
10.	Energy intensity is the ratio of a) fuel consumption / GDP b) GDP/fuel consumption c) GDP/energy consumption d) energy consumption/GDP
Short Type Questions	
S-1	Write a short description about Availability Based Tariff (ABT)
S-2	Briefly explain 'Renewable Purchase Obligation (RPO) and means by which this requirement can be met?

S-3	Give a short description about primary and secondary energy with examples
S-4	Covert the following into tonnes of oil equivalent 10,000 kg of coal with a calorific value of 4000 kcal/kg 10 lac kWh
S-5	What is meant by PPP?
Long Type Questions	
L-1	Explain the difference between energy conservation and energy efficiency with a suitable example
L-2	List five strategic measures for meeting energy security of a country.

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4. ENERGY MANAGEMENT AND AUDIT

Definition, Energy audit, Need, Types of energy audit. Energy management (audit) approach, Understanding energy costs, Benchmarking energy performance, Matching energy use to requirement, Maximizing system efficiencies, Optimizing the input energy requirements, Fuel and energy substitution, Energy audit instruments and metering, Manner and intervals of EA regulation.

4.1 Definition and Objectives of Energy Management

The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental effect. The definition of energy management is:

"The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions" (or)

"The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems"

The objectives of Energy Management include,

- ✓ To achieve and maintain optimum energy procurement and utilisation, throughout the organization
- ✓ To minimise energy costs / waste without affecting production and quality
- ✓ To minimise environmental effects.

Successful energy management must combine an effective strategy with the right practical action. It begins with the key decision makers, and then involves every employee on a day-to-day basis. Many organisations would like to save energy, but to have the most impact and success, they need to give priority to energy management and make it an integral part of company management strategy.

4.2 Energy Audit Definition

Energy Audit is the key to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial Energy Audit is fundamental to a comprehensive energy management programme and is defined in EC Act 2001 as follows:

"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.

4.3 Need for Energy Audit

In any industry, the three top operating costs are often found to be energy (both electrical and thermal), labour and materials. Among the three, energy has the highest potential for cost reduction. Energy audit will help to understand more about the ways energy is used in the industry, and help in identifying the areas where waste can occur and where scope for improvement exists. Such an audit programme will review variations in energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment etc. In general, energy audit is the translation of conservation ideas into realities, by evolving technically feasible solutions with economic and other organizational considerations within a specified time.

4.4 Types of Energy Audit and Approach

The type of energy audit to be performed depends on the type of industry, the depth to which final audit is needed, and the potential and magnitude of cost reduction desired. Thus energy audit can be classified into the following types: Preliminary Audit, Targeted Energy Audits and Detailed Audit.

Preliminary Energy Audit

Preliminary energy audit, which is also known as Walk-Through Audit and Diagnostic Audit, is a relatively quick exercise and uses existing, or easily obtained data. The scope of preliminary energy audit is to:

- Establish energy consumption in the organization (sources: energy bills and invoices)
- Obtain related data such as production for relating with energy consumption
- Estimate the scope for energy savings
- Identify the most likely and the easiest areas for attention (e.g. unnecessary lighting, higher temperature settings, leakage etc.)
- Identify immediate (especially no-/low-cost) improvements/ savings
- Set up a *baseline* or *reference point* for energy consumption
- Identify areas for more detailed study/measurement

Some example of no-cost energy management measures are:

- Arresting leaks (steam, compressed air)
- Controlling excess air by adjusting fan damper

Some examples of low-cost energy management measures are:

- Shutting equipment when not needed (e.g. idle running of motors)
- Replacement with appropriate lamps and luminaires

Areas for detailed study/measurement are:

- Converting from direct to indirect steam heated equipment and recovery of condensate
- Installing / upgrading insulation on equipment

- Modifying process to reduce steam demand
- Investigating scheduling of process operations to reduce peak steam or water demands
- Evaluating waste heat streams for potential waste heat recovery

Targeted Energy Audits

Targeted energy audits often results from preliminary audits. They provide data and detailed analysis on specified target projects. For example, an organization may target its lighting system or boiler system or steam system or compressed air system with a view of effecting energy savings. Targeted audits therefore involve detailed surveys of the target subjects and analysis of the energy flows and cost associated with the targets. Final outcome is the recommendations regarding actions to be taken.

Detailed Energy Audit

Detailed energy audit is a comprehensive audit and results in a detailed energy project implementation plan for a facility, since it accounts for the energy use of all major equipment. It considers the interactive effects of various projects and offers the most accurate estimate of energy savings and cost. It includes detailed energy cost saving calculations and project implementation costs.

One of the key elements in a detailed energy audit is the energy balance. This is based on an inventory of energy-using systems, assumptions of current operating conditions, measurements and calculations of energy use.

Detailed energy auditing is carried out in three phases: a) Pre Audit Phase b) Audit Phase and c) Post Audit Phase. A comprehensive ten-step methodology for conducting detailed energy audit is suggested as follows. However, methodology is flexible and can be adapted depending upon the industry concerned.

Ten Steps Methodology for Conducting Detailed Energy Audit

Step No	PLAN OF ACTION	PURPOSE / RESULTS
PHASE I –PRE AUDIT PHASE		
Step 1	• **Plan and Organise** • **Walk through Audit** • **Informal Interview** with Energy Manager, Production / Plant Manager	• Establish/organize a **Energy audit team** • Organize Instruments and time frame • Macro data collection (suitable to type of industry.) • Familiarization with process / plant activities • First hand observation and Assessment of current level of operation and practices
Step 2	• **Introductory Meeting** with all divisional heads and persons concerned with energy management (1-2 hrs.)	• To built up cooperation and rapport • Orientation, awareness creation • Issue questionnaire tailored for each department

PHASE II –AUDIT PHASE		
Step 3	• **Primary data gathering, Process Flow Diagram and Energy Utility Diagram**	• Historic data collection and analysis for setting up **Baseline energy consumption** • All service **utilities system diagram** (e.g. Single line power distribution diagram, water, and compressed air and steam distribution). • Prepare **process flow charts** • Design, operating data and schedule of operation • Annual Energy Bill and **energy consumption pattern** (Refer manual, logbook, name plate etc.)
Step 4	• **Conduct survey and monitoring**	• **Measurements** : Motor survey, Insulation, lighting survey etc. with portable instruments for operating data. Confirm and compare operating data with design data.
Step 5	• **Conduct of detailed trials** / tests for selected major energy equipment	• **Trials / Tests** - 24 hours power monitoring (MD, PF, kWH etc.). - Load variations trends in pumps, fan compressors etc. - Boiler Efficiency trials for (4-8 hours) - Furnace Efficiency trials - Equipments Performance tests etc
Step 6	• **Analysis of energy use**	• **Energy and Material balance** • **Energy loss/waste analysis**
Step 7	• **Identification and development of Energy Conservation (ENCON) opportunities**	• Conceive, develop and refine ideas • Review ideas suggested by unit personnel • Review ideas suggested in previous energy audit report if any • Use brainstorming and value analysis techniques • Contact vendors for new / efficient technology
Step 8	• **Cost benefit analysis**	• Assess technical feasibility, economic viability and prioritization of ENCON options for implementation • Select the most promising projects • Prioritise by low, medium, long term measures
Step 9	• **Reporting and Presentation** to the Top Management	• Documentation, draft Report Presentation to the top Management. • Final report preparation on feedback from unit
PHASE II –POST AUDIT PHASE		
Step 10	• **Implementation and Follow-up**	**Implementation of ENCON recommendation measures** and Monitor the performance • Action plan, schedule for implementation • Monitoring and periodic review

Phase I – Pre Audit Phase

An initial study of the site should always be carried out as proper planning is a pre-requisite for an effective audit. An initial site visit should take only one day and gives the Energy Auditor an opportunity to meet the personnel concerned, to familiarize with the site and to assess the procedures necessary to carry out the energy audit.

During the initial site visit the Energy Auditor/Engineer should carry out the following actions:

- Discuss with the site's senior management about the aims of the energy audit.
- Explain the purpose of the audit and indicate the kind of information needed during the facility tour
- Discuss economic guidelines associated with the recommendations of the audit.
- Analyze the major energy consumption data with the relevant personnel.
- Obtain site drawings where available – plant / building layout, steam distribution, compressed air distribution, electricity distribution etc.
- Tour the site accompanied by site representative.

Typically, Energy Auditor should ask,

1. What function does this system serve?
2. How does this system serve its function?
3. What is the energy consumption of this system?
4. What are the indications that this system is probably working?
5. If this system is not working, how can it be restored to good working conditions?
6. How can the energy cost of this system be reduced?

The outcome of this visit should be:

- To finalise Energy Audit team
- To know the expectation of management from the audit
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify existing instrumentation and additional metering required prior to audit e.g. for measurement of electricity, steam, oil or gas consumptions
- To plan for audit with time frame
- To collect macro data on plant energy resources, major energy consuming equipments
- To build up awareness and support for detailed energy audit

Phase II – Detailed Energy Audit Phase

Depending on the nature and complexity of the site, a detailed audit can take from several weeks to several months to complete. Detailed studies would involve investigation and establishment of material and energy balances for specific plant departments or process equipment. Whenever possible, checks of plant operations are carried out over extended periods of time, at night and at weekends as well as during normal daytime working hours, to ensure that nothing is overlooked.

