UNIT – I

ENERGY AND ENVIRONMENT

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 a critical importance in view of the ever-increasing energy needs requiring huge investments to meet them.

Energy can be classified into several types based on the following criteria:

- Primary and Secondary energy
- Commercial and Non commercial energy
- Renewable and Non-Renewable energy

1.2 Primary and Secondary Energy

Primary energy sources are those that are either found or stored in nature. Common primary energy sources are coal, oil, natural gas, and biomass (such as wood). Other primary energy sources available include nuclear energy from radioactive substances, thermal energy stored in earth's interior, and potential energy due to earth's gravity. The major primary and secondary energy sources are shown in Figure 1.1

Primary energy sources are mostly converted in industrial utilities into *secondary energy* sources; for example coal, oil or gas converted into steam and electricity.

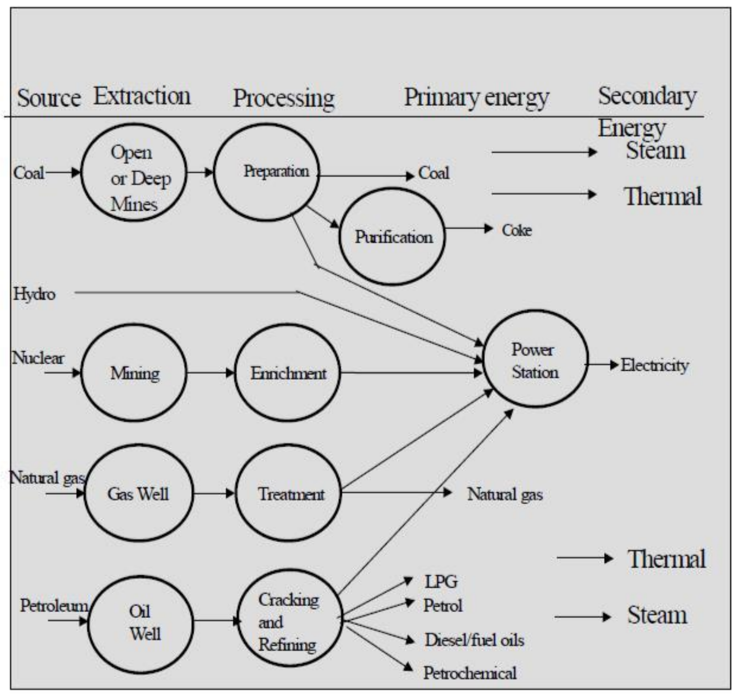


Figure 1.1 Major Primary and Secondary Sources

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.

1.3 Commercial Energy and Non Commercial Energy

Commercial Energy

The energy sources that are available in the market for a definite price are known as commercial energy. By far the most important forms of commercial energy are electricity, coal and refined petroleum products. Commercial energy forms the basis of industrial, agricultural, transport and commercial development in the modern world. In the industrialized countries, commercialized fuels are predominant source not only for economic production, but also for many household tasks of general population.

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

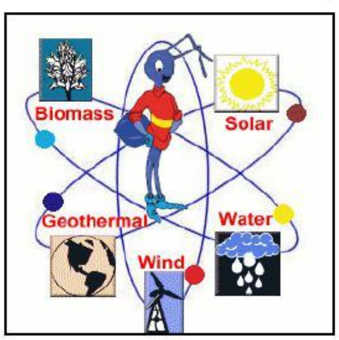
Non-Commercial Energy

The energy sources that are not available in the commercial market for a price are classified as non-commercial energy. Non-commercial energy sources include fuels such as firewood, cattle dung and agricultural wastes, which are traditionally gathered, and not bought at a price used especially in rural households. These are also called traditional fuels. Non-commercial energy is often ignored in energy accounting.

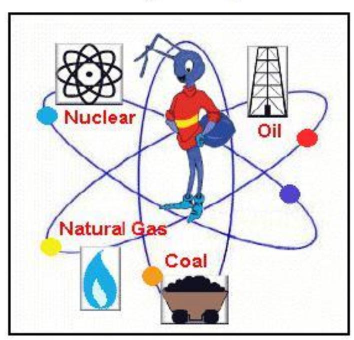
Example: Firewood, agro waste in rural areas; solar energy for water heating, electricity generation, for drying grain, fish and fruits; animal power for transport, threshing, lifting water for irrigation, crushing sugarcane; wind energy for lifting water and electricity generation.

1.4 Renewable and Non-Renewable Energy

Renewable energy is energy obtained from sources that 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. Non-renewable energy is the conventional fossil fuels such as coal, oil and gas, which are likely to deplete with time.



Renewable



Non-Renewable

Figure 1.2 Renewable and Non-Renewable Energy

1.5 Global Primary Energy Reserves*

Coal

The proven global coal reserve was estimated to be 9,84,453 million tonnes by end of 2003. The USA had the largest share of the global reserve (25.4%) followed by Russia (15.9%), China (11.6%). India was 4th in the list with 8.6%.

