Module-1
Introduction & Energy from Sun

1. ENERGY SOURCES:

"Energy is fundamental to daily life. Whether it is providing lights for our classrooms, refrigeration for our food and medicine, pumps to irrigate our crops, or electricity to run our commercial and industrial enterprises, energy provides the means for economic growth and social and political development". –USAID.

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

- Coal
- Lignite
- Petrol
- Diesel
- Furnace oil
- Kerosene
- LPG
- Natural gas
- LNG

Electricity: Thermal, Hydro, Nuclear, Wind, solar, Biomass etc

The energy is classified into several types based on the following criteria:

- Primary and Secondary Energy
- Commercial and Non Commercial Energy
- Renewable and Non-Renewable Energy

1.1 Primary and Secondary Energy sources:

The common primary energy sources are fossil fuels like coal, lignite, oil, natural gas, and biomass such as wood, which are either found or stored in nature. The coal is mined from open and deep underground coal mines, the oil is found in oil wells and is refined to produce products like petrol, diesel, furnace oil, kerosene and LPG, the natural gas is also found in well, and the biomass is procured from forests and agricultural wastes.

The other primary energy sources include nuclear energy from radioactive substances, thermal energy stored in earth's interior, and potential energy due to earth's gravity. The primary energy sources are mostly converted in industrial utilities into secondary energy sources, for example coal, oil or gas converted into steam and electricity. It is also used directly. Some primary energy sources have non-energy uses too, for example, the coal or natural gas is used as a feedstock in fertilizer plants.

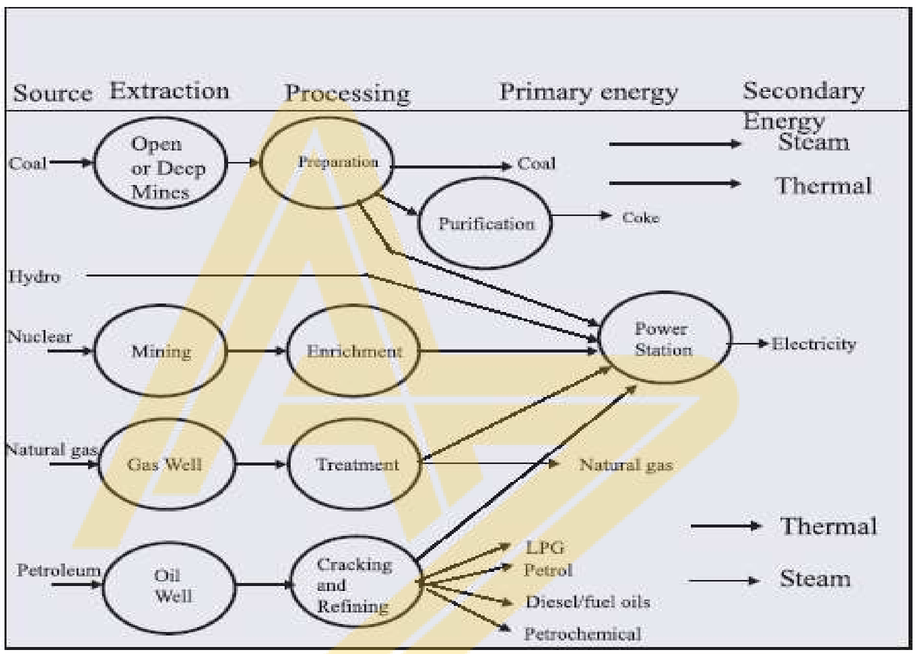


Fig 1.1 Primary and secondary Energy Sources

1.2 Commercial and non commercial Energy sources:

Commercial Energy sources:

The commercial energy is the lifeline for industrial, agricultural, Transport and commercial development in the modern world. In the industrially well-developed countries, the commercial energy is also largely used for many household tasks. By far the most important forms of commercial energy are electricity, coal, lignite, refined petroleum products and natural gas that are available in the market for a price.

Non-Commercial Energy sources:

The traditional fuels like firewood, cattle dung and agro wastes that are gathered for use in rural households, and not bought at a price, are classified as non-commercial energy sources are often ignored in energy accounting. The other form of non-commercial energy includes renewable sources of energy like solar and wind as well as animal power. The solar energy is used for electricity generation, water heating, drying grain, fish and fruits. The wind energy finds use for electricity generation and water lifting. The animal power is largely used in villages for lifting water for irrigation and crushing sugarcane, threshing and transportation.

1.3. Renewable and Non-Renewable Energy sources:

Renewable energy is obtained from sources that are essentially inexhaustible. It includes wind power, solar power, geothermal energy, tidal power and hydroelectric power. Bio-diesel is the latest to join this list. The most important feature of renewable energy is that it is very clean and does not pollute the environment.

The non-renewable energy includes the conventional fossil fuels such as coal, oil and gas, and they go on depleting with time.

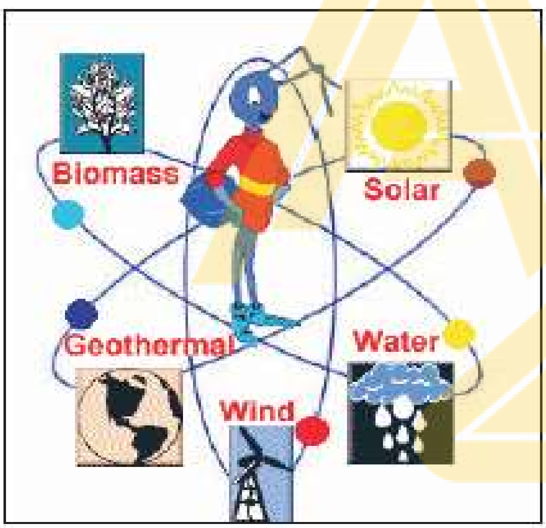


Fig-1.3(a) Renewable

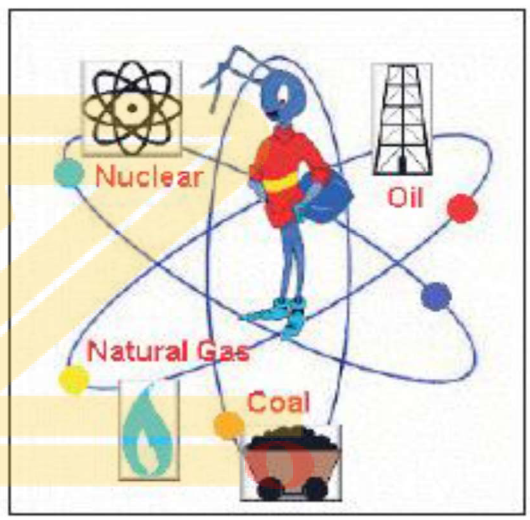


Fig-1.3 (b) Non Renewable

Renewable and Non-Renewable Energy sources

1.4. World energy scenario:

The international Energy outlook 2004 projects strong growth for worldwide energy demand over the 24 year projection period from 2001 to 2025. Total world consumption of marketed energy is expected to expand by 54%, from 404 quadrillion Btu in 2001 to 623 quadrillion Btu in 2025. The major growth in energy demand is developing countries as two billion people lack access to affordable and reliable energy supplies.

The world coal reserves are likely to last a little over 200 years but the oil and gas reserves are estimated at just 45 years and 65 years, respectively. Of the three major primary sources of energy-coal, oil and gas, the coal consumption is heavily concentrated in the electricity generation sector. Almost 65% of the world's coal use is for electricity generation. The power generation accounts for virtually all the projected growth in coal consumption worldwide. One exception is China, where coal continues to be the main fuel in rapidly growing industrial sector, reflecting the country's abundant coal reserves and limited access to other sources of energy.

Despite the rapid strides made in the development and adoption of new sources of energy, particularly renewable energy, petroleum remains the primary energy source all over the world. Since the first commercial exploitation of oil in Pennsylvania, USA, in 1859, the importance. In 1920, only 95 million tons of oil was produced annually around the world. This rose to 4 billion tones in 2003. The consumption of petroleum in the world, which started as a few tones per year about 140 years ago, has now reached to over 3000 million metric Tonnes (MMT) per year.