The information to be collected during the detailed audit includes:

1. Sources of energy supplies (e.g. electricity from the grid or self-generation)
2. Energy cost and tariff data
3. Generation and distribution of site services (e.g. compressed air, steam, water, chilled water).
4. Process and material flow diagrams
5. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc.)
6. Energy consumption by type of energy, by department, by major process equipment, by end-use
7. Potential for fuel substitution, process modifications, and the use of co-generation system
8. Review of ongoing energy management procedures and energy awareness training programs.

Energy audit team should ensure that the following baseline data are collected:

- ✓ Quantity and type of raw materials
- ✓ Technology, process used and equipment used
- ✓ Capacity utilization
- ✓ Efficiencies / yield
- ✓ Percentage rejection / reprocessing
- ✓ Quantity and types of wastes
- ✓ Consumption of fuel, water, steam, electricity, compressed air, cooling water, chilled water

Energy auditor must specially interview the supervisors and equipment operators as they have information related to the equipment. Maintenance manager is often the primary person to talk about types of lighting, lamps, sizes of motors, A/c plant and electrical load and related performance problems.

Preparing Process Flow Diagram

An overview of unit operations, important process steps, material and energy use and waste generation is then assembled in the form of process flow diagram. Information from existing drawings, records and shop floor survey will help in preparing the flow chart. Simultaneously the team should identify the various inputs and output streams at each process step. **A typical example of flowchart of Penicillin-G manufacturing** is given in the Figure 4.1.

It may be noted that waste stream (Mycelium) and obvious energy wastes such as condensate drained and steam leakages have been identified in this flow chart. The audit focus will depend upon consumption of input resources, energy efficiency potential, impact of process step on entire process or intensity of waste generation / energy consumption. In case of Penicillin-G manufacturing, the unit operations such as germinator, pre-fermentor, fermentor and extraction are the major energy conservation potential areas identified.

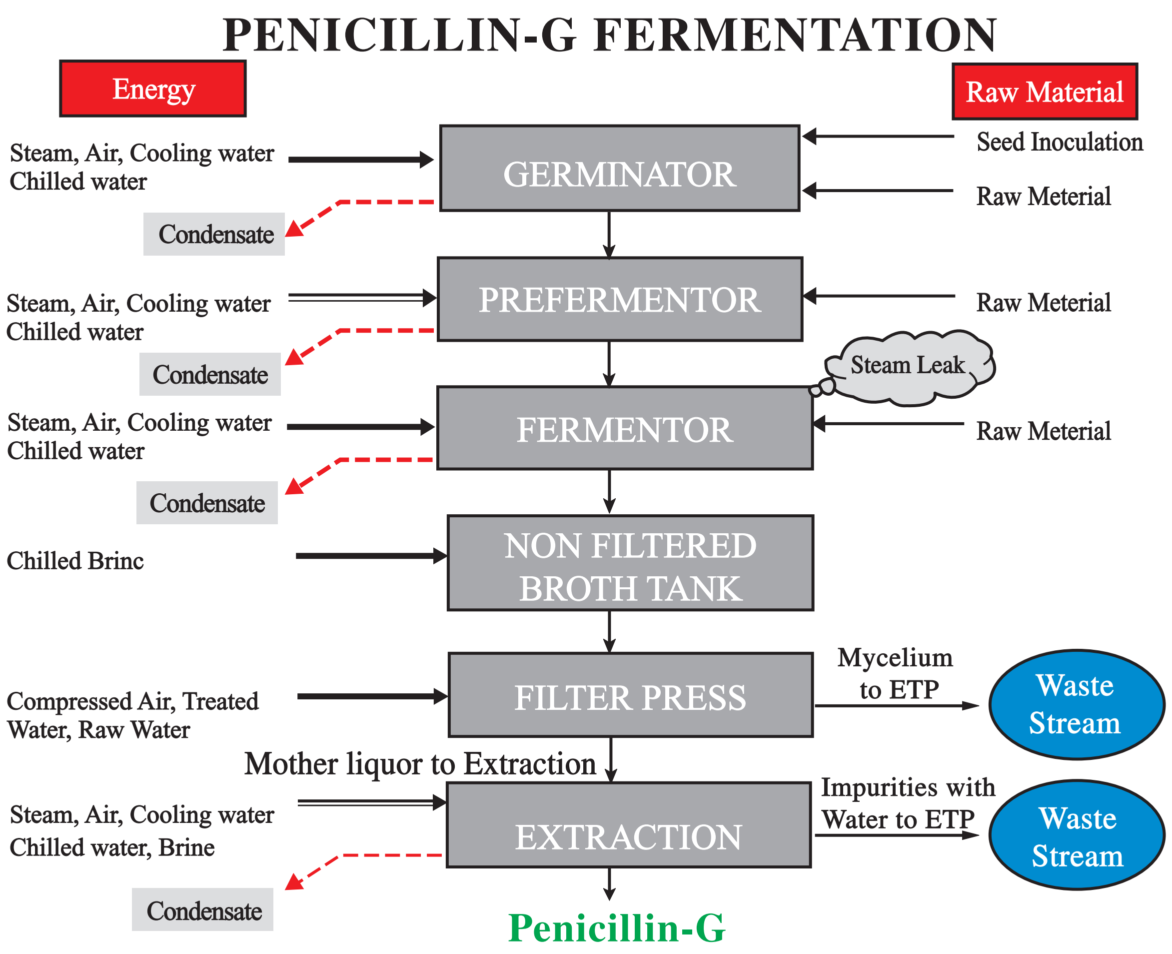


Figure 4.1 Flow Chart for Penicillin-G Manufacture

Identification of ENCON Opportunities

Fuel substitution: Identifying the appropriate fuel for efficient energy conversion

Energy Generation: Identifying efficiency opportunities in energy conversion equipment/utility such as feasibility for high efficient DG sets, optimal loading of DG sets, boiler optimization - minimum excess air combustion with boilers / thermic fluid heating, optimising existing efficiencies, efficient energy conversion equipment, biomass gasifiers, Cogeneration etc.

Energy Distribution: Identifying efficiency opportunities in electrical systems such as transformers, cables, switchgears and power factor improvement in electrical systems and chilled water, cooling water, hot water, compressed air, etc.

Energy Usage by Processes: This is where the major opportunity for improvement lies and many of them are hidden. Process analysis is a useful tool for process integration measures.

Technical and Economic Feasibility

The technical feasibility should address the following issues:

- Technology availability, space, skilled manpower etc
- The impact of energy efficiency measure on safety, quality, production or process.
- Reliability, service issues, maintenance requirements and spares availability

The Economic viability often becomes the key parameter for the management acceptance. The economic analysis can be conducted by using Pay back method, Internal Rate of Return method, Net Present Value method etc. For low investment short duration measures, which have attractive economic viability, payback method is sufficient. A sample worksheet for assessing economic feasibility is provided below:

Worksheet for Economic Feasibility

Name of the Energy Efficiency Measure		
1. Investment	2. Annual Operating costs	3. Annual Savings
1. Equipment 2. Civil works 3. Instrumentation 4. Auxiliaries	1. Cost of capital 2. Maintenance 3. Manpower 4. Energy 5. Depreciation	1. Thermal energy 2. Electrical energy 3. Raw materials 4. Waste disposal
Net Savings /year = Annual savings – Annual operating costs **Payback period in months = Investment / Net Savings /year x 12**		

Classification of ENCON Measures

The potential energy saving measures (ENCON) may be classified into three categories:

(a) Low cost – high return
(b) Medium cost – medium return
(c) High cost – high return

Normally the low cost – high return projects receive priority. Other projects have to be analyzed, engineered and budgeted for implementation in a phased manner, Projects relating to equipment and process changes almost always involve high costs coupled with high returns, and required careful scrutiny before funds can be committed. They are complex and need long lead times before they can be implemented. Refer Table 4.1 for project priority guideline.

Table 4.1 Project Priority Guideline			
Priority	**Economical Feasibility**	**Technical Feasibility**	**Risk / Feasibility**
A- good	Well defined and attractive	Existing technology adequate	No Risk/ Highly feasible
B-May be	Well defined and only marginally acceptable	Existing technology may be updated, lack of confirmation	Minor operating risk/ May be feasible
C-Held	Poorly defined and marginally unacceptable	Existing technology is inadequate	Doubtful
D-No	Clearly not attractive	Need major breakthrough	Not feasible

Energy Audit Report

The length and detail of energy audit report will depend upon the facility audited. The report should begin with an executive summary that provides the management of the audited facility with brief synopsis of the total savings and highlight of each energy saving measure. Executive summary should be tailored to non-technical personnel. The reader who understands the report is more likely to implement the recommended ENCON measures.