Oil

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 litres)

Gas

The global proven gas reserve was estimated to be 176 trillion cubic metres by the end of 2003. The Russian Federation had the largest share of the reserve with almost 27%.

(*Source: BP Statistical Review of World Energy, June 2004)

World oil and gas reserves are estimated at just 45 years and 65 years respectively. Coal is likely to last a little over 200 years

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 Figure 1.3 shows in what proportions the sources mentioned above contributed to this global figure.

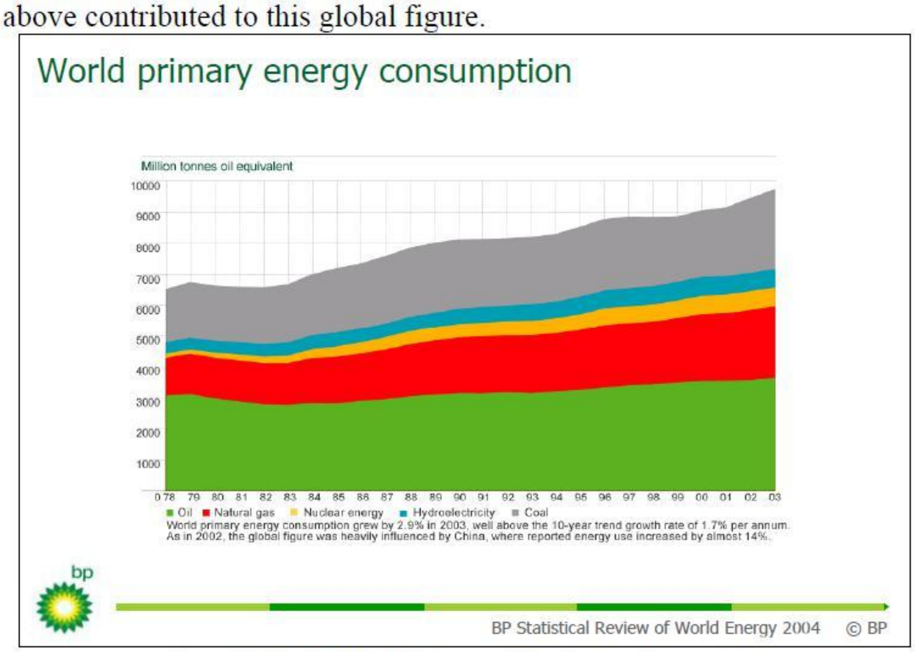


Figure 1.3 Global Primary Energy Consumption

The primary energy consumption for few of the developed and developing countries are shown in Table 1.1. It may be seen that 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 U.K respectively.

Table 1.1: Primary Energy Consumption by Fuel , 2003

Country	In Million tonnes oil equivalent					
	Oil	Natural Gas	Coal	Nuclear Energy	Hydro electric	**Total**
USA	914.3	566.8	573.9	181.9	60.9	**2297.8**
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**
Russian Federation	124.7	365.2	111.3	34.0	35.6	**670.8**
United Kingdom	76.8	85.7	39.1	20.1	1.3	**223.2**
China	275.2	29.5	799.7	9.8	64.0	**1178.3**
India	**113.3**	**27.1**	**185.3**	**4.1**	**15.6**	**345.3**
Japan	248.7	68.9	112.2	52.2	22.8	**504.8**
Malaysia	23.9	25.6	3.2	-	1.7	**54.4**
Pakistan	17.0	19.0	2.7	0.4	5.6	**44.8**
Singapore	34.1	4.8	-	-	-	**38.9**
TOTAL WORLD	**3636.6**	**2331.9**	**2578.4**	**598.8**	**595.4**	**9741.1**

Energy Distribution Between Developed And Developing Countries

Although 80 percent of the world's population lies in the developing countries (a fourfold population increase in the past 25 years), their energy consumption amounts to only 40 percent of the world 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 developed countries.

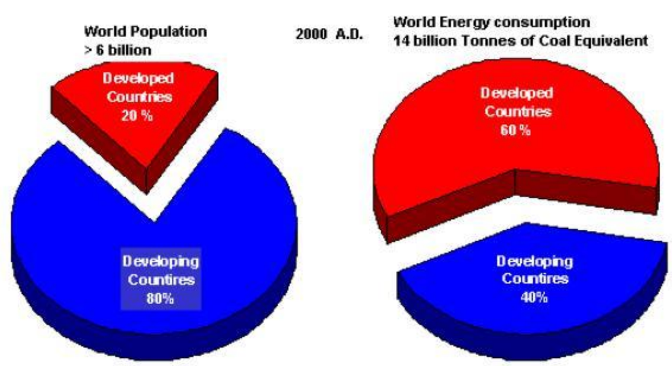


Figure 1.4: Energy Distribution Between Developed and Developing Countries

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 an Indian.