1.5. Global Primary energy consumption:

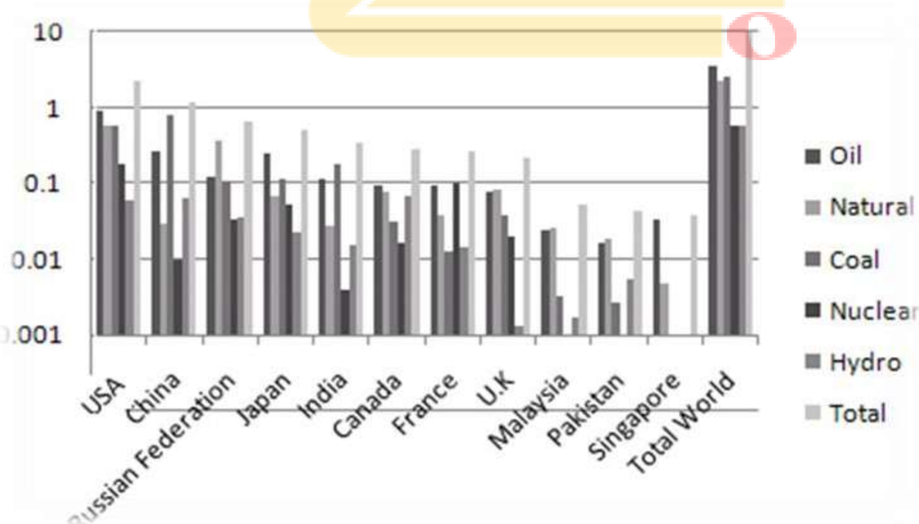
The global primary energy consumption at the end of 2003 was equivalent to 9741 million Tonnes of oil equivalent (MTOE). The primary energy consumption in some developed and developing countries is shown in table 1.5 and world primary energy consumption is projected up to year 2025 is shown in Bar chart 1.5

Energy consumption in developing countries:

Although 80 percent of the world's population lies in the developing countries. Their energy consumption amounts to only 40 percent of the world's total energy consumption. The high standards of living in the developed countries are attributable to high-energy consumption levels. Also, the rapid population growth in the developing countries has kept the per capita energy consumption low compared with that of highly industrialized countries. The world average energy consumption per person is equivalent to 2.2 Tonnes of coal. In industrialized countries, people use four to five times more than the world average and nine times more than the average for the developing countries. An American uses 32 times more commercial energy than Indian.

Country	Oil	Natural Gas	Coal	Nuclear Energy	Hydro electric	Total
USA	14.3	66.8	73.9	81.9	0.9	297.8
China	275.2	29.5	799.7	9.8	4.0	178.3
Russian Federation	124.7	365.2	111.3	34.0	35.6	670.8
Japan	48.7	68.9	112.2	2.2	22.8	504.8
India	113.3	27.1	185.3	4.1	15.6	345.3
Canada	96.4	78.7	31.0	16.8	68.6	291.4
France	94.2	39.4	12.4	99.8	14.8	260.6
U.K	76.8	85.5	39.1	20.1	1.3	223.2
Malaysia	3.9	5.6	-	-	1.7	54.4
Pakistan	7.0	9.0	7	0.4	5.6	44.8
Singapore	4.1	4.8	-	-	-	38.9
Total World	636.6	331.9	578.4	98.8	595.4	9741.1

Table1.5 World energy resources overview



Bar chart 1.5 World energy resources overview

1.6. World energy consumption projections:

According to analysts, about two billion people lack access to affordable and reliable energy supplies in developing countries. Women and children are disproportionately burdened by dependence on traditional fuels. The international Energy outlook 2004(Ieo2004) Projects strong growth for worldwide energy demand over the 24-year projection period from 2001 to 2025. Total world consumption of marketed energy is expected to expand by 54 Percent, from 404 quadrillion Btu (British thermal units) in 2001 to 623 quadrillion Btu in 2025. In the IEO 2004 mid-term outlook developing nations of the world are largely expected to account for the increment in the world energy consummation. In particular, energy demand in the emerging economies of developing Asia, which include china and India, is projected to more than double over the next quarter century. In the developing world as a whole, primary energy consummation is projected to grow at an average annual rate of 2.7 percent between 2001 and 2005. In contrast, in the industrialized world, with its more mature energy use is expected to grow at a much slower rate 1.2 percent per year over the same period, and in the transitional economics of Eastern Europe and the former Soviet Union growth in energy demand is projected to average 1.5 percent per year.

Outlook for primary energy consumption:

Coal use worldwide is projected to increase by 2.3 billion Tonnes between 2001 and 2025. Substantial declines in coal use are projected for Western Europe and Eastern Europe, where natural gas is increasingly being used it fuel new growth in electric power generation and for other uses as in the industrial building sectors. In the developing world, however, larger increase in coal use are projected for China and India account for 85 percent of the projected rise in coal use in the developing world and 70 percent of the total world increment in coal demand over the forecast period.

Oil is expected to remain the dominant energy fuel throughout the forecast period, with its share of total world energy consumption remaining unchanged at 39 percent through 2025. In the industrialized world, increase in oil use are projected primarily in the transportation sector, where there are currently no available fuels to complete significantly with oil product. The IEO2004 reference case projects declining oil use for electricity generation, with other fuels, especially natural gas, expected to provide more favorable alternatives to oil-fired generation. Fig-1.6 (a) and (b) illustrates the world primary energy consumption projection from year 1970 to 2025

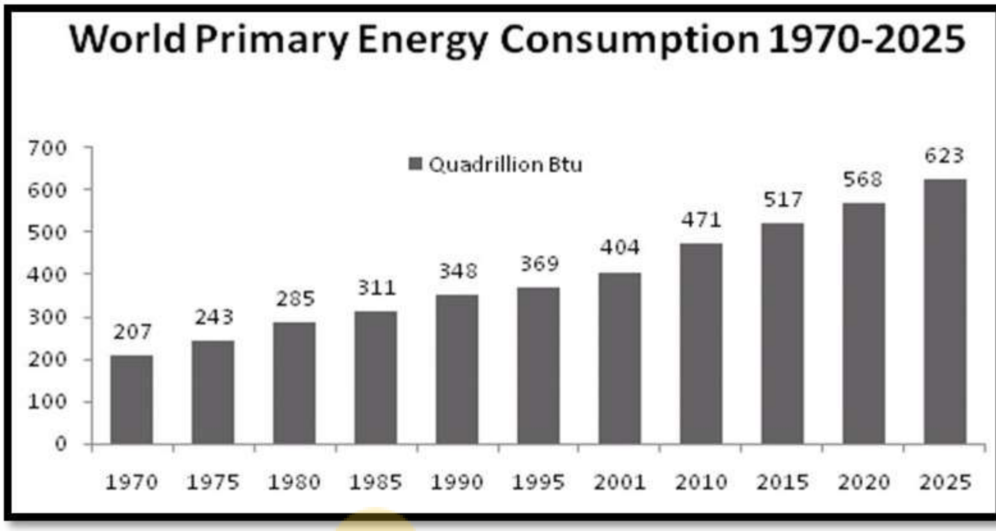


Fig-1.6 (a) World energy consumption projections

Global primary energy consumption Natural gas is projected to be the fastest growing primary energy source worldwide, maintaining average growth of 2.2 percent annually over the 2001-2025 periods. In comparison 1.9 percent average annual growth rates are projected for oil and for renewable, 1.6 percent annual growth is projected for coal, and 0.6 percent annual growth is projected for nuclear power (on a Btu basis)

Total world natural gas consumption is projected to rise for 90 trillion cubic feet in 2025. In the United States, the industrial sector is expected to remain the largest end use consumer of natural gas, growing by 1.4 percent per year on average, from 7.3 trillion cubic feet in 2001 to 10.3 trillion cubic feet in 2025. In the electric power sector, natural gas is projected to increase by 1.9 percent per year, from 5.4 trillion cubic feet to 8.4 trillion cubic feet.

Electricity generation is expected to nearly double between 2001 and 2025, from 13,290 billion kilowatt-hours to 23,702 billion kilowatt-hours. Strongest growth is projected for the countries of the developing world, where net electricity consumption rises by 3.5 percent per year in the IE02004 reference case, compared with a projected average increase of 2.3 percent per year worldwide. Robust economic growth in many of the developing nations is expected to boost demand for electricity to run newly purchased home appliances for air conditioning, cooking space and water heating, and refrigeration. For the industrialized world and refrigeration. For the industrialized world and the transitional economies of the Eastern Europe/former Soviet Union, where electricity markets are more modest annual growth rates of 1.5 and 2 percent, respectively, are projected.

Over the 2011-2025 forecast horizons, renewable maintain their share of total energy consumption at 8percent. Moreover, despite the high rates of growth projected for renewable energy sources, such as wind power in Western Europe and the United States, much of the growth is expected to result from large-scale hydroelectric power projects in the developing countries, particularly among the nations of developing Asia. China, India, Malaysia, and Vietnam are already constructing or have plans to construct ambitions hydroelectric projects in the coming decades.