The main report should start with general description of the process or facility. Then annual energy consumption and bills should be presented with tables and graphs. This should be followed by description of energy inputs and outputs by major department or by major process and evaluation of efficiency of each step in the process. Then recommended ENCON measures should be presented with calculations for cost and benefits along with expected payback on any capital investment.

The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require high investments.

Regardless of the audience for the audit report, it should be written in a clear, concise and easy to understand format and style.

Report on

DETAILED ENERGY AUDIT

TABLE OF CONTENTS

The following worksheets (refer Table 4.2 & Table 4.3) can be used as guidance for energy audit assessment and reporting in Executive Summary. Table 4.4 shows the reporting format for energy conservation recommendations in the main report.

Table 4.2 Summary Of Energy Saving Recommendations

S.No.	Energy Saving Recommendations	Annual Energy (Fuel & Electricity) Savings (kWh/MT or kL/MT)	Annual Cost Savings (Rs. Lakhs)	Capital Investment (Rs. Lakhs)	Simple Payback Period
1					
2					
3					
4					
Total					

Table 4.3 Types and Priority of Energy Saving Measures

	Type of Energy Saving Options	Annual Electricity / Fuel Savings	Annual Savings	Priority
		kWh/MT or kJ/MT	(Rs. Lakhs)	
A	No Investment (Immediate) • Operational improvement • Housekeeping			
B	Low Investment (Short to Medium Term) • Controls • Equipment modification • Process change			
C	High Investment (Long Term) • Energy efficient devices • Product modification • Technology change			

Phase III-Post Audit Phase

On completion of energy audit, energy action plan should be prepared. The energy action plan list the ENCONs which should be implemented first, and suggest an overall implementation schedule. Energy audit is incomplete without monitoring and its associated feedback. Monitoring consist of collecting and interpreting data. The data to be collected depends upon goals chosen in the energy action plan. Electrical power consumption and fuel consumption must be evaluated and monitored. The monitoring data should provide direct feedback to those most able to implement the changes. Often additional instruments should be installed in various departments in addition to main metering.

Monitoring should result in more action. Good practices should be replicated. If the gap between planned objectives and actual achievements is large, reasons should be analyzed and new objectives, new actions should be initiated and results should be monitored. In this way, analysis, action and monitoring are a cyclic process.

Table 4.4 Reporting Format for Energy Conservation Recommendations		
A: Title of Recommendation	:	**Combine DG set cooling tower with main cooling tower**
B: Description of Existing System and its Operation	:	Main cooling tower is operating with 30% of its capacity. The rated cooling water flow is 5000 m3/hr. Two cooling water pumps are in operation continuously with 50% of its rated capacity. A separate cooling tower is also operating for DG set operation continuously.
C: Description of Proposed System and its Operation	:	The DG Set cooling water flow is only 240 m3/h. By adding this flow into the main cooling tower will eliminate the need for a separate cooling tower operation for DG set, besides improving the %loading of main cooling tower. It is suggested to stop the DG set cooling tower operation.
D: Energy Saving Calculations		
Capacity of main cooling tower	=	5000 m^3/ hr
Temp across cooling tower (design)	=	8 ^oC
Present capacity	=	3000 m^3/hr
Temperature across cooling tower (operating)	=	4 ^oC
% loading of main cooling tower	=	(3000 x 4) / (5000 x 8) = 30%
Capacity of DG Set cooling tower	=	240 m^3/hr
Temp across the tower	=	5 ^oC
Heat Load (240 x 1000 x 1 x 5)	=	1200,000 kcal/hr
Power drawn by the DG set cooling tower		
No of pumps and its rating	=	2 Nos x 7.5 kW
No of fans and its rating	=	2 Nos x 22 kW
Power consumption@ 80% load	=	(22 x2 +7.5 x2) x.80 = 47 kW
Additional power required for main cooling tower for additional water flow of 240m^3/h (66.67 l/s) with 6 kg/cm^2	=	(66.67 x 6) / (102 x 0.55) = 7 kW
Net Energy Savings	=	47 – 7 = 40 kW
E: Cost Benefits		
Annual Energy Saving Potential	=	40 kW x 8400 hr = 3,36,000 Units/Year
Annual Cost Savings	=	3,36,000 x Rs.4.00 = Rs.13.4 Lakh per year
Investment (only cost of piping)	=	Rs 1.5 Lakhs
Simple Payback Period	=	**Less than 2 months**

4.5 Understanding Energy Costs

Contrary to common belief, energy costs are not a fixed overhead, there is often a huge potential for making savings. Understanding energy cost is vital factor for awareness creation and saving calculation. In many industries sufficient meters may not be available to measure all the energy used. In such cases, invoices for fuels and electricity will be useful. The annual company balance sheet is the other sources where fuel cost and power are given with production related information.

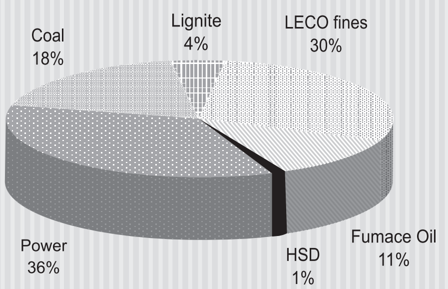
Energy invoices can be used for the following purposes:

- They provide a record of energy purchased in a given year which gives a baseline for future reference
- Energy invoices may indicate the potential for savings when related to production requirements or to air conditioning requirements/space heating etc.
- When electricity is purchased on the basis of maximum demand tariff
- They can suggest where savings are most likely to be made.
- In later years invoices can be used to quantify the energy and cost savings made through energy conservation measures.

Fuel Costs

A wide variety of fuels are available for thermal energy supply. Some of the fuels are listed below:

- Fuel oil
- Low Sulphur Heavy Stock (LSHS)
- Light Diesel Oil (LDO)
- Liquefied Petroleum Gas (LPG)
- Coal
- Lignite
- Wood etc.



Total Energy Bill - Rs. 6 Crores/annum

Understanding fuel cost is fairly simple and it is purchased in Tons or Kiloliters. Availability, cost and quality are the main three factors that should be considered while purchasing. The following factors should be taken into account during procurement of fuels for energy efficiency and economics.

- Price at source, transport charge, type of transport
- Quality of fuel (contaminations, moisture etc)
- Energy content (calorific value)

Power Costs

Electricity price in India not only varies from State to State, but also city to city and consumer to consumer though it does the same work everywhere. Many factors are involved in deciding final cost of purchased electricity such as:

- Maximum demand charges, kVA
  (i.e. **How fast** the electricity is used?)
- Energy Charges, kWh
  (i.e. **How much** electricity is consumed?)
- TOD Charges, Peak/Non-peak period
  (i.e. **When** electricity is utilized ?)
- Power factor Charge, P.F
  (i.e., **Real power use versus Apparent power use factor**)
- Other incentives and penalties applied from time to time
- High tension tariff and low tension tariff rate changes
- Slab rate cost and its variation
- Type of tariff clause and rate for various categories such as commercial, residential, industrial, Government, agricultural, etc.
- Tariff rate for developed and underdeveloped area/States
- Tax holiday for new projects

4.6 Benchmarking

Benchmarking forms the basis for monitoring and target setting

Benchmarking can be a useful tool for understanding energy consumption patterns in an industrial sector and for taking measures to improve energy efficiency. Energy benchmarking for industry is a process in which the energy performance of an individual plant or an entire sector of similar plants is compared against a common metric that represents 'standard' or 'optimal' performance. It may also entail comparing the energy performance of a number of plants against each other.

Since benchmark tool is used for comparison across a number of plants or sectors, there are two important features they should have. First, because they are applied to plants or sectors of different sizes and outputs, the metric used should be common irrespective of plant size. The most common metric used is *energy intensity* which measures *'energy use per unit of output'*. Second, the tool should be used in a wide range of facilities so as to compensate for differences in production at similar facilities.

Industrial Benchmarking Programs

There are three approaches for energy benchmarking. The first approach is to evaluate an entire industrial sector, such as iron and steel, aluminum, cement, etc. This evaluation is used to answer the following questions: How well is this sector performing compared to how it would perform using the best available technologies? How well is it performing compared to the same sector in other countries? Has the sector been improving over time?

The second approach is the comparison of individual plants within a sector. A benchmark-type indicator is calculated for all the facilities within a sector so that they can be compared on even terms. This evaluation can answer the following questions: What is the state-of-the-art performance in this given sector? How does my plant compare against the state-of-the-art? How does it compare against the majority of other plants in the sector? In developing benchmarks at the level of individual plants, the issue of proprietary data becomes important. Individual companies are very reluctant to disclose information about their production processes, particularly if it will be released to their competitors. It is important that the indicators developed are general enough not to reveal any proprietary information and that a credible system is established that encourages plants to trust the process.

External benchmarking relates to inter unit comparison across a group of similar units to identify best practices. However, it would be important to ascertain similarities, as, otherwise, findings can be grossly misleading. Few comparative factors which need to be carefully looked into while external benchmarking extremely are:

- Scale of operation
- Vintage of technology
- Raw material specifications and quality
- Product specifications and quality

The third approach for energy benchmarking that has been seen widely in recent years is for large companies to set themselves energy efficiency goals by using historical best performance as benchmark. Companies use this approach to set targets for reducing energy use by certain percentages over given time frames. Companies do not need to reveal any proprietary information, since the benchmarking is done internally.