1.6 Indian Energy Scenario

Coal dominates the energy mix in India, contributing to 55% of the total primary energy production. Over the years, there has been a marked increase in the share of natural gas in primary energy production from 10% in 1994 to 13% in 1999. There has been a decline in the share of oil in primary energy production from 20% to 17% during the same period.

Energy Supply

Coal Supply

India has huge coal reserves, at least 84,396 million tonnes of proven recoverable reserves (at the end of 2003). This amounts to 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.

Reserves/Production (R/P) ratio- 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.

India is the fourth largest producer of coal and lignite in the world. Coal production is concentrated in these states (Andhra Pradesh, Uttar Pradesh, Bihar, Madhya Pradesh, Maharashtra, Orissa, Jharkhand, West Bengal).

Oil Supply

Oil accounts for about 36 % of India's total energy consumption. India today 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. The country's annual crude oil production is peaked at about 32 million tonne as against the current peak demand of about 110 million tonne. In the current scenario, India's oil consumption by end of 2007 is expected to reach 136 million tonne(MT), of which domestic production will be only 34 MT. India will have to pay an oil bill of roughly $50 billion, assuming a weighted average price of $50 per barrel of crude. In 2003-04, against total export of $64 billion, oil imports accounted for $21 billion. India imports 70% of its crude needs mainly from gulf nations. The majority of India's roughly 5.4 billion barrels in oil reserves are located in the Bombay High, upper Assam, Cambay, Krishna-Godavari. In terms of sector wise petroleum product consumption, transport accounts for 42% followed by domestic and industry with 24% and 24% respectively. India spent more than Rs.1,10,000 crore on oil imports at the end of 2004.

The ever rising import bill

Year	Quantity (MMT)	Value (Rs Crore)
1996-97	33.90	18,337
1997-98	34.49	15,872
1998-99	39.81	19,907
1999-00	57.80	40,028
2000-01	74.10	65,932
2001-02	84.90	8,116
2002-03	90	85,042
2003-04	95	93,159
*2004-05	100	1,30,000

* Estimated

Source: Ministry of Petroleum and Natural Gas

Natural Gas Supply

Natural gas accounts for about 8.9 per cent of energy consumption in the country. The current demand for natural gas is about 96 million cubic metres per day (mcmd) as against availability of 67 mcmd. By 2007, the demand is expected to be around 200 mcmd. Natural gas reserves are estimated at 660 billion cubic meters.

Electrical Energy Supply

The all India installed capacity of electric power generating stations under utilities was 1,12,581 MW as on 31st May 2004, consisting of 28,860 MW- hydro, 77,931 MW - thermal and 2,720 MW- nuclear and 1,869 MW- wind (Ministry of Power). The gross generation of power in the year 2002-2003 stood at 531 billion units (kWh).

Nuclear Power Supply

Nuclear Power contributes to about 2.4 per cent of electricity generated in India. India has ten nuclear power reactors at five nuclear power stations producing electricity. More nuclear reactors have also been approved for construction.

Hydro Power Supply

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 31st May 2004. It is assessed that exploitable potential at 60% load factor is 84,000 MW.

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 transport, transmission & distribution and refinement. The actual final energy consumption (past and projected) is given in Table 1.2.

Table 1.2 DEMAND FOR COMMERCIAL ENERGY FOR FINAL CONSUMPTION (BAU SCENARIO)

Source	Units	1994-95	2001-02	2006-07	2011-12
Electricity	Billion Units	289.36	480.08	712.67	1067.88
Coal	Million Tonnes	76.67	109.01	134.99	173.47
Lignite	Million Tonnes	4.85	11.69	16.02	19.70
Natural Gas	Million Cubic Meters	9880	15730	18291	20853
Oil Products	Million Tonnes	63.55	99.89	139.95	196.47

Source: Planning Commission *BAU:_Business As Usual*

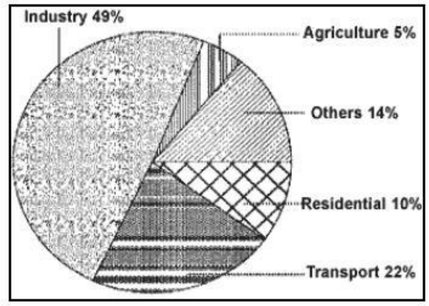


Figure 1.5 Sector Wise Energy Consumption (1999-2000)

Sector wise Energy Consumption in India

The major commercial energy consuming sectors in the country are classified as shown in the Figure 1.5. As seen from the figure, industry remains the biggest consumer of commercial energy and its share in the overall consumption is 49%. (Reference year: 1999/2000)