1.7. World energy resources overview:

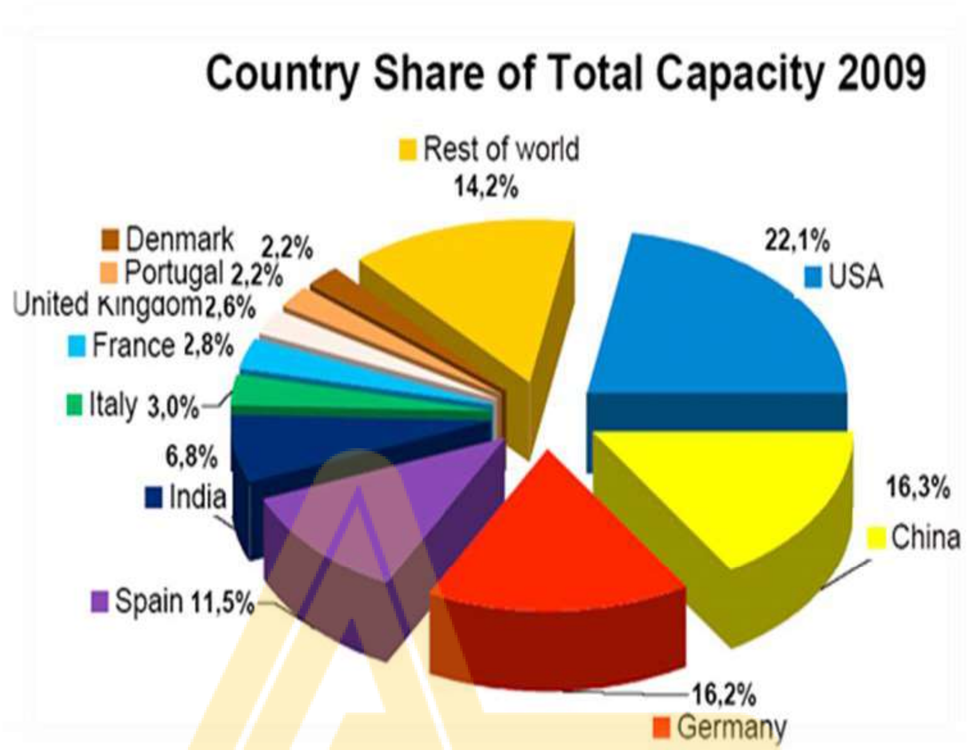
The main findings of the 2001 Survey of Energy Resources, produced by the World Energy Council, confirm that conventional commercial fossil fuels encompassing coal, oil and natural gas, remain in adequate supply with a substantial resource base. Compared to the 1998 Surveys, coal and natural gas reserves increased somewhat, while those of oil declined slightly, within the total coal reserves, both sub-bituminous coal and lignite reserves declined from the previously reported levels by 15% and 3% respectively, but bituminous coal reserves increased by 2%

While coal supply in the medium and long term is assured, the future prospects for delivery and use of coal will largely depend on the impact of deregulation of electricity markets, policies to reduce greenhouse gases, and technological advances (cleaner use of coal and carbon sequestration i). Coal could contribute in a sustainable way to satisfying demand for energy from the two billion people n the world who today. Primary energy consumption by fuel in selected countries of the world – 2003In million tones oil equivalent

In the commentary on oil, the pessimistic and optimistic reserve assessments have been propounded and appear to incline towards the former, for the following reasons:

- Proved recoverable reserves of oil, which are largely concentrated in the Middle East, declined, while those of gas which are more evenly spread, increased;
- Fever giant fields were discovered in the 1990's than in the 1960's (albeit larger proportion were in deeper offshore waters);
- The discoveries of new oil fields were concentrated in a smaller number of countries in the 1990's than in the earlier periods;
- More recently, the additional discoveries have been less than the oil produced
- The oil industry's technological challenges posed by the ultra deep offshore have not yet been met satisfactorily.

is in 6th place. Other countries contribution can be analyzed by the pie chart given below.



Pie chart 1.7

1.8. World reserves of primary energy sources:

As per BP Statistical Review of World Energy, June 2004, the world reserves of the three major primary energy sources like coal, oil and gas in as follows:

1.8 (i) Coal:

The proven global coal reserve was estimated to be 9, 84,453 million tones by end of 2003. The USA alone with 25.4% had the largest share of the global reserve, followed by Russia 15.9%, China 11.6% and India8.6%

Fig-1.8(i) Coal

1.8 (ii) Oil:

Despite the rapid strides made in the development and adoption of new sources of energy, particularly renewable energy, oil remains the primary energy source all over the world. The global proven oil reserve was estimated to be 1147 billion barrels by the end of 2003. Saudi Arabia had the largest share of the reserve with almost 23%. One barrel of oil is approximately 160 liters.

1.8 (iii) Gas:

The current century is already being described as the “Century of Gas”. While the world’s oil reserves are falling, the potential gas reserves keep increasing. In fact, much of the new discoveries in the world, including India, is gas. The global proven gas reserve was estimated to be 176 trillion cubic meters by the end of 2003. The Russian Federation had the largest share of the reserve3 with almost 27%.

Fig-1.8(iii) Gas

World oil and Gas Reserves are estimated at just 45 Years and 65 years respectively and coal is likely to lost a little over 200 Years

1.9 Indian Energy Scenario:

India's absolute primary energy consumption is only 1/29th of the world, 1/7th of USA, 1/1.6th time of Japan but 1.1,1.3,1.5 times that of Canada, France and UK, respectively. The reform measures since 1991 have helped to brighten India's economic picture. Sustained measures over the past decade have led to some improvements in the Indian economy and aligned it more closely with the major economics of the world. Today India is one of the fastest growing economies in Asia.

The economic growth of a country is often closely linked to its consumption of energy. As compared to developed countries, the per capita energy consumption is too low in India. It is just 4% of USA and 20% of the world average Driven by the expanding economy, rising population and a quest for improved quality of life, energy usage in India is expected to rise to around 450 kg/year by 2010 from the present over 350 kg/year.

"The economic growth of a country is often closely linked to its consumption of energy. Although, we rank sixth in the world so far as total energy is concerned, but still much more energy needed to keep pace with our economic development objectives Most of our energy requirement are met through fossil fuel that is limited and petroleum fuel that leads to dependence on Imports and energy Insecurity".

R.V.Shahi, Power Secretary, Govt, Of India.

Most of India's energy requirements are not met through fossil fuels. The coal dominates the energy mix I n India contributing to 55% of the total primary energy production. Over the year, there has been a marked decline in oil production from 20% to 17% but during the same period the share of natural gas production has increased from 10% in 1994 to 13% in 1999. The decline in India's oil production is mainly due to it being relatively poor in oil reserves, which amount to 5.9 billion barrels. It is just 0.5 % of global reserves. India imports 70% of its oil, much of it from West Asia. In the next decade, India's oil, much of it from West Asia. In the next decade, India's oil imports are likely to go up to 85% and by the year 2020, further to about 92%.

1.10 Sector wise Energy Consumption:

The major commercial energy consuming sectors in the country are classified into four major sectors, namely agriculture, domestic, industry, transport and others as shown in the graph. Among these, the industry remains the biggest consumer with 49% share in total commercial energy consumption, followed by transport 22%, domestic 10% agriculture has 5% and other remaining 14%.

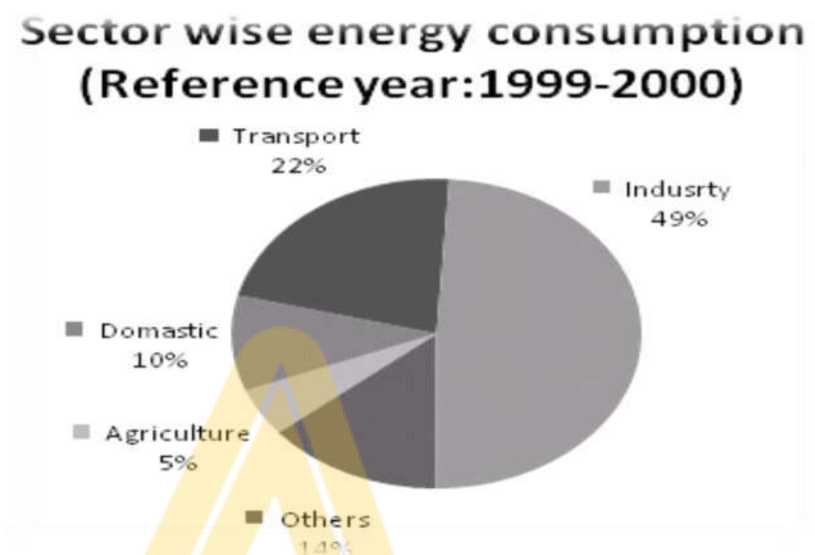


Fig-1.10

1.11 India's Primary Energy Sources:

1.11 (i) Coal:

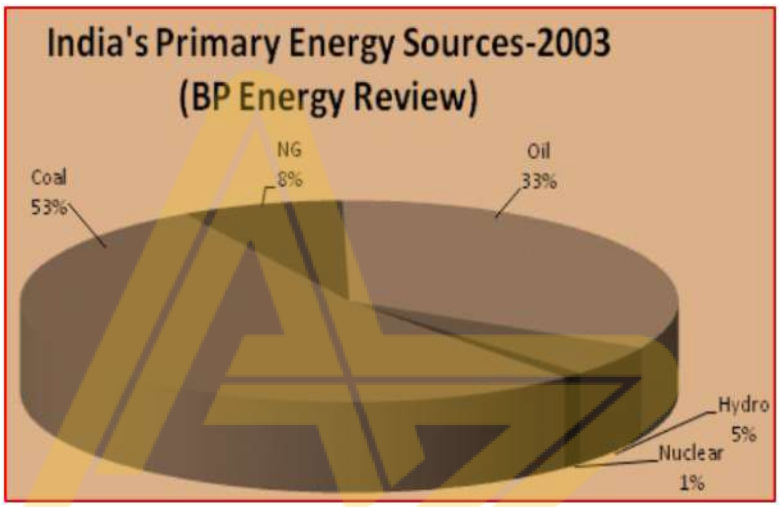
More than 50 percent of Indian energy demand is met though coal. Power generation alone accounts for about 70 percent of India's coat consumption followed by heavy industry. As per the, International Energy Annual 2002, the coal consumption in India is projected to increase from 369 million Tonnes in the year 2000 to 450 million Tonnes by the year 2010.

India is the world's third largest coal producer, after China and the United States. Its current coal production stands at around 290 million Tonnes per year. Presently the major coal production is concentrated in eight Indian States, namely: Andhra Pradesh, Bihar, Jharkhand, Madhya Pradesh, Maharashtra, Orissa, Uttar Pradesh, and West Bengal. Indian coal is typically of poor quality and such requires being beneficiated to improve the quality. At the beginning of 2004, India's huge coal reserves were estimated at 84,396 million tones. This is almost 8.6% of the world reserves and it may last for about 230 years at the current reserve to production(R/P) ratio. In contrast, the world's proven coal reserves are expected to last only for 192 years at the current R/P ratio.

1.11 (ii) Lignite:

Lignite is the second stage of transformation of wood into coal. India is also one of the largest producers of lignite in the world. The total lignite reserves identified in India are 36,008 million tones and those about 85 percent are in Tamil Nadu.

The presence of lignite deposits in the Neyveli region was first revealed during well boring operations. The Government of India with the services of Powell Duffyrin Technical Services, London, developed a project report for an integrated project to mine and utilize the lignite available in the region. In order to exploit the deposits of Tamil Nadu Neyveli Lignite Corporation Limited was incorporated as a Central PSU in 1956.



Pie Chart 1.11(ii) India's primary energy sources

1.11 (iii) Oil:

India is one of the top ten oil – guzzling nations in the world and will soon overtake Korea as the third largest consumer of oil in Asia after china and japan. Oil accounts for about 36% of India's total energy consumption. In sector wise petroleum product consumption transport sector alone accounts for 42% , industry 24% and domestic 24%.

India's oil consumption has increased at a very steep rate from 3.50 MMT in 1950 – 51 to 112.56 MMT in 2002 – 03 and it is expected to reach 175 MMT in 2006 – 07 Future oil consumption is expected to grow rapidly to 3.2 million barrels / day by 2010, from 2 million barrels / day in 2002.

India has oil reserves of about 504 billion barrels and the majority of them are located in the Bombay High, upper Assam, Cambay, and Krishna – Godavari. Its annual crude oil production is peaked at about 32 million tones. By the end of the 10th plan period, the domestic production is likely to rise marginally to 33.97 million tones. India's self-sufficiency in oil production has consistently declined from 60% in the 50s to 30% currently. Same is expected to go down further to 8% by 2020.

Currently India import 70% of its crude needs, mainly from gulf nations. At the end of 2004, India spent more than Rs. 1, 10,000 crore on oil import alone. By the year 2020 around 92% of India's total oil demand has to be met by imports. Figure 1.13 illustrates the oil net imports and domestic production

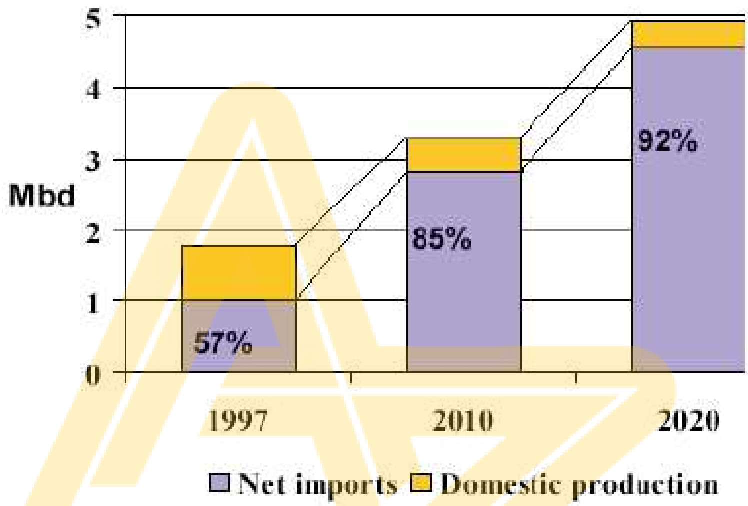


Fig-1.11(iii) oil net imports and domestic production

1.11 (iv) Natural Gas:

Natural gas is clean, environment friendly, and the most economical fuel in term of delivered price of energy. Compared to coal and other liquid hydrocarbons. Therefore, Indian Consumption of natural gas has raised faster any other fuel in recent years and today it accounts for about 8.9 percent of energy consumption in the country.

In India, the current demand for natural gas about 96 million cubic meters per day (MCMD) as against availability of 67 MCMD. By 2007, the demand is expected to be around 200 MCMD. In 2002-03, the gas production was 86.56 MCMD, which in 2006-07 is likely to rise to 103.08.MCMD.It, is mainly based on the strength of more than doubling of production by private operators to 38.25 MCMD. The natural gas reserves in India are estimated at 660 billion cubic meters.

Through currently natural gas accounts for only 8 percent of Indian's total commercial energy, compared to nearly 25% in the develop world, the share of gas is bound to increase to around 14% in total energy mix of India by 2025. Currently, about 10 percent of Indian's electricity is generated by CCGT plants using dual fuel – naphtha or gas. But since naphtha is a relatively expensive fuel, CCGT plants will switch to gas if it is made available. Gas is also used as feedstock in fertilizer industry. Nearly 82 percent of annual gas production is consumed by power and fertilizer industries in India.

1.11 (v) LNG:

Liquefied natural gas (LNG) is a relatively recent phenomenon. Natural gas is cooled to extreme low temperatures to liquefy it and the liquid to transport in cryogenic ships to the destination. In liquid from the gas occupies just about one-six hundredth of its gaseous volume, but at the receiving end, the liquid has to be degasified through the process of heating. Thus LNG requires substantial infrastructure both at the shipping point and the destination which adds to its cost. Petro net LNG, promoted by a consortium of public sector oil and gas companies, has set up Indian's first LNG terminal Dahej in Gujarat with an initial capacity of 5 million metric tons per annum (MMTPA), which amounts to 20 MCM/D. shell, transnational oil major, is in the process of setting up an LNG terminal at Hazira.

The year 2004 could well go down as the start of a new era for the Indian petroleum sector. The first consignment of LNG – the alternative fuel for gas, landed of Indian shores in January 2004. The gas was sourced from Qatar's Ras Gas with which Petro net has signed a 25 – years 'take-or-pay' contract. The marketing of the gas is being down by GAIL, Indian Oil Corporation and Bharat Petroleum Corporation in the ratio of 60:30:10, respectively. During the year, Petro net supplied 10 MCM/D LNG to consumers along the HBJ pipeline.

1.11 (vi) Electrical Energy:

As on March 31,2005,the all India electric power generating installed capacity under utilities was 1,18,419MW,consisting of 80,902MW of thermal(69%), 30,936MW of hydro(26%),2770MW of nuclear(2%) and 2488 MW of wind power (3%). During the year 2004-05, the gross generation was 587.3 billion units.

India is endowed with a vast and viable hydro potential for power generation of which only 15% has been harnessed so far. The share of hydropower in the country's total generated units has steadily decreased and it presently stands at 25% as on May 31, 2004. It is assessed that exploitable hydro power potential at 60% load factor is 84,000MW. India currently has a peak demand shortage of around 14% and energy Deficit Of 8.4%. Keeping this view and to maintain a GDP growth of 8% to

10%, the Government of India has very prudently set a target of 215,804MW Power Generation capacity by March 2012.