Steps in energy conservation benchmarking are summarized below:

- Identify the best available technology for the individual process units.
- Collect information to thoroughly understand the process and identify key/controlling parameters.
- Determine the performance of the process unit.
- Analyse the gap between the existing and the benchmark for the key controlling parameters.
- Set targets or benchmarks, keeping constraints in view, and implement improvements based on the findings

The benchmark parameters for various sectors are given as follows:

- Gross Production Related

  kWh/MT clinker or cement produced (Cement plant)

  kWh/kg yarn produced (Textile unit)

kWh/MT, kcal/kg paper produced (Paper plant)

kcal/kWh Power produced (Heat rate of a power plant)

Million Calories/MT Urea or Ammonia (Fertilizer plant)

kWh/MT of liquid metal output (in a foundry)

- Equipment / Utility Related

kWh/ton of refrigeration (on Air-conditioning plant)

% thermal efficiency of a boiler plant

% cooling tower effectiveness in a cooling tower

kWh/Nm^3 of compressed air generated

kWh/litre in a diesel power generation plant.

While such benchmarks are referred to, related crucial process parameters need to be stated for meaningful comparison among similar industries. For instance, in the above case:

- For a cement plant – type of cement, blaine number (fineness) i.e. Portland and process used (wet/dry) are to be reported alongside kWh/MT figure.
- For a textile unit – average count, type of yarn i.e. polyester/cotton, is to be reported along side kWh/kg figure.
- For a paper plant – paper type, raw material (recycling extent), GSM quality are some important factors to be reported along with kWh/MT, kcal/kg figures.
- For a power plant / cogeneration plant – plant % loading, condenser vacuum, inlet cooling water temperature, would be important factors to be mentioned alongside heat rate (kcal/kWh).
- For a fertilizer plant – capacity utilization(%) and on-stream factor are two inputs worth comparing while mentioning specific energy consumption
- For a foundry unit – melt output, furnace type, composition (mild steel, high carbon steel/cast iron etc.) raw material mix, number or power trips could be some useful operating parameters to be reported while mentioning specific energy consumption data.
- For an A/C plant – parity of chilled water temperature level is crucial while comparing kW/TR.
- For a boiler plant – fuel quality, type, steam pressure, temperature, flow are useful comparators alongside thermal efficiency and more importantly, whether thermal efficiency is on gross calorific value basis or net calorific value basis or whether the computation is by direct method or indirect heat loss method, mean a lot in benchmarking exercise for meaningful comparison.
- For a cooling tower - Effectiveness – ambient air wet/dry bulb temperature, relative humidity, air and circulating water flows are required to be reported to make meaningful sense.
- For a compressed air system - specific power consumption – is to be compared at similar inlet air temperature and pressure of generation.
- Diesel power plant performance – is to be compared at similar loading %, steady run condition.

4.7 Energy Performance

Plant Energy Performance

Plant energy performance (PEP) is the measure of whether a plant is now using more or less energy to manufacture its products than it did in the past: a measure of how well the energy management programme is doing.

Plant energy performance monitoring compares plant energy use of a reference year and the subsequent years considering production output to determine the improvement (or deterioration) that has been made.

However, since the plants' production output varies from year to year, it has significant impact on plant's energy use. For a meaningful comparison it is necessary to determine the energy that would have been required to produce current year's production output had the plant operated in the same way as it did during the reference year. This calculated value can then be compared with the actual value to determine the improvement or deterioration that has taken place since the reference year.

Production Factor

Production factor is the ratio of production in the current year to that in the reference year.

$$\textbf{Production factor} = \frac{\textbf{Current year's production}}{\textbf{Reference year's production}}$$

Production factor is used to determine the *energy* that would have been required to produce this year's production output if the plant had operated in the same way as it did in the reference year.

Reference Year Equivalent Energy Use

The *reference year's equivalent energy use (or reference year equivalent)* is the energy that would have been used to produce the current year's production output.

The reference year equivalent is obtained by multiplying the reference year energy use by the production factor (obtained above)

Reference year equivalent = Reference year energy use x Production factor

Plant Energy Performance is the improvement or deterioration from the reference year. It is a measure of plant's energy progress.

$$\textbf{Plant energy performance} = \frac{\textbf{Reference year equivalent – Current year's energy}}{\textbf{Reference year equivalent}} \times 100$$

The energy performance is the measure of energy saved at the current rate of use compared to the reference year rate of use. The greater the improvement, the higher the number will be.

Plant energy performance (PEP) is the starting point for evaluating energy performance. It does not require detailed calculations of the energy used by every place of equipment, the energy use of every process or the energy use of buildings. It utilizes the most effective measure of energy savings, the actual measurement of energy consumption compared to production output. Yearly comparisons minimize seasonal effects.

Sometimes, once a plant has started measuring yearly energy performance, management wants more frequent performance information in order to monitor and control energy use on an on-going basis. In such cases PEP can just as easily be used for monthly reporting as yearly reporting.

4.8 Matching Energy Usage to Requirement

Mismatch between equipment capacity and user requirement often leads to energy inefficiencies due to part load operations, wastages etc.

The designer always considers safety margins while laying specifications for new equipment leading to oversized equipment. This presents opportunity for energy manager for matching the equipment capacity with user requirement. Some examples for matching energy usage to requirements are listed below:

- Eliminating throttling of a pump by impeller trimming, installing variable speed drives and resizing pump
- Eliminating damper operations in fans by impeller trimming, installing variable speed drives, pulley diameter modification for belt drives, fan resizing for better efficiency.
- Moderating chilled water temperature as per process chilling needs
- Recovering energy lost in control valve pressure drops with back pressure turbine adoption
- Adopting of task lighting in place of less effective area lighting

4.9 Maximizing System Efficiencies

Once the energy usage and sources are matched properly, the next step is to operate the equipment efficiently through best operation and maintenance practices and adoption of best available technology, if feasible. Some examples are:

- Eliminating steam leakages by using appropriate steam traps
- Maximising condensate recovery
- Adopting combustion controls for maximizing combustion efficiency
- Replacing pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy conservation equipment, wherever significant energy efficiency margins exist
- Ensuring rated electrical parameters at the motor terminals

4.10 Optimising Input Energy Requirements

After fine-tuning the energy use practices, attention should be given for minimizing energy input requirements. The measures include:

- Maximising heat recovery from waste energy streams, to minimize purchased energy
- Adopting cogeneration plants for balancing heat and power requirements, leading to reduced energy purchases
- Adopting cost effective renewable sources of energy such as solar, wind and biomass energy

4.11 Fuel and Energy Substitution

Fuel substitution is basically substituting existing fossil fuel with more efficient and less cost/less polluting fuel such as natural gas, biogas and locally available agro-residues.

Fuel substitution has taken place in all the major sectors of the Indian economy.

Few examples of fuel substitution

- Natural gas is increasingly the fuel of choice as fuel and feedstock in the fertilizer, petrochemicals, power and sponge iron industries.
- Replacement of coal by coconut shells, rice husk etc.
- Replacement of LDO by LSHS

There are two ways to reduce energy dependency; energy conservation and substitution.

Few examples of energy substitution

✓ Replacement of electric heaters by steam heaters

✓ Replacement of steam based hot water by solar systems

Case Study: Example on Fuel Substitution

A textile process industry replaced old fuel oil fired thermic fluid heater with agro fuel fired heater. The economics of the project are given below:

A: Title of Recommendation	**:**	**Use of Agro Fuel (coconut chips) in place of Furnace oil in a Boiler**
B: Description of Existing System and its operation	**:**	A thermic fluid heater with furnace oil currently. In the same plant a coconut chip fired boiler is operating continuously with good performance.
C: Description of Proposed system and its operation	**:**	It was suggested to replace the oil fired thermic fluid heater with coconut chip fired boiler as the company has the facilities for handling coconut chip fired system.

D: Energy Saving Calculations

Old System

Type of fuel firing	**:**	**Furnace Oil Fired Heater**
GCV	:	10,200 kcal/kg
Avg. Thermal Efficiency	:	82%
Heat Duty	:	15 lakh kcal / hour
Operating Hours	:	25 days x 12 month x 24 hours = 7,200 hrs.
Annual Fuel Cost	:	Rs.130 lakh (7200 x 1800 Rs./hr.)