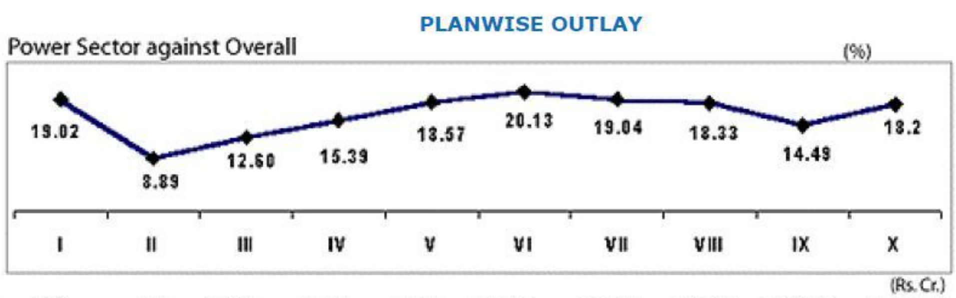
1.7 Energy Needs of Growing Economy

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. For example, under present conditions, 6% increase in India's Gross Domestic Product (GDP) would impose an increased demand of 9 % on its energy sector.

In this context, the ratio of energy demand to GDP is a useful indicator. A high ratio reflects energy dependence and a strong influence of energy on GDP growth. The developed countries, by focusing on energy efficiency and lower energy-intensive routes, maintain their energy to GDP ratios at values of less than 1. The ratios for developing countries are much higher.

India's Energy Needs

The plan outlay vis-à-vis share of energy is given in Figure 1.6. As seen from the Figure, 18.0% of the total five-year plan outlay is spent on the energy sector.



	I	II	III	IV	V	VI	VII	VIII	IX	X
Power	393	427	1,020	2,448	7,294	19,265	34,273	79,589	1,24,526	2,70,276
Overall	2,069	4,800	8,094	15,902	39,287	95,700	1,80,000	4,34,100	8,59,200	14,84,131

Figure 1.6 Expenditure Towards Energy Sector

Per Capita Energy Consumption

The per capita energy consumption (see Figure 1.7) is too low for India as compared to developed countries. It is just 4% of USA and 20% of the world average. The per capita consumption is likely to grow in India with growth in economy thus increasing the energy demand.

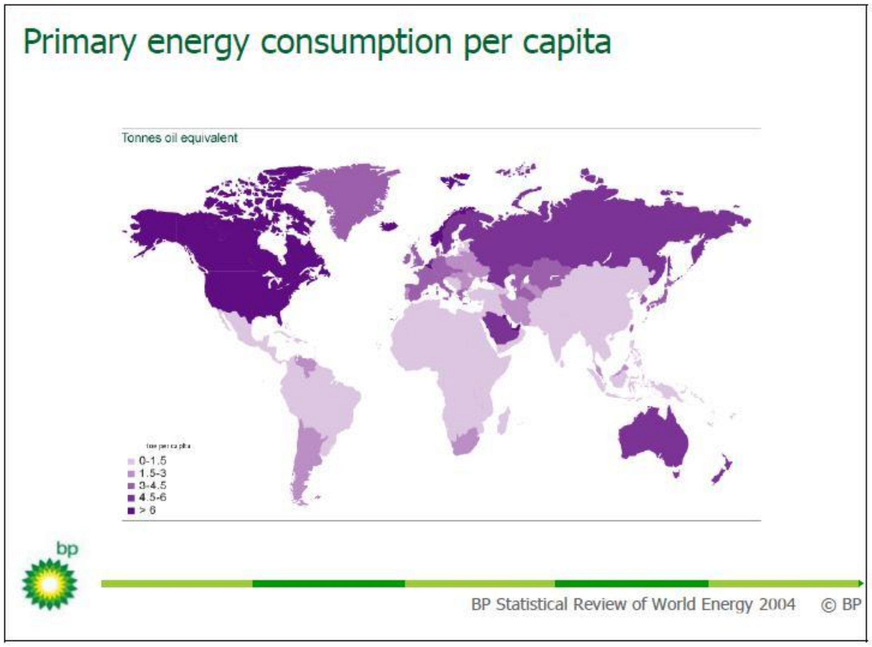


Figure 1.7 Per Capita Energy Consumption

Energy Intensity

Energy intensity is energy consumption per unit of GDP. Energy intensity indicates the development stage of the country. India's energy intensity is 3.7 times of Japan, 1.55 times of USA, 1.47 times of Asia and 1.5 times of World average.

1.8 Long Term Energy Scenario For India

Coal

Coal is the predominant energy source for power production in India, generating approximately 70% of total domestic electricity. Energy demand in India is expected to increase over the next 10-15 years; although new oil and gas plants are planned, coal is expected to remain the dominant fuel for power generation. Despite significant increases in total installed capacity during the last decade, the gap between electricity supply and demand continues to increase. The resulting shortfall has had a negative impact on industrial output and economic growth. However, to meet expected future demand, indigenous coal production will have to be greatly expanded. Production currently stands at around 290 Million tonnes per year, but coal demand is expected to more than double by 2010. Indian coal is typically of poor quality and as such requires to be beneficiated to improve the quality; Coal imports will also need to increase dramatically to satisfy industrial and power generation requirements.