1.12 Final energy consumption:

Final energy consumption is the actual energy demand at the user end. This is the difference between primary energy consumption and the losses that takes place in transportation, transmission and distribution and refinement. The past and projected actual final energy consumption is given in the table below:

India's Energy scenario for the year June 2010 is given in the Table-1.13(i) to 1.13(vii) and from Chart-1.13(i) to 1.13(vi) below.

Total Installed Capacity (MOP website as on 30.6.2010)

SECTOR	MW	PERCENTAGE
State Sector	80,775	52.5
Central Sector	51,158	34.0
Private Sector	30,434	13.5
Total	**1,62,367**	**100**

Table-1.13(i)

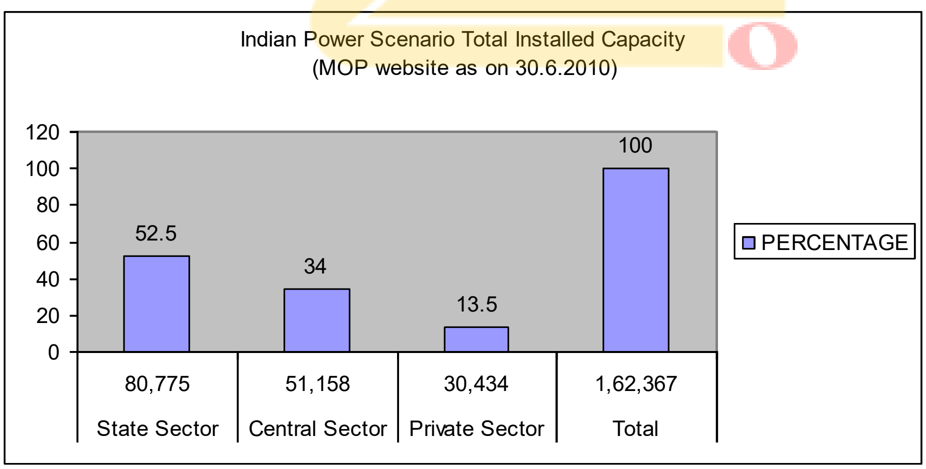


Chart-1.13(i)

Total Installed Capacity (fuel-wise)

(MOP website as on 30.6.2010)

Fuel	MW	Percentage
Thermal	104,424	64.6
Coal	86,003	53.3
Gas	17,221	10.5
Oil	1,200	0.9
Hydro	36,953	24.7
Nuclear	4,560	2.9
Renewable	16,429	7.7
Total	1,62,367	

Table-1.13(ii)

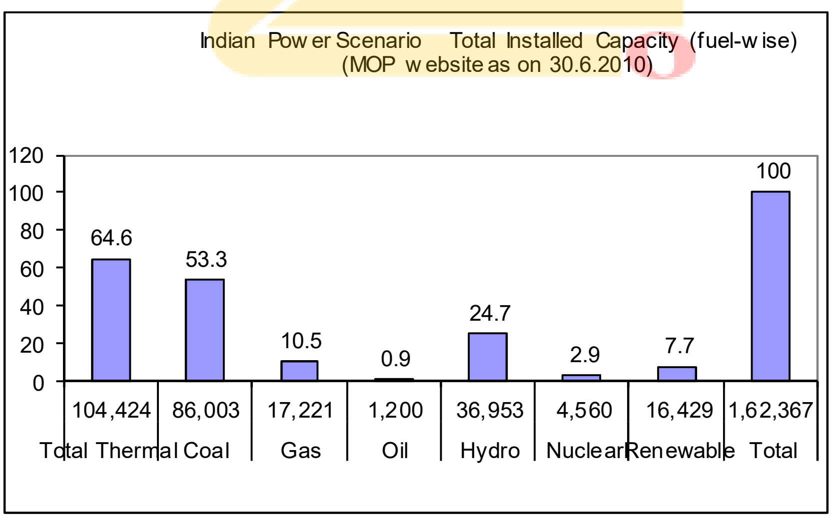


Chart-1.13(ii)

Region	Coal	Gas	Nuclear	Hydro	R.E.S	Total
Northern	21,950	3,563	1,620	13,350	2,690	43,188
Western	28,525	8,144	1,840	7,448	4,850	50,824
Southern	18,573	4.558	1,100	11,157	8,330	44,656
Eastern	16,895	190	0	3,882	335	21,321
North Eastern	60	766	0	1,116	218	2,303
All India	86,003	17,221	4,560	36,953	16,429	162,367

Table-1.13(iii) Installed Capacity in MW (Region wise)

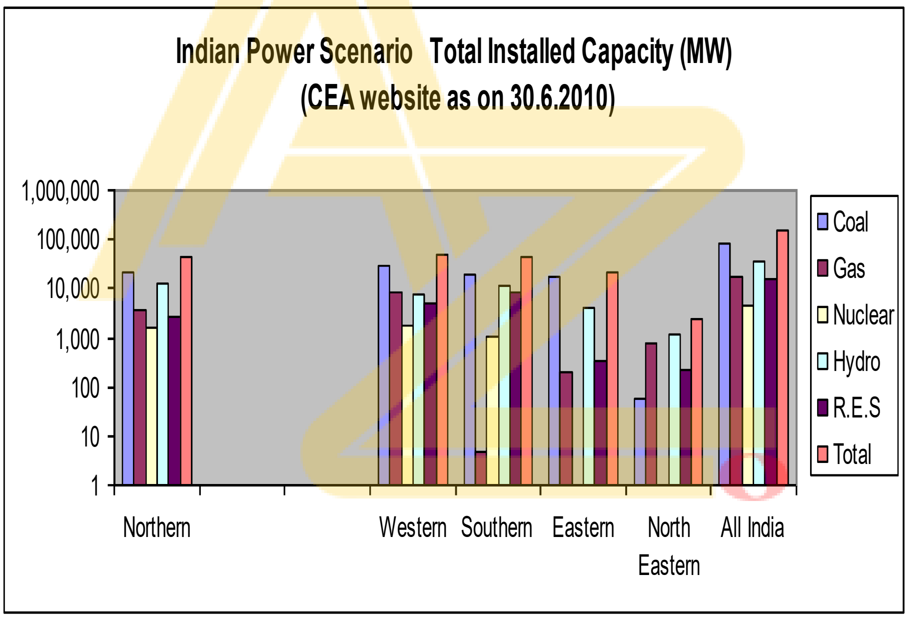


Chart-1.13(iii)

Power Supply Scenario (April – May 2010: CEA)

	Energy Requirement (MU)	Energy Availabilty (MU)	Energy Deficit (%)
Northern Region	43,900	37,971	13.5
Western Region	49,035	40,341	17.7
Southern Region	39,398	35,871	9.0
Eastern Region	15,851	14,699	7.3
N E Region	1,438	1,234	14.2
Total for the Country	149,622	130,116	13.0

Table-1.13(iv)

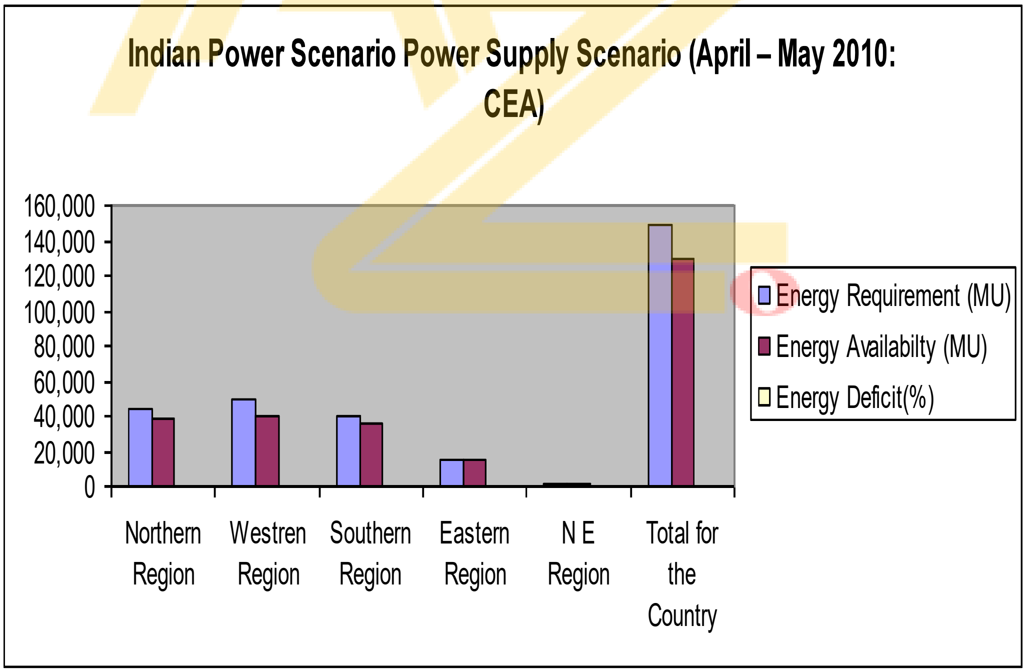


Chart-1.13(iv)