Modified System

Type of fuel saving	**=**	**Coconut Chips Fired Heater**
GCV	=	4200 kcal/kg
Average Thermal Efficiency	=	72 %
Heat Duty	=	15 lakh kcal / hour
Annual Operating Cost	=	7200 x 700 Rs./hr = 50 lakh
Annual Savings	=	130 - 50 = Rs.80 lakh .
Additional Auxiliary Power + Manpower Cost	=	Rs. 10 lakh
Net Annual Saving	=	Rs. 70lakh
Investment for New Coconut Fired heater	=	Rs.35 lakh
Simple payback period	**=**	**6 months**

4.12 Instruments and Metering For Energy Audit

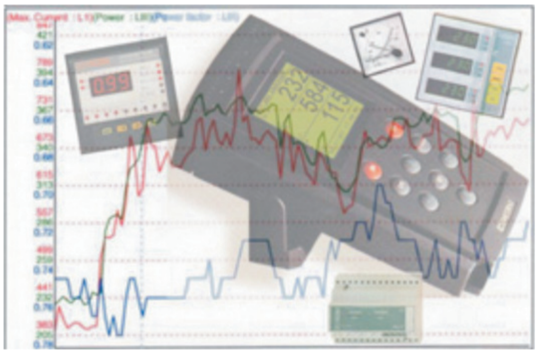
The requirement for an energy audit is to identify and quantify where energy is being used necessitates measurements. These measurements require the use of instruments. The basic instruments used in energy audit work are listed below. These instruments are portable, durable, easy to operate and relatively inexpensive.

Key Performance Parameters for Energy Audit

Basic Electrical Parameters in AC & DC systems – Voltage (V), Current (I), Power factor, Active power (kW), Maximum demand (kVA), Reactive power (kVAr), Energy consumption (kWh), Frequency (Hz), Harmonics, etc.

Parameters of importance other than electrical such as Temperature and Heat Flow, Radiation , Air and Gas Flow, Liquid Flow, RPM , Air Velocity, Noise and Vibration, Dust Concentration, TDS, PH, Moisture Content, Relative Humidity, Flue Gas Analysis – CO_2, O_2, CO, SO_x, NO_x, Combustion Efficiency etc.

Some of the instruments commonly used in an energy audit are described as follows.

 	**Electrical Measuring Instruments:** These are instruments for measuring major electrical parameters such as KVA, KW, PF, Hertz, KVAr, Amps and Volts. In addition some of these instruments also measure harmonics. These instruments are applied on-line i.e. on running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals. **Some precautions and safety measures:** To avoid short circuits and potentially life-threatening hazards, never attach the clamp to a circuit that operates at more than the maximum rated voltage, or over bare conductors. While using the instrument, use rubber hand gloves, boots, and a safety helmet, to avoid electrical shocks, and do not use the instrument when hands are wet.
	**Fyrite**: In this, a hand bellow pump draws the flue gas sample into the solution inside the fyrite. Thereafter, a chemical reaction changes the liquid volume that reveals the amount of gas percentage. Oxygen or CO_2 can be read from the scale. The FYRITE employs the well-known "Orsat method of volumetric analysis" using chemical absorption of a sample gas such as carbon dioxide or oxygen. The reagent used to absorb carbon dioxide (CO_2) is potassium hydroxide (dyed red), and chromous chloride (blue) is the absorbent for oxygen (O_2). The unique feature of the FYRITE is that the absorbing fluid is also used as the indicating fluid so that one vessel takes the place of both measuring burette and absorption pipette.

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Fuel Efficiency Monitor:

This measures Oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency.

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Combustion Gas Analyzer:

This instrument has in-built chemical cells which measure various gases such as CO_2, CO, NO_X, SO_X etc.

Gas analyzers are flexible in what must be measured depending on the requirements of the customer/user.

They have specific sensors sealed inside the equipment that can be changed to measure the different components in the gas. But because a maximum of two sensors can be connected, only two or three parameters can be measured at one time.

It is light and easier to handle compared to the fuel efficiency monitor.

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Manometer with Pitot Tube:

Digital flexible membrane manometer is used for measuring pressures in air ducts carrying exhaust flue gases (boiler, furnaces), or air from fans and blowers.

- To measure pressure in air pipes, manometers must be used in combination with a pitot tube
- Attach flexible rubber tubes to the inlet and outlet probes of the manometer. Tighten these to ensure that there is no leakage of air.
- Attach these two tubes to the ends of the pitot tube
- Make a 6-cm monitoring hole in the duct or pipeline
- Insert the pitot tube into the monitoring hole

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Contact Thermometer:

These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream.

For surface temperature a leaf type probe is used with the same instrument.

Non Contact Infrared Thermometer:

Infrared thermometers calculate the amount of thermal radiation (infrared radiation) emitted from the object. By knowing the emissivity of the object and the amount of infrared energy emitted by the object, the object's temperature can be determined. With the help of infrared thermometers, temperatures of the objects placed in hazardous or hard-to-reach places or other situations can be determined.

The most common design of a IR thermometer consists of a lens to focus the infrared energy on to a detector. The detector changes the energy to an electrical signal that can be shown in units of temperature after being corrected for ambient temperature variation.

Ultrasonic Flow Meter:

This is one of the popular means of non-contact flow measurement. There are two main types of ultrasonic flow meters: Transit time and Doppler. Transit time ultrasonic meters have both a sender and a receiver. They send two ultrasonic signals across a pipe: one traveling with the flow and one traveling against the flow.

The ultrasonic signal traveling with the flow travels faster than a signal traveling against the flow. The ultrasonic flow meter measures the transit time of both signals. The difference between these two timings is proportional to flow rate.

Transit time ultrasonic flow meters usually monitor clean liquids. Doppler ultrasonic flow meters measure dirty liquids. They compute flow rate based on a frequency shift that occurs when their ultrasonic signals reflect off particles in the flow stream.

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Tachometer</td>
<td>
Stroboscope</td>
<td>Speed Measurements:

In any audit exercise speed measurements are critical as they may change with factors such as frequency, belt slip, loading, etc. A simple tachometer is a contact type instrument, which can be used where direct access is possible.

More sophisticated and safer ones are non contact instruments such as stroboscopes. A stroboscopic light source provides high-intensity flashes of light, which can be caused to occur at a precise frequency. When this light source is made to fall on an object with periodic motion it appears that the motion is slowed down, or stopped when both the frequencies bear a definite relationship. A stroboscope uses this principle for measurement of RPM.</td>
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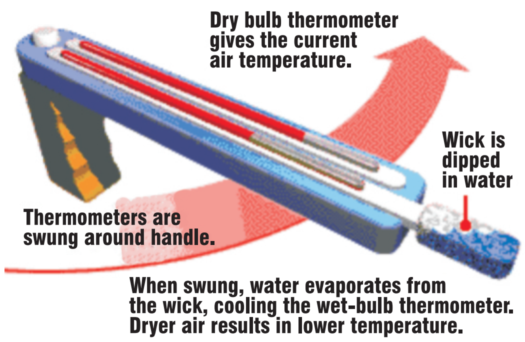
<td colspan="2">
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<td>Psychrometer:

A sling psychrometer - consists of two thermometers mounted together with a handle. One thermometer is ordinary and measures the dry bulb temperature. The other has a wet cloth wick, over its bulb and is called a wet-bulb thermometer. When a reading is to be taken the psychrometer is whirled around. The water evaporates from the wick, cooling the wet-bulb thermometer. Then the temperatures of both thermometers are read. If the surrounding air is dry, more moisture evaporates from the wick, cooling the wet-bulb thermometer more, so there is a greater difference between the temperatures of the two thermometers. By using these temperatures the humidity is computed.</td>
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Lux Meters:

A light sensitive cell measures the incident light (all light in the visible spectrum is measured) and evaluates that against the human daylight sensitivity curve. The resulting value is the measurement result in lux. This works well but it requires a different correction factor for every light spectrum.

The much more expensive lux meters with one cell are optimized and tuned with optical filters and lenses such that the sensitivity of this set of lenses and the cell itself directly matches the eye's light sensitivity curve (so only one correction value needed for light of any spectral content).

Smart Energy Meters

The term smart meter usually refers to electric meters which keep detailed statistics on usage, but it can be used for fuels or water applications as well performing the same job. The primary purpose of smart meters is to provide information on how end users use their electricity on a real-time basis. The smart energy meters use a wireless communication to help track the electricity consumption and thus save both electricity and money. It can be easily installed and gives an accurate reading of electricity consumption which can also be monitored / controlled through mobile or internet.

	**Thermography** Infra-red thermal monitoring and imaging (non-contact type) measures thermal energy radiation from hot/cold surfaces of an object and provides input for assessing health of equipment and predictive maintenance. The thermal camera unit converts electromagnetic thermal energy (IR) radiated from an object into electronic video signals. These signals are amplified and transmitted via interconnected cable to a display monitor where the resulting image is analysed and interpreted for hot/cold spots.

4.13 Bureau of Energy Efficiency (the manner and intervals of time for conduct of energy audit) Regulations, 2008

Intervals of time for conduct of energy audit

(1) Every designated consumer shall have its first energy audit conducted, by an accredited energy auditor within 18 months of the notification issued by the Central Government

(2) The interval of time for conduct and completion of subsequent energy audits shall be three years with effect from the date of submission of the previous energy audit report by the accredited energy auditor to the management of the designated consumer.