Oil

India's demand for petroleum products is likely to rise from 97.7 million tonnes in 2001-02 to around 139.95 million tonnes in 2006-07, according to projections of the Tenth Five-Year Plan.

The plan document puts compound annual growth rate (CAGR) at 3.6 % during the plan period. Domestic crude oil production is likely to rise marginally from 32.03 million tonnes in 2001-02 to 33.97 million tonnes by the end of the 10th plan period (2006-07). India's self sufficiency in oil has consistently declined from 60% in the 50s to 30% currently. Same is expected to go down to 8% by 2020. As shown in the figure 1.8, around 92% of India's total oil demand by 2020 has to be met by imports.

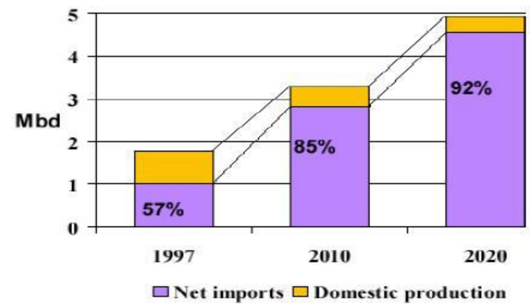


Figure 1.8 India's Oil

Natural Gas

India's natural gas production is likely to rise from 86.56 million cmpd in 2002-03 to 103.08 million cmpd in 2006-07. It is mainly based on the strength of a more than doubling of production by private operators to 38.25 mm cmpd.

Electricity

India currently has a peak demand shortage of around 14% and an energy deficit of 8.4%. Keeping this in view and to maintain a GDP (gross domestic product) growth of 8% to 10%, the Government of India has very prudently set a target of 215,804 MW power generation capacity by March 2012 from the level of 100,010 MW as on March 2001, that is a capacity addition of 115,794 MW in the next 11 years (Table 1.3).

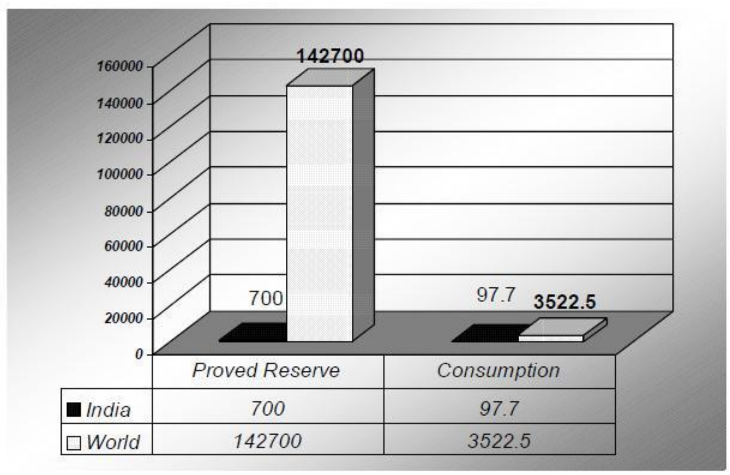


Figure 1.9 Proven Oil Reserve / Consumption (in Million Tonnes) India Vs World (At End 2002)

Table 1.3 India's Perspective Plan For Power For Zero Deficit Power By 2011/12 (Source Tenth And Eleventh Five-Year Plan Projections)

	Thermal (Coal) (MW)	Gas / LNG / Diesel (MW)	Nuclear (MW)	Hydro (MW)	Total(MW)
Installed capacity as on March 2001	61,157	Gas: 10,153 Diesel: 864	2720	25,116	100,010
Additional capacity (2001-2012)	53,333	20,408	9380	32,673	115,794
Total capacity as on March 2012	114,490 (53.0%)	31,425 (14.6%)	12,100 (5.6%)	57,789 (26.8%)	215,804

In the area of nuclear power the objective is to achieve 20,000 MW of nuclear generation capacity by the year 2020.

1.9 Energy Pricing in India

Price of energy does not reflect true cost to society. The basic assumption underlying efficiency of market place does not hold in our economy, since energy prices are undervalued and energy wastages are not taken seriously. Pricing practices in India like many other developing countries are influenced by political, social and economic compulsions at the state and central level. More often than not, this has been the foundation for energy sector policies in India. The Indian energy sector offers many examples of cross subsidies e.g., diesel, LPG and kerosene being subsidised by petrol, petroleum products for industrial usage and industrial, and commercial consumers of electricity subsidising the agricultural and domestic consumers.