Indian Power Scenario

Power Supply Scenario (April – May 2010: CEA)

	Peak Demand (MW)	Peak Demand Met (MW)	Peak Deficit (%)
Northern Region	33,911	31,176	8.1
Western Region	39,560	32,142	18.8
Southern Region	32,214	29,054	9.8
Eastern Region	13,317	11,8011	11.4
N E Region	1,578	1,358	13.9
Total for the Country	119,437	103,003	13.8

Table-1.13(v)

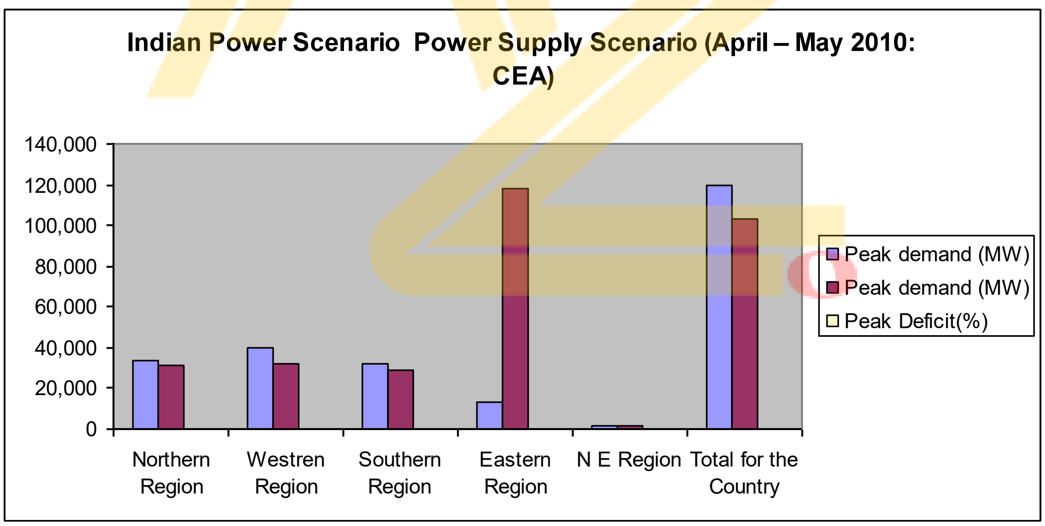


Chart-1.13(v)

T&D Losses (2006 –2007), (CEA Annual Report)

Region	Losses
Northern Region	20 to 52 (%)
Western Region	21 to 39 (%)
Southern Region	19 to 26 (%)
Eastern Region	24 to 50 (%)
N E Region	34 to 57 (%)
All India	28.65 (%)

Table-1.13(vi)

Installed Power Generating Capacity in Karnataka:

(Approximate figures in some years)

Year	**Installed capacity (MW)**	**Increase over previous decade**
Year 1948	83	-
Year 1950	107	-
Year 1960	189	77 %
Year 1970	888	470 %
Year 1980	1310	48 %
Year 1990	2760	210 %
Year 2000	5824	211 %
Year 2009	9250 *(Own capacity + Central sector share)*	150 % (111 times of 1948)

Table-1.13(vii) (Reference: "Belakaayitu Karnataka' by Dr. Gajanana Sharma)

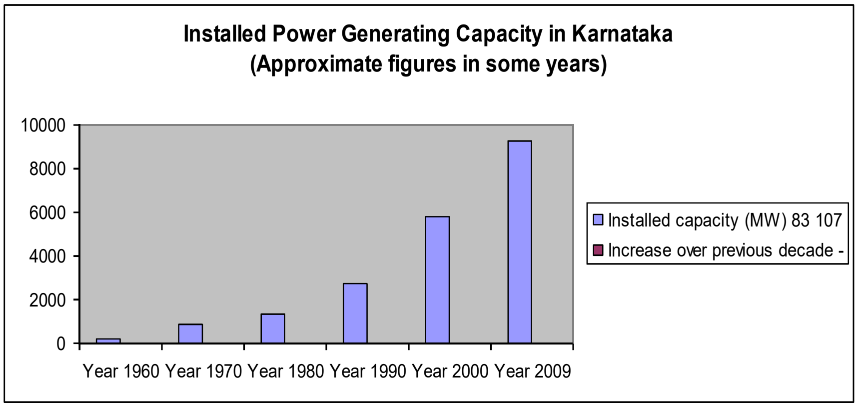


Chart-1.13(vii)

Points to be Remember

- Demand for energy will continue to grow even if governments adopt strict vigorous policies to conserve energy.
- Coal has the potential to contribute substantially to future energy supplies, but its reserves are limited.
- The supply of oil will fail to meet increasing demand.
- Natural gas reserves are large enough to meet projected demand provided the incentives are sufficient enough to encourage the development of extensive and costly inter-continental gas transportation system.
- Electricity from nuclear power is capable of making an important contribution to the global energy supply. However, its acceptance is yet to be established globally.
- Other than hydropower, renewable energy sources are likely to become increasingly important in 21st century.
- Energy efficiency improvements and Energy conservation techniques will play a major role in reducing the gap between energy demand and energy supply.

SOLAR ENERGY BASICS

Introduction:

1. Solar energy can be converted directly or indirectly in to other forms of energy.
2. In-exhaustible source of useful energy.
3. Major drawbacks to the extensive application of S.E
    1. The intermittent and variable manner in which it arrives at the earth's surface and
    2. The large area required to collect the energy at useful rate.
4. Experiments are under way to use this energy.
5. Energy is radiated by the sun as electromagnetic waves of which 99% have wave lengths in the range of 0.2 to 4.0 µm
6. Solar energy reaches the top of the earth atmosphere consists of about
    1. 8% Ultraviolet radiation (short wave length, less than 0.39µm)
    2. 46% visible light (0.39 to 0.78µm) and 46% Infrared radiation (long wave length more than 0.78µm

Solar Constant:

1. The sun is a large sphere of very hot gases, the heating being generated by various kinds of fusion reactions.
2. Sun diameter is $1.39X10^6$ km, while earth is $1.27X10^4$ km.
3. Mean distance between sun and earth is $1.50X10^8$ km
4. The beam of radiation received from the sun on the earth is almost parallel.
5. The brightness of the sun varies from its center to its edge. For calculations, it is customary to assume that the brightness all over the solar disc is uniform.
6. Radiation coming from the sun approximately-5762^0 K.
7. The rate at which solar energy arrives at the top of the atmosphere is called the solar constant I_{SC}. This is the amount energy received in unit time on unit area perpendicular to the sun's direction at mean distance of the earth from the sun. The rate of arrival of solar radiation varies throughout the year.
8. Solar constant is an average from which actual values vary up to about 3% in either direction.
9. NASA has expressed solar constant in three common units

    1. 1.353KW/ m^2 or 1353 W/m^2

2. 116.5 langleys (calories/cm^2) per hour, or

   1165/kcal/m^2/hr (1 langley=1cal/cm^2) solar radiation received in one day.

3. 429.2 Btu/ square feet/hr.

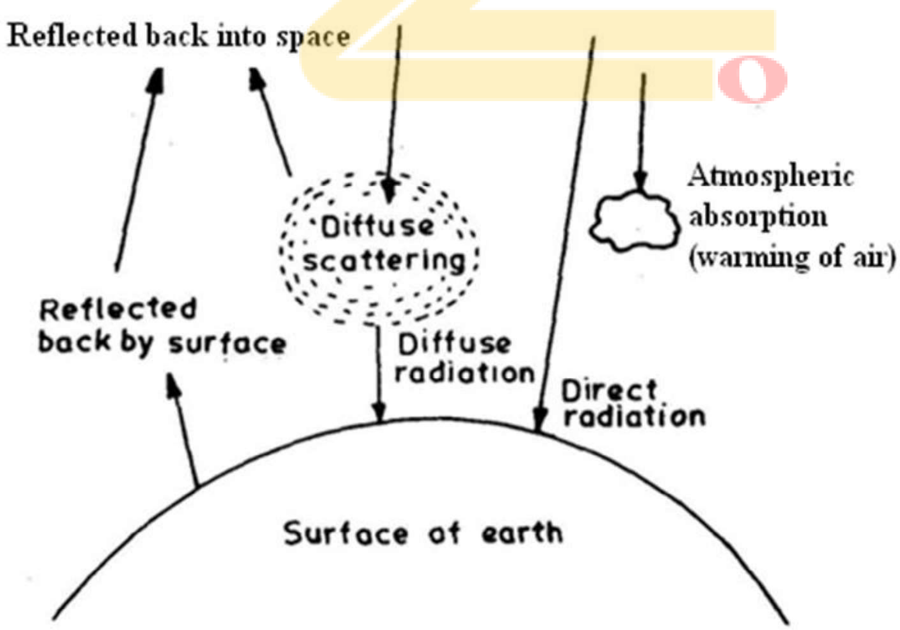
10. The distance b/w the earth and sun varies a little through the year. Because of this variation, the extra-terrestrial (outside the atmosphere) flux also varies. The earth is closest to the sun in the summer and farthest away in the winter.
11. The variation in the distance produces a nearly sinusoidal variation in the intensity of solar radiation ‘ I’ that reaches the earth approximately,

    $I/I_{sc} = 1+0.033 \cos(360(n-2))/365$ (or)

    $= 1+ 0.033 \cos(360 \times n)/365$

SOLAR RADIATION AT EARTH’S SURFACE

The solar radiation that penetrates the earth’s atmosphere and reaches the surface differs in both amount and character from radiation at the top of the atmosphere. The radiation entering the atmosphere is partly absorbed by molecules, and a part of the radiation is reflected back into the space by clouds. Part of the solar radiation is scattered by droplets in clouds by atmospheric molecules and dust particles. Oxygen and ozone absorb nearly all the ultraviolet radiation whereas CO_2 and H_2O vapour absorb some energy from infrared range.