Manner of energy audit

1. Verification of data of energy use

a) Verify the information submitted to the designated agency under the Energy Conservation (the form and manner for submission of report on the status of energy consumption by the designated consumers) Rules, 2007 for the previous two years

b) Establish specific energy consumption for the year referred to in clause (a);

c) Disaggregate the energy consumption data and identify major energy using equipment, processes and systems.

2. Scope of energy audit

The accredited energy auditor jointly with the energy manager of the designated consumer shall-

(a) Develop a scope of work for the conduct of energy audit with a view to ensuring adequate coverage in terms of the share of total energy use

(b) Select energy intensive equipment or processes for energy auditing;

(c) Agree on best practice procedures on measuring the energy efficiency performance of selected equipment and on methodology to estimate energy performance and energy savings;

(d) Collect energy consumption, and production data for the equipment and processes covered within the scope of energy audit, operating data, and schedule of operation, non proprietary process flow charts, and production level disaggregated by product, if applicable, and other related historical data essential by the accredited energy auditor for achieving the purpose of energy audit.

3. Monitoring and analysis of the use of energy data for energy audit

The accredited energy auditor shall-

(a) Verify the accuracy of the data collected in consultation with the energy manager as per standard practice to assess the validity of the data collected;

(b) Analyse and process the data with respect to-

(i) Consistency of designated consumers' data monitoring compared to the collected data;

(ii) Recommendations to reduce energy consumption and improve energy efficiency;

(iii) Summary overview of energy consumption in plant by fuel type and by section;

(c) Conduct equipment energy performance measurements with due diligence and caution.

4. Preparation of recommendations on energy saving measures, their cost benefit analysis

The accredited energy auditor having regard to the overall efficiency of the production process, techno-economic viability of energy saving measures, site conditions and capacity of the designated consumer to invest for their implementation, shall prepare a list of recommendations to save energy and the list shall include:

(a) A brief description of each recommended measure

(b) The estimated energy saving as well as energy cost reduction potential over a reasonable technical or economic life of the measure;

(c) Any known or expected technical risks associated with each measure;

(d) A preliminary assessment of the financial attractiveness of each measure or assessment of the maximum investment feasible based on the estimated energy cost saving potential over the life of the measure;

(e) Tabulated summary of recommendations listed as per their implementation schedule (short, medium and long term);

(f) Where different alternatives for implementation of an energy efficiency measure are available, the accredited energy auditor shall examine and discuss such options and recommend the techno-financially better option;

(g) Where the installation or implementation of any recommended energy saving measure affects procedures for operation and maintenance, staff deployment and the budget, the recommendation shall include discussion of such impacts including their solutions.

Prioritization and preparation of action plan

(1) The accredited energy auditor jointly with the energy manager shall select from the energy audit report such recommended measures which in the opinion of the designated consumer are technically viable, financially attractive and within its financial means, prioritise them and prepare plan of action for their implementation. This action plan shall include-

(a) Preparation of detailed techno-economic analysis of selected measures;

(b) A monitoring and verification protocol to quantify on annual basis the impact of each measure with respect to energy conservation and cost reduction for reporting to Bureau and the concerned State designated agency;

(c) A time schedule agreed upon by the designated consumer of selected measures taking into consideration constraints such as availability of finance and availability of proposed equipment.

(2) The accredited energy auditor based on the activities undertaken under sub-regulation (4) of regulation 4 and regulation 5 shall submit a report in Form 2 to the management of designated consumer.

(3) The accredited energy auditor shall evaluate the implementation of each recommended energy saving measure in the previous audit report and submit a report in Form 3 to the management of the designated consumer.

Structure of the energy audit report

(1) The energy audit report structure shall be jointly decided by the accredited energy auditor and designated consumer.

(2) The energy audit report shall highlight, details of specific energy consumption, list of recommendations to reduce energy consumption and costs, monitoring and evaluation of impact of selected measures and conclude with certification by accredited energy auditor stating that -

a) The data collection has been carried out diligently and truthfully.a)

b) All data monitoring devices are in good working condition and have been calibrated or certified by approved or authorized agencies and no tempering of such devices have occurred.

c) All reasonable professional skill, care and diligence have been taken in preparing the energy audit report and the contents thereof are a true representation of the facts.

d) Adequate training provided to personnel involved in daily operations after implementation of recommendations.

e) The energy audit has been carried out in accordance with the Bureau of Energy Efficiency (the manner and intervals of time for conduct of energy audit) Regulation, 2008.

(3) The accredited energy auditor shall highlight the strengths and weaknesses of the designated consumer in the management of energy and energy resources in the energy audit report and recommend necessary action to improve upon method of reporting data, energy management system in detail along with their underlying rationale, and improving energy efficiency and reducing energy consumption of the designated consumer.

(4) The accredited energy auditor shall sign the energy audit report under the seal of its firm giving all the accreditation details along with details of manpower employed in conducting the energy audit.

(5) The energy audit report shall include a work schedule sheet duly signed by accredited energy auditor and energy manager of the designated consumer.

Solved Example:

An Energy Manager in a factory has gathered following data to arrive at the Plant Energy Performance.

Reference Year (2009) energy use	:	12 million kcal
Production Factor (PF) for the current year (2010)	:	0.9
Current year's energy	:	11 million kcal

What is the Plant energy Performance (PEP) of the factory for the year 2010? State your inference.

Ans:

Reference year equivalent energy = Reference year energy use ∗ P.F

$$= 12 * 0.9 = 10.8 \text{ Mkcal}$$

$$\text{Plant Energy Performance} = \frac{(\text{Reference year equivalent} - \text{current year's energy})*100}{\text{Reference Year equivalent}}$$

$$= (10.8 - 11) / 10.8$$

$$= -1.85\ \%$$

Inference: Plant energy performance is marginally negative. Energy manager/plant manager has to take action to improve the performance.

QUESTIONS	
Objective Type Questions	
1.	"The judicious and effective use of energy to maximise profits and enhance competitive positions". This can be the definition of: a) energy conservation b) energy management c) energy policy d) energy Audit
2.	Role of energy manger is a) energy auditor and in charge of the finance department of the plant b) intermediate player between top management, energy and cost centres of the plant c) in charge of the captive power plant and mediator between plant and electricity boards d) as well as called production manger and project manager
3.	The objective of energy management includes a) minimising energy costs b) minimising waste c) minimising environmental degradation d) all the above
4.	The ratio of current year's production to the reference year's production is a) demand factor b) production factor c) utilisation factor d) load factor
5.	One unit of electricity is equivalent to _______ kcal heat units. a) 800 b) 860 c) 400 d) 680
6.	The benchmarking parameter for air conditioning equipment is a) kW/Ton of refrigeration b) kW/ kg of refrigerant handled c) kcal/m^3 of chilled water d) differential temperature across chiller
7.	Which instrument is used to monitor O_2, CO in flue gas? a) combustion analyzer b) power analyzer c) pyrometer d) fyrite
8.	Non contact speed measurements can be carried out by a) tachometer b) stroboscope c) oscilloscope d) speedometer
9.	Which one of the following is not considered for external benchmarking: a) scale of operation b) vintage of technology c) energy price d) quality of raw material and products
10.	Transit time method is used in which of the instruments a) lux meter b) ultrasonic flow meter c) Pitot tube d) fyrite
Short Type Questions	
S-1	Explain what is meant by targeted energy audit
S-2	Explain the major differences between preliminary energy audit and detailed energy audit
S-3	What are the areas that need to be focused during pre audit phase ?

S-4	What is meant by energy benchmarking ? How is it helpful ?
S-5	What do you understand by matching energy use to requirements ? Give three examples
Long Type Questions	
L-1	Explain the following i) Production factor ii) Reference Year Equivalent iii) Plant Energy Performance
L-2	Write short notes on i) psychrometer ii) infrared thermometer iii) stroboscope iv) pitot tube

REFERENCES

1. NPC Energy Audit Manual and Reports
2. Energy Management Handbook, John Wiley and Sons - Wayne C. Turner
3. Guide to Energy Management, Cape Hart, Turner and Kennedy
4. Cleaner Production – Energy Efficiency Manual for GERIAP, UNEP, Bangkok prepared by National Productivity Council

www.eeca.govt.nz

www.energyusernews.com

10. ENERGY EFFICIENCY AND CLIMATE CHANGE

Energy and environment, Air pollution, Climate change, United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol, Conference of Parties (COP), Clean Development Mechanism (CDM), CDM methodology and procedure, Sustainable development.

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).

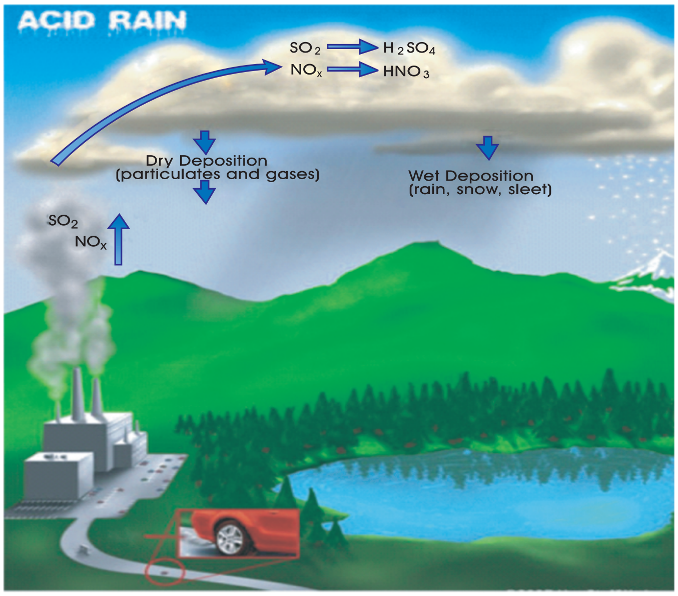

Figure 10.2 Acid Rain Formation

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.