Coal

Grade wise basic price of coal at the pithead excluding statutory levies for *run-of-mine* (ROM) coal are fixed by Coal India Ltd from time to time. The pithead price of coal in India compares favourably with price of imported coal. In spite of this, industries still import coal due its higher calorific value and low ash content.

Oil

As part of the energy sector reforms, the government has attempted to bring prices for many of the petroleum products (naphtha, furnace oil, LSHS, LDO and bitumen) in line with international prices. The most important achievement has been the linking of diesel prices to international prices and a reduction in subsidy. However, LPG and kerosene, consumed mainly by domestic sectors, continue to be heavily subsidised. Subsidies and cross-subsidies have resulted in serious distortions in prices, as they do not reflect economic costs in many cases.

Natural Gas

The government has been the sole authority for fixing the price of natural gas in the country. It has also been taking decisions on the allocation of gas to various competing consumers. The gas prices varies from Rs 5 to Rs.15 per cubic metre.

Electricity

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 electricity boards. The price per kWh varies significantly across States as well as customer segments within a State. Tariffs in India have been modified to consider the time of usage and voltage level of supply. In addition to the base tariffs, some State Electricity Boards have additional recovery from customers in form of fuel surcharges, electricity duties and taxes. For example, for an industrial consumer the demand charges may vary from Rs. 150 to Rs. 300 per kVA, whereas the energy charges may vary anywhere between Rs. 2 to Rs. 5 per kWh. As for the tariff adjustment mechanism, even when some States have regulatory commissions for tariff review, the decisions to effect changes are still political and there is no automatic adjustment mechanism, which can ensure recovery of costs for the electricity boards.

1.10 Energy Sector Reforms

Since the initiation of economic reforms in India in 1991, there has been a growing acceptance of the need for deepening these reforms in several sectors of the economy, which were essentially in the hands of the government for several decades. It is now been realized that if substance has to be provided to macroeconomic policy reform, then it must be based on reforms that concern the functioning of several critical sectors of the economy, among which the infrastructure sectors in general and the energy sector in particular, are paramount.

Coal

The government has recognized the need for new coal policy initiatives and for rationalization of the legal and regulatory framework that would govern the future development of this industry. One of the key reforms is that the government has allowed importing of coal to meet our requirements. Private sector has been allowed to extract coal for captive use only. Further reforms are contemplated for which the Coal Mines Nationalization Act needs to be amended for which the Bill is awaiting approval of the Parliament.

The ultimate objective of some of the ongoing measures and others under consideration is to see that a competitive environment is created for the functioning of various entities in this industry. This would not only bring about gains in efficiency but also effect cost reduction, which would consequently ensure supply of coal on a larger scale at lower prices. Competition would also have the desirable effect of bringing in new technology, for which there is an urgent and overdue need since the coal industry has suffered a prolonged period of stagnation in technological innovation.

Oil and Natural Gas

Since 1993, private investors have been allowed to import and market liquefied petroleum gas (LPG) and kerosene freely; private investment is also been allowed in lubricants, which are not subject to price controls. Prices for naphtha and some other fuels have been liberalized. In 1997 the government introduced the New Exploration Licensing Policy (NELP) in an effort to promote investment in the exploration and production of domestic oil and gas. In addition, the refining sector has been opened to private and foreign investors in order to reduce imports of refined products and to encourage investment in downstream pipelines. Attractive terms are being offered to investors for the construction of liquefied natural gas (LNG) import facilities.

Electricity

Following the enactment of the Electricity Regulatory Commission Legislation, the Central Electricity Regulatory Commission (CERC) was set up, with the main objective of regulating the Central power generation utilities. State level regulatory bodies have also been set up to set tariffs and promote competition. Private investments in power generation were also allowed. The State SEBs were asked to switch over to separate Generation, Transmission and Distribution corporations. There are plans to link all SEB grids and form a unified national power grid.

1.11 Energy and Environment

The usage of energy resources in industry leads to environmental damages by polluting the atmosphere. Few of examples of air pollution are sulphur dioxide (SO_2), nitrous oxide (NO_X) and carbon monoxide (CO) emissions from boilers and furnaces, chloro-fluro carbons (CFC) emissions from refrigerants use, etc. In chemical and fertilizers industries, toxic gases are released. Cement plants and power plants spew out particulate matter. Typical inputs, outputs, and emissions for a typical industrial process are shown in Figure 1.10.