1. Part of the radiation is reflected back into the space, especially by clouds.
2. Oxygen and ozone absorbs nearly all the ultraviolet radiation and water vapour and CO2 absorb some of the energy in the infrared range.
3. Some part of the solar energy radiation is scatted by droplets in the clouds by atmospheric molecules, and by dust particles.

Beam radiation:

- Solar radiation that has not been absorbed or scattered and reaches the ground directly from the sun is called ‘direct radiation’ or ‘ Beam radiation’.
- It is the radiation which produces a shadow when interrupted by an opaque object.

Diffusion radiation:

Diffuse radiation is that solar radiation received from the sun after its direction has been changed by reflection and scattering by the atmosphere

1. The total solar radiation received at any point on the earth’s surface is the sum of the direct and diffuse radiation. This referred to in a general sense as the insolation at that point.
2. The insolation is defined as the total solar radiation energy received on a horizontal surface of unit area on ground in unit time.
3. The insolation at a given location on the earth surface depends on the altitude of the sun in the sky. The altitude is the angle between the sun’s direction and the horizontal)
4. Since the sun’s altitude changes with the date and time of the day and with the geographic latitude at which the observations are made, the rate of arrival of solar radiation on the ground is variable quantity even in the time.

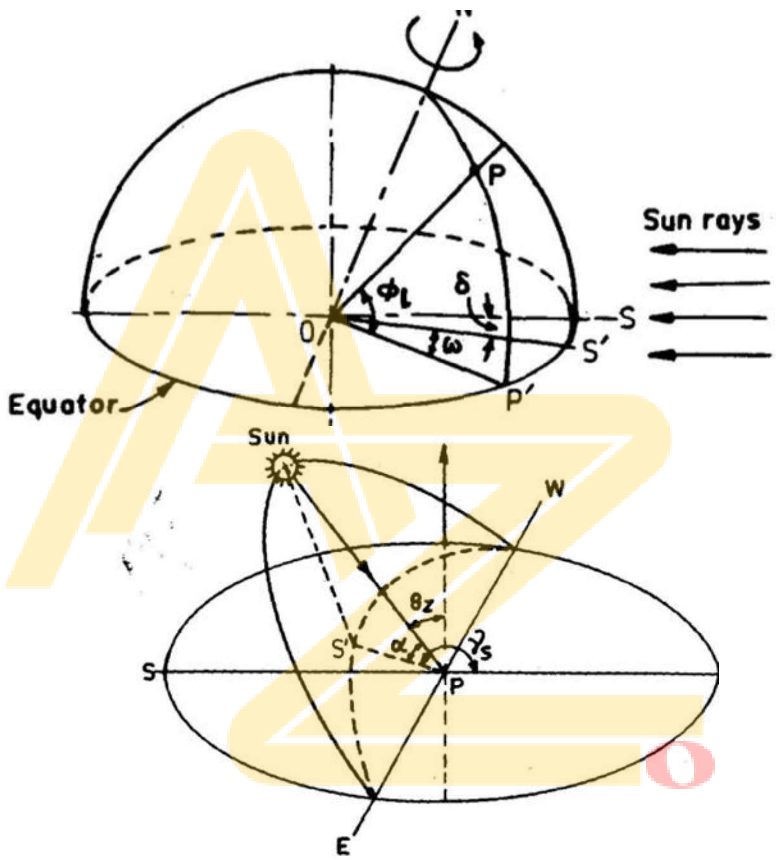
SOME DEFINITIONS

1. Sun at zenith: It is the position of the sun directly overhead.
2. Air mass: It is the path length of radiation through the atmosphere to the length of path and when the sun is at the zenith. Air mass = cos (altitude angle) except for very low solar altitude angles.

3. Solar angles Let θ = Angle between an incident beam radiation I and the normal to the plane surface. Then, radiation intensity normal to the surface is I = I cosθ

Where θ = Incident angle, Latitude, Øl

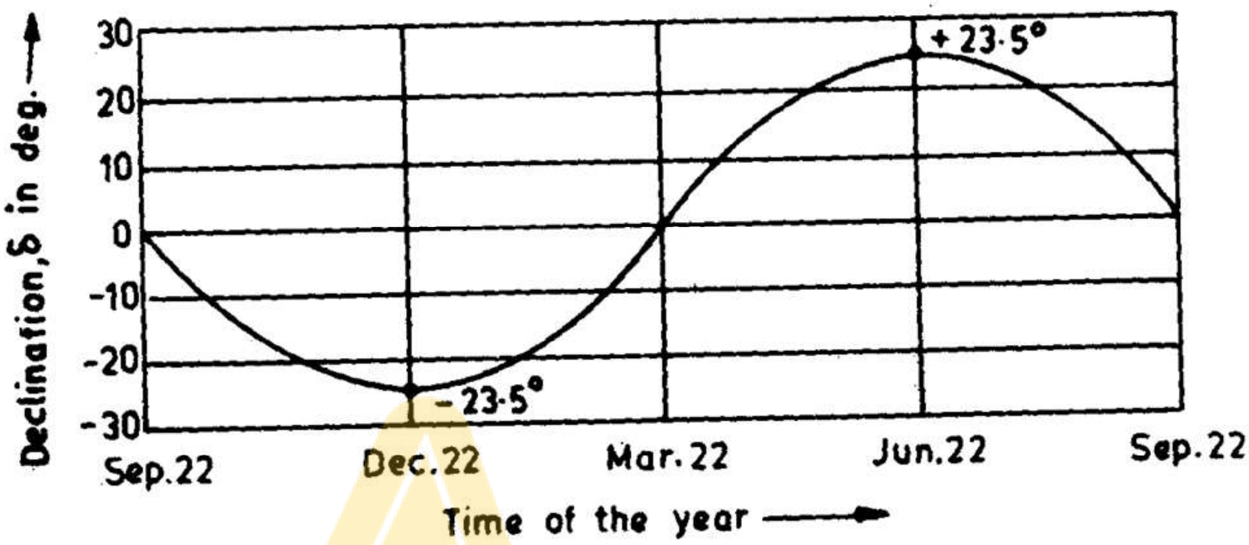
It is the angle made by the radial line joining the location to the center of earth with the projection of the line on the equatorial plane, denoted by Øl. It is also given by the angular distance north or south of the equator measured from the center of the earth.



Latitude, hour angle w, and sun's declination

1. If P is the location on the earth's surface and O is the centre of the earth, the Øl is given by the angle between the line OP and projection of OP on the equatorial plane. As a method of convention, the latitude will be measured as +ve for the northern hemisphere.
2. ii) Declination (δ)
3. It is the angular distance of sun's rays north or south of the equator. It is the angle between the line extending from the centre of the sun to the centre of the earth and the projection of this line

upon the earth's equatorial plane. Declination varies between 23.5 oon June 22 to 23.5o on December 22.



Variation of sun's declination

4. The declination in degrees for any given day may be given by Cooper's equation.
   a. δ (in degrees) = $23.45 \sin[360/365(284+n)]$ where n is the day of the year
   b. e.g.: March 22 is the 31 + 29 + 22 = 82nd day $\therefore n = 82$
5. Hour angle (ω)

   It is the angle through which the earth must turn to bring the meridian of a point directly in line with the sun's rays. The hour angle is equivalent to 15o per hour.
6. It is measured from noon based on the solar local time (LST) or local apparent time, being positive in the morning an negative in the afternoon. It is the angle measured in the earth's equatorial plane, between the projection of OP and the projection of O line from the centre of the sun to the centre of the earth
7. Altitude angle (α) It is the vertical angle between the projection of the sun's rays on the horizontal plane and the direction of sun's rays passing through the point.
8. Zenith angle (θZ)

   It is the angle between the sun's rays and a line perpendicular to the horizontal plane through the point P. i.e., the angle between the beam from the sun and the vertical. Zenith angle is complimentary angle of sun's altitude angle.

$$\theta Z = \pi/2 - \alpha$$

9. Solar azimuth angle (γS)

   It is the solar angle in degrees along the horizon cost or west of north or it is the horizontal angle measured from the north to the horizontal projection of sun's rays. It is considered +ve when measured west wise.

   In terms of basic angles, $\cos\theta_Z = \cos\varnothing.\cos\omega.\cos\delta+\sin\varnothing.\sin\delta$

   $$\cos \gamma S = \sec\alpha(\cos\varnothing.\sin\delta-\cos\delta.\sin\varnothing.\cos\omega)$$

   $$\sin\gamma S = \sec\alpha.\cos\delta.\sin\omega$$

   If north latitudes are considered positive and south latitudes negative, the declination will be positive for summer period between the vernal equinox and autumnal equinox and negative at other times

10. The slope (s)

    It is the angle made by the plane surfaces with the horizontal. It is considered positive for surfaces slopping towards the south and negative for surface slopping towards the north.

11. Surface azimuth angle (γ)

    It is the angle of deviation of the normal to the surface from the local meridian, the zero point being south, east positive and west negative.

    Fig. Surface azimuth angle and slope defined

12. Incident angle (θ)

It is the angle being measured from a plane and is equal to the angle between the beam of rays and normal to the plane. It is expressed as

$$\cos\theta=\sin\varnothing l(\sin\delta.\cos s+\cos\delta.\cos\gamma.\cos\omega.\sin s)$$
$$+ \cos\varnothing l (\cos\partial.\cos\omega.\cos s-\sin\delta.\cos\gamma.\sin s)$$
$$+\cos\delta.\sin\gamma.\sin\omega.\sin(s) \text{ -- } (1)$$

Where $\varnothing l$ = Latitude (North positive)

δ= Declination (North positive)

ω= Hour angle (Positive between solar mid night and noon, otherwise negative)

Hour angle is mathematically expressed as,

$\omega = 15(12 - LST)$ --- (2)

Note:

At solar noon, $\omega = 0$ and each hour angle is 15^o with morning positive and afternoon negative

For vertical surfaces $s = 90^o$ in equation 1 above

$\cos\theta = \sin\emptyset.\cos\delta.\cos\gamma.\cos\omega - \cos\emptyset.\sin\delta.\cos\gamma + \cos\delta.\sin\gamma.\sin\omega$ ------------- (3)

For horizontal surfaces s= oo, $\theta = \theta Z$ in equation above

$\cos\theta Z = \sin\delta.\cos\emptyset + \cos\delta.\cos\emptyset.\cos\omega$

$= \sin\propto$ -- (4)

For surfacing facing due south, $\gamma = 0$; $\theta = \theta t$(tilted)

$\cos\theta t = \sin\emptyset(\sin\delta.\cos s + \cos\delta.\cos\omega.\sin s)$

$= \cos\emptyset(\cos\delta.\cos\omega.\cos s - \sin\delta.\sin s)$

$= \sin\delta \sin(\emptyset - s) + \cos\delta\cos\omega \cos(\emptyset - s)$ --------------------------------------- (5)

For vertical surfaces facing due south, s = 90 ;$\gamma=0$

$\cos\theta Z = \sin\emptyset\cos\delta\cos\omega - \cos\emptyset\sin\delta$ --- (6)

13) Day Length

At the time of sun rise or sunset, $\theta Z = 90o$ substituting in equation (4), sun rise hour angle ωs is given by,

$\cos\omega_{s} = (\sin\emptyset.\sin\delta)/(\cos\emptyset.\cos\delta) = -\tan\emptyset.\tan\delta$

$\omega s = \cos^{-1}(-\tan\emptyset.\tan\delta)$

At 15o of the hour angle = 1hour, day length

$td1 = 2\omega s/15 = 2/15 \cos^{-1}(-\tan\emptyset.\tan\delta)$ --- (7)

Note:

For hour angle at the time of sun rise or sunset on an inclined surface $\theta Z=90o$, from equation (5),

$\omega st = \cos^{-1}(-\tan(\emptyset - s)\tan\delta)$

Hence day length

$td = 2/15 \cos^{-1}(-\tan(\emptyset - s.\tan\delta))$ --- (8)

14) Local Solar Time

It is also known as local apparent time which is the time used for calculating the hour angle. The local solar time is obtained from the standard time observed on a clock by making two corrections.

The first correction takes into account the difference in longitude between a location and a meridian on which the standard time is based. For every degree difference in longitude this difference is 4 minutes.

The second correction takes into account time correction arising due to small perturbations in earth's orbit and rate of rotation.

LST = Standard time ±4(Standard time longitude – Longitude of location) + Equation of time correction.

Note:- The –ve sign is applied for eastern hemisphere.

General points:

1. The smaller the sun's altitude, the greater the thickness of atmosphere through which the solar radiation must pass and reach the ground.
2. As a result of absorption and scattering, the insolation is less when sun is low in the sky than when it is higher.
3. Scattering occurs diffuse radiation constitutes a larger fraction of the total received.
4. On a clear, cloudless day, about 10 to 20% of the insolation is from diffuse radiation, proportion increases upto 100% when the sun is completely obscured by clouds.
5. When the humidity is high, insolation as high as 50% of the insolation on a clear day at same time and place.
6. Insolation is not isotropic (from the observer point of view)

Solar Radiation Data:

1. Solar radiation data are available in several forms and should include the following information.
    1. Whether they are instantaneous measurements or values integrated over some period of time
    2. The time or time period of the measurements
    3. Whether the measurements are of beam, diffuse or total radiation and the instrument used.
    4. The receiving surface orientation
    5. If averaged, the period over which they averaged.
2. Solar radiation received on the surface of the earth are measured by solarimeter, which give readings for instantaneous measurement at rate throughout the day for total radiation on a horizontal surface.
3. 1 langley =1 cal/cm^2
4. In Calcutta =680 langleys = 680 cal/cm^2/day

Solar Radiation measurement Data:

1. India lies between latitude 7^0 and 37^0N , and receives an annual average intensity of solar radiation between 16700-29260 kj/m^2/day (400-700 cal/cm^2/day)
2. Peak values are measured in April or May

3. Peak values in Rajasthan and Gujarat are 25100 kj/m^2/day (600 cal/cm^2/day)
4. During monsoon and winter daily solar radiation decreases to about 16700 KJ/m^2/day (400 cal/cm^2/day)
5. The annual daily diffuse radiation received over the whole country is observed to be about 7300 kj/m^2/day (175 cal/cm^2/day)
6. The Minimum values of diffuse radiation, measured over many parts of the country during November and December are between 3135-4180 Kj/m^2/day (75-100 cal/cm^2/day)
7. Maximum values in july are 12550 kj/m^2/day (300 cal/cm^2/day) (in Gujarat)

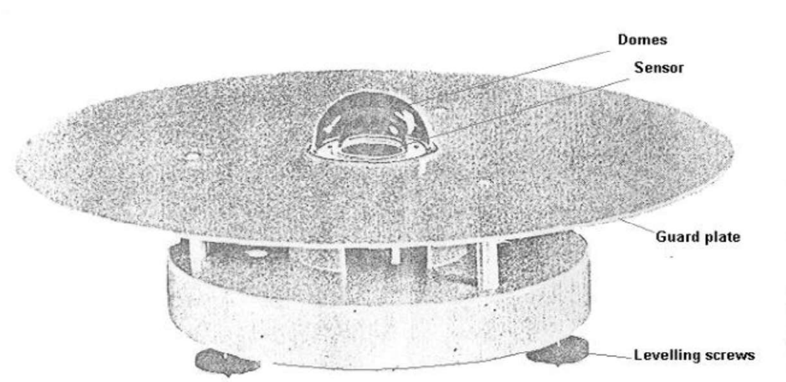
Estimation of average solar radiation

Monthly average horizontal solar radiation was given by angstrom is $H_{av} = H_o'\,(a'+b'(n/N))$

Thermoelectric Pyranometer

- Measures solar irradiance from 300-4000 nm
- Sensor: Blackened copper constantan thermopile covered with two concentric glass domes which are transparent to radiation from 300-4000 nm.
- Generated emf by thermopile is proportional to incident radiation. The typical value is approximately 5 micro Volts/watt/sq. metre
- Used for instantaneous measurement and continuous recording of Global, Diffused, Reflected Solar irradiance.

Pyranometer (Installation View)



Pyranometer