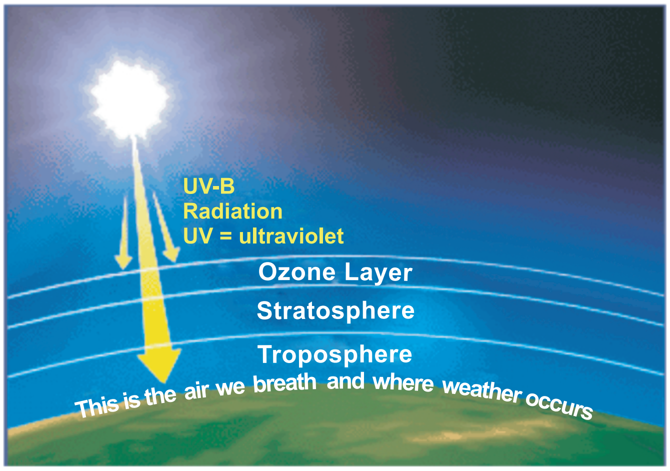

Figure 10.3 Ozone Layer

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.

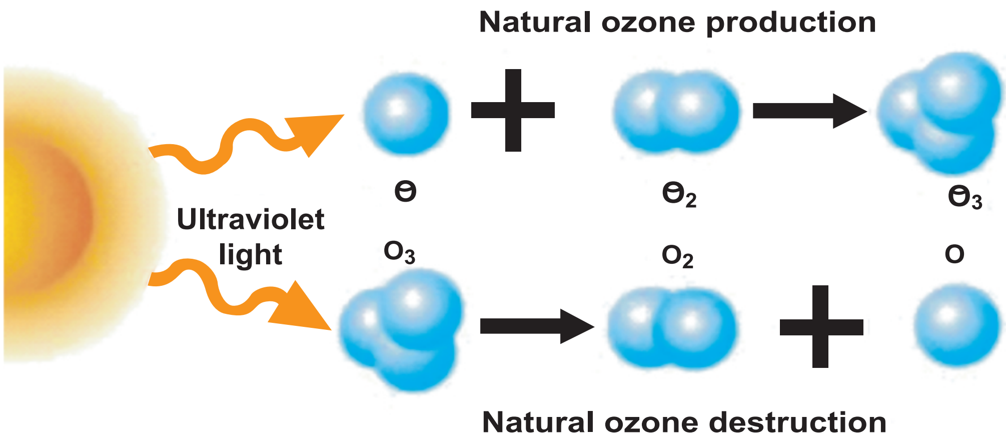

Figure 10.4 Ozone Formation and Destruction

Ozone Depletion Process

In recent years, scientists have measured a seasonal thinning of the ozone layer primarily at the South Pole. This phenomenon is being called the ozone layer depletion. It was found that ozone is easily broken down by man-made chlorine and bromine compounds. These compounds are found to be responsible for most of the ozone layer depletion. The main chemical responsible for the problem is identified as Chloro fluro carbons (CFCs) which were used in refrigerator and air conditioners.

The ozone depletion process begins when Chloro fluro carbons (CFCs) and other ozone-depleting substances (ODS) emitted into the atmosphere reach stratosphere by diffusion. Strong UV radiations break apart the ODS molecules. CFCs, HCFCs, carbon tetrachloride, methyl chloroform release chlorine atoms, and halons and methyl bromide release bromine atoms. It is the chlorine and bromine atom that actually destroys ozone, not the intact ODS molecule. It is estimated that one chlorine atom can destroy from 10,000 to 100,000 ozone molecules before it is finally removed from the stratosphere.

Chemistry of Ozone Depletion

When ultraviolet light waves strike CFC ($CFCl_3$) molecules in the upper atmosphere, a carbon-chlorine bond breaks, producing a chlorine (Cl) atom. The chlorine atom then reacts with an ozone (O_3) molecule breaking it apart and so destroying the ozone. This forms an ordinary oxygen molecule (O_2) and a chlorine monoxide (ClO) molecule. Then a free oxygen atom breaks up the chlorine monoxide, releasing chlorine. The released chlorine is free to repeat the process of destroying more ozone molecules. A single CFC molecule can destroy 100,000 ozone molecules. The chemistry of ozone depletion process is shown in Figure 10.5.

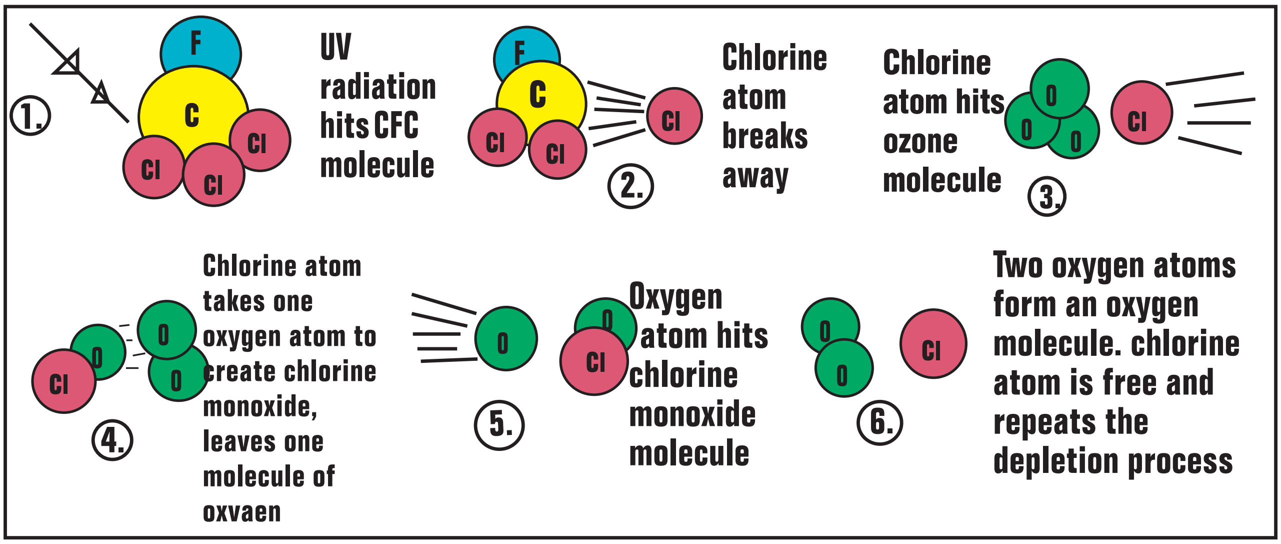

Figure 10.5 Chemistry of Ozone Depletion Process

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.

Ozone Depletion Counter Measures

International cooperation and agreement was signed at Montreal Protocol in 1974 to phase out ozone depleting chemicals. The ozone depletion counter measures include,

- Tax imposed on use of ozone depleting substances
- Use of ozone friendly substitutes- HCFC and HFC (less ozone depleting potential and shorter life)
- Recycle of CFCs and Halons

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.