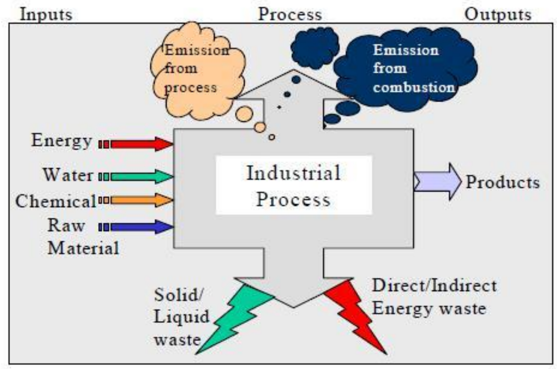


Figure 1.10 Inputs & Outputs of Process

Air Pollution

A variety of air pollutants have known or suspected harmful effects on human health and the environment. These air pollutants are basically the products of combustion from fossil fuel use. Air pollutants from these sources may not only create problems near to these sources but also can cause problems far away. Air pollutants can travel long distances, chemically react in the atmosphere to produce secondary pollutants such as acid rain or ozone.

Evolutionary Trends in Pollution Problems

In both developed and rapidly industrialising countries, the major historic air pollution problem has typically been high levels of smoke and SO_2 arising from the combustion of sulphur-containing fossil fuels such as coal for domestic and industrial purposes.

Smogs resulting from the combined effects of black smoke, sulphate / acid aerosol and fog have been seen in European cities until few decades ago and still occur in many cities in developing world. In developed countries, this problem has significantly reduced over recent decades as a result of changing fuel-use patterns; the increasing use of cleaner fuels such as natural gas, and the implementation of effective smoke and emission control policies.

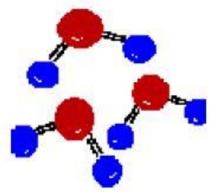
In both developed and developing countries, the major threat to clean air is now posed by traffic emissions. Petrol- and diesel-engined motor vehicles emit a wide variety of pollutants, principally carbon monoxide (CO), oxides of nitrogen (NO_x), volatile organic compounds (VOCs) and particulates, which have an increasing impact on urban air quality.

In addition, photochemical reactions resulting from the action of sunlight on NO_2 and VOCs from vehicles leads to the formation of ozone, a secondary long-range pollutant, which impacts in rural areas often far from the original emission site. Acid rain is another long-range pollutant influenced by vehicle NOx emissions.

Industrial and domestic pollutant sources, together with their impact on air quality, tend to be steady-state or improving over time. However, traffic pollution problems are worsening world-wide. The problem may be particularly severe in developing countries with dramatically increasing vehicle population, infrastructural limitations, poor engine/emission control technologies and limited provision for maintenance or vehicle regulation.

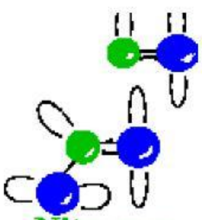
The principle pollutants produced by industrial, domestic and traffic sources are sulphur dioxide, nitrogen oxides, particulate matter, carbon monoxide, ozone, hydrocarbons, benzene, 1,3-butadiene, toxic organic micropollutants, lead and heavy metals.

Brief introduction to the principal pollutants are as follows:



Sulphur Dioxide

Sulphur dioxide is a corrosive acid gas, which combines with water vapour in the atmosphere to produce acid rain. Both wet and dry deposition have been implicated in the damage and destruction of vegetation and in the degradation of soils, building materials and watercourses. SO_2 in ambient air is also associated with asthma and chronic bronchitis. The principal source of this gas is power stations and industries burning fossil fuels, which contain sulphur.



Nitrogen Dioxide

Nitrogen oxides are formed during high temperature combustion processes from the oxidation of nitrogen in the air or fuel. The principal source of nitrogen oxides - nitric oxide (NO) and nitrogen dioxide (NO_2), collectively known as NO_x - is road traffic. NO and NO_2 concentrations are greatest in urban areas where traffic is heaviest. Other important sources are power stations and industrial processes.

Nitrogen oxides are released into the atmosphere mainly in the form of NO, which is then readily oxidised to NO_2 by reaction with ozone. Elevated levels of NO_x occur in urban environments under stable meteorological conditions, when the air mass is unable to disperse.

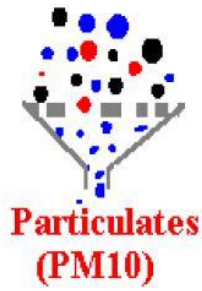
Nitrogen dioxide has a variety of environmental and health impacts. It irritates the respiratory system and may worsen asthma and increase susceptibility to infections. In the presence of sunlight, it reacts with hydrocarbons to produce photochemical pollutants such as ozone.

Nitrogen oxides combine with water vapour to form nitric acid. This nitric acid is in turn removed from the atmosphere by direct deposition to the ground, or transfer to aqueous droplets (e.g. cloud or rainwater), thereby contributing to acid deposition.

Acidification from SO_2 and NOx

Acidification of water bodies and soils, and the consequent impact on agriculture, forestry and fisheries are the result of the re-deposition of acidifying compounds resulting principally from the oxidation of primary SO_2 and NO_2 emissions from fossil fuel combustion. Deposition may be by either wet or dry processes, and acid deposition studies often need to examine both of these acidification routes.

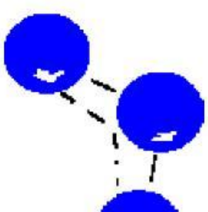
Airborne **particulate matter** varies widely in its physical and chemical composition, source and particle size. PM_{10} particles (the fraction of particulates in air of very small size (<10 μm)) are of major current concern, as they are small enough to penetrate deep into the lungs and so potentially pose significant health risks. In addition, they may carry surface-absorbed carcinogenic compounds into the lungs. Larger particles, meanwhile, are not readily inhaled, and are removed relatively efficiently from the air by settling.



A major source of fine primary particles are combustion processes, in particular diesel combustion, where transport of hot exhaust vapour into a cooler exhaust pipe can lead to spontaneous nucleation of "carbon" particles before emission. Secondary particles are typically formed when low volatility products are generated in the atmosphere, for example the oxidation of sulphur dioxide to sulphuric acid. The atmospheric lifetime of particulate matter is strongly related to particle size, but may be as long as 10 days for particles of about 1mm in diameter.

Concern about the potential health impacts of PM_{10} has increased very rapidly over recent years. Increasingly, attention has been turning towards monitoring of the smaller particle fraction $PM_{2.5}$ capable of penetrating deepest into the lungs, or to even smaller size fractions or total particle numbers.

Carbon monoxide (CO) is a toxic gas, which is emitted into the atmosphere as a result of combustion processes, and from oxidation of hydrocarbons and other organic compounds. In urban areas, CO is produced almost entirely (90%) from road traffic emissions. CO at levels found in ambient air may reduce the oxygen-carrying capacity of the blood. It survives in the atmosphere for a period of approximately 1 month and finally gets oxidised to carbon dioxide (CO_2).



Ground-level ozone (O_3), unlike other primary pollutants mentioned above, is not emitted directly into the atmosphere, but is a secondary pollutant produced by reaction between nitrogen dioxide (NO_2), hydrocarbons and sunlight. Ozone can irritate the eyes and air passages causing breathing difficulties and may increase susceptibility to infection. It is a highly reactive chemical, capable of attacking surfaces, fabrics and rubber materials. Ozone is also toxic to some crops, vegetation and trees.

Whereas nitrogen dioxide (NO_2) participates in the formation of ozone, nitrogen oxide (NO) destroys ozone to form oxygen (O_2) and nitrogen dioxide (NO_2). For this reason, ozone levels are not as high in urban areas (where high levels of NO are emitted from vehicles) as in rural areas. As the nitrogen oxides and hydrocarbons are transported out of urban areas, the ozone-destroying NO is oxidised to NO_2, which participates in ozone formation.

Hydrocarbons

There are two main groups of hydrocarbons of concern: volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs). VOCs are released in vehicle exhaust gases either as unburned fuels or as combustion products, and are also emitted by the evaporation of solvents and motor fuels. Benzene and 1,3-butadiene are of particular concern, as they are known carcinogens. Other VOCs are important because of the role they play in the photochemical formation of ozone in the atmosphere.

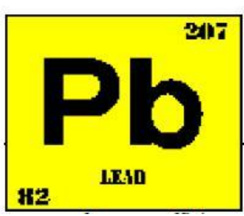
Benzene is an aromatic VOC, which is a minor constituent of petrol (about 2% by volume). The main sources of benzene in the atmosphere are the distribution and combustion of petrol. Of these, combustion by petrol vehicles is the single biggest source (70% of total emissions) whilst the refining, distribution and evaporation of petrol from vehicles accounts for approximately a further 10% of total emissions. Benzene is emitted in vehicle exhaust not only as unburnt fuel but also as a product of the decomposition of other aromatic compounds. Benzene is a known human carcinogen.

1,3-butadiene, like benzene, is a VOC emitted into the atmosphere principally from fuel combustion of petrol and diesel vehicles. Unlike benzene, however, it is not a constituent of the fuel but is produced by the combustion of olefins. 1,3-butadiene is also an important chemical in certain industrial processes, particularly the manufacture of synthetic rubber. It is handled in bulk at a small number of industrial locations. Other than in the vicinity of such locations, the dominant source of 1,3-butadiene in the atmosphere are the motor vehicles. 1,3 Butadiene is also a known, potent, human carcinogen.

TOMPs (Toxic Organic Micropollutants) are produced by the incomplete combustion of fuels. They comprise a complex range of chemicals some of which, although they are emitted in very small quantities, are highly toxic or and carcinogenic. Compounds in this category include:

- PAHs (PolyAromatic Hydrocarbons)
- PCBs (PolyChlorinated Biphenyls)
- Dioxins
- Furans

Heavy Metals and Lead



Particulate metals in air result from activities such as fossil fuel combustion (including vehicles), metal processing industries and waste incineration. There are currently no emission standards for metals other than lead. Lead is a cumulative poison to the central nervous system