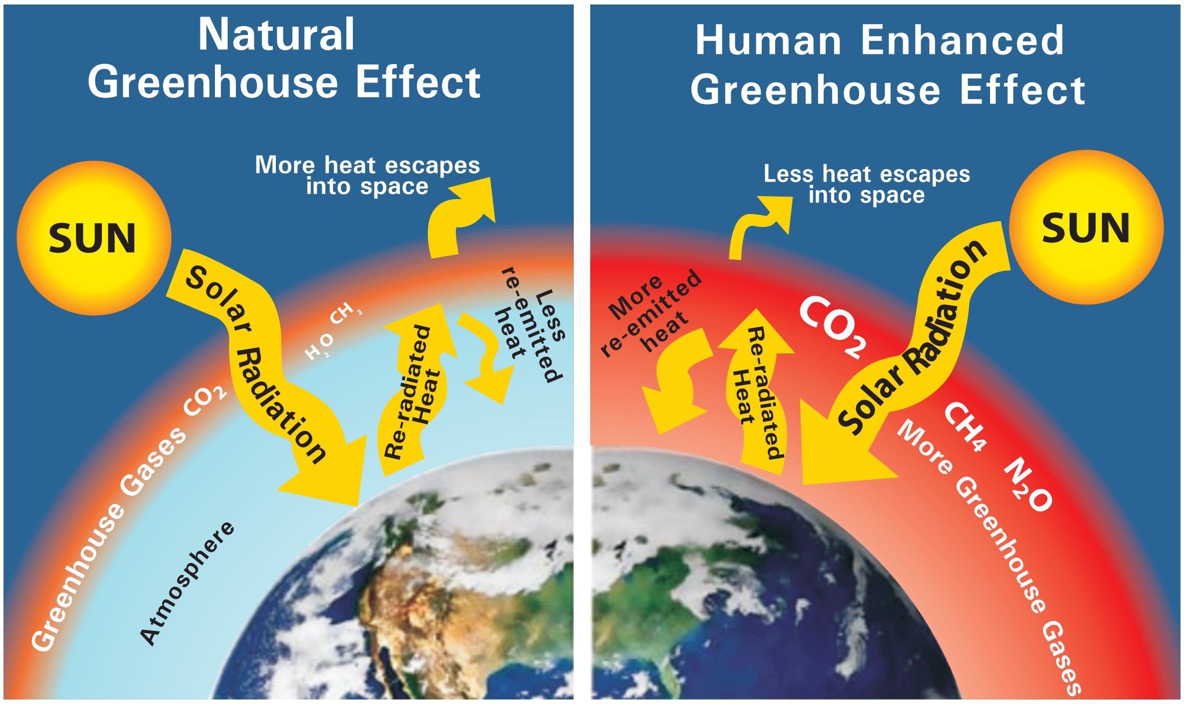

Figure 10.6 Greenhouse Effect

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.

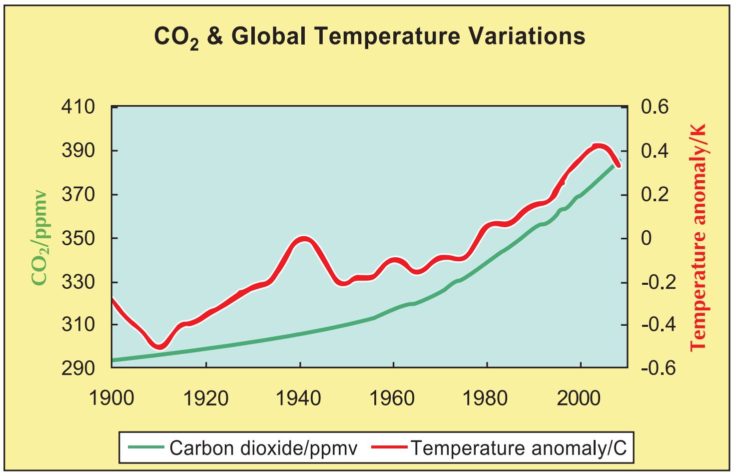

Figure 10.7 Rising Global Temperatures

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.

Because of their shorter lifetime, and lower concentrations, their contribution to global warming for a given rate of emission, will be less than for the CFCs. However, since their rate of manufacture could increase substantially their potential contribution to global warming is being included alongside other greenhouse gases.

The main sources of Hydroflurocarbons are leakage from refrigeration equipment, release during end of life destruction of equipment, use of HFC containing aerosols, air conditioners etc. These are best contained by recycling the refrigerants.

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.

Some greenhouse gases are 140 to 23,900 times more potent than CO_2 in terms of their ability to trap and hold heat in the atmosphere over a 100-year period. Even though these gases represent a very small proportion of the atmosphere, their enormous heat-holding potential makes them significant and represents a serious addition to global warming.

In order to understand specific greenhouse gases' potential impact, they are rated on the basis of their global warming potential (GWP). The GWP of a greenhouse gas is the ratio of global warming—or radiative forcing—from one unit mass of a greenhouse gas to that of one unit mass of CO_2 over a period of time, making the GWP a measure of the "potential for global warming per unit mass relative to carbon dioxide." In other words, greenhouse gases are rated on how potent they are compared to CO_2.

GWPs take into account the absorption strength of a molecule and its atmospheric lifetime. Therefore, if methane has a GWP of 23 and carbon has a GWP of 1 (the standard), this means that methane is 23 times more powerful than CO_2 as a greenhouse gas. The higher the GWP value, the larger the infrared absorption and the longer the atmospheric lifetime. As shown in Table10.1, even small amounts of sulfur hexafluoride and HFC-23 can contribute a significant amount to global warming. The increasing concentration of greenhouse gases, GWP and lifetime is given in Table 10.1.

Table 10.1 Increasing Concentration of Atmospheric Greenhouse Gases

Greenhouse gas	Baseline	Current level	GWP	Lifetime in atmosphere (years)
Carbon dioxide (CO_2)	280 ppm	395 ppm	1	5-200
Methane (CH_4)	700 ppb	1893 ppb	23	12
Nitrous oxide (N_2O)	275 ppb	326 ppb	300	114
Ozone	-	-	-	Days/weeks
Chloroflurocarbons (CFC) and related chemicals	0	ppt levels	4000-8000	5-100
Perfluromethane, one of the Perfluorcarbons (PFC)	40 ppt	80 ppt	5700	50000
Sulphur hexafluoride (SF_6)	0.01 ppt	7.79 ppt	22000	3200

Source: Carbon Dioxide Information Analysis Centre (CDIAC) Data
1 ppm = 1g in 1000 kg, 1 ppb = 1 g in 1000 tonnes, 1 ppt = 1 g in 1000 000 tonnes

Global Greenhouse Gas Emissions

Since the Industrial Revolution, annual CO_2 emissions from fuel combustion dramatically increased from near zero to almost 36 Giga tonnes of CO_2 in 2013. Among the many human activities that produce greenhouse gases, the use of energy represents by far the largest source of emissions.

Smaller shares correspond to agriculture, producing mainly CH_4 and N_2O from domestic livestock and rice cultivation, and to industrial processes not related to energy, producing mainly fluorinated gases and N_2O. Within the energy sector, CO_2 resulting from the oxidation of carbon in fuels during combustion dominates the total GHG emissions. CO_2 from fossil fuels & cement contributes almost 70% of global GHG emissions (Figure 10.8).

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.

Temperatures that people from a hotter climate consider normal can be termed a heat wave in a cooler area if they are outside the normal pattern for that area. Severe heat waves have caused catastrophic crop failures, thousands of deaths from heat stroke, and widespread power blackouts due to increased use of air conditioners.

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.

10.7 International Agreements: United Nations Framework Convention on Climate Change (UNFCCC)

The United Nations Framework Convention on Climate Change (UNFCCC) was signed by over 160 countries at the United Nations Conference on Environment and Development held at Rio de Janeiro in June 1992 came into force from 1994.

QUESTIONS

Objective Type Questions

1.	The Global Warming Potential (GWP) of sulfur hexafluoride is a) 1 b) 23 c) 300 d) 22,000
2.	Global warming will not result in a) melting of the ice caps b) increasing sea levels c) increasing the size of the hole in the ozone layer d) unpredictable climate patterns
3.	The ozone layer found in the stratosphere: a) protects against the sun's harmful UV rays b) can react with atmospheric pollutants to form smog c) is toxic to plants d) is capable of disintegrating fabric and rubber on earth
4.	The main constituent of greenhouse gases (GHG) in atmosphere is a) CO2 b) SOx c) nitrogen d) water vapour
5.	The Global Warming Potential (GWP) of nitrous oxide (N2O) is a) 1 b) 23 c) 300 d) 5700
6..	Which of the following is not an environmental issue of global significance? a) ozone layer depletion b) global Warning c) loss of Biodiversity d) suspended particulate Matter
7.	Which among the following has the lowest Global Warming Potential? a) Perflurocarbon b) chloroflurocarbons c) methane d) nitrous oxide
8.	The depletion of Ozone layer is caused mainly by __________ a) nitrous oxide b) carbon dioxide c) choloroflourocarbons d) methane
9.	Which of the following statements regarding responsibility of climate change mitigation is correct? a) industrialized countries bare the sole responsibility in climate change mitigation because they are responsible for most of the GHG emitted to date due to their economic growth b) developing countries bare the sole responsibility as they will be responsible for most of the GHG emission increase in the future due to their population growth c) both industrialized and developing countries share the equal responsibility as a member of the international community d) both industrialized and developing countries share common responsibility but taking into account the respective capabilities towards mitigation
10.	The process of capturing CO2 from point sources and storing them is called __________. a) carbon sequestration b) carbon sink c) carbon capture d) carbon adsorption

Short Type Questions	
S-1	A renovation and modernization (R&M) program of a 110 MW coal-fired thermal power plant was carried out to enhance the operating efficiency from 28% to 32%. The specific coal consumption was 0.7 kg/kWh before R&M. For 7000 hours of operation per year and assuming the coal quality remains the same, calculate a) the coal savings per year and b) the expected avoidance of CO_2 into the atmosphere in Tons/year if the emission factor is 1.53 kg CO_2/kg coal
S-2	Explain the linkage between energy and environmental issues with examples
S-3	Explain the significance of GWP?
S-4	List four impacts of global warming
S-5	Explain what do you mean by biodiversity
Long Type Questions	
L-1	Explain green house effect and enhanced green house effect?
L-2	Explain COPs, purpose and its implications for developed and developing countries?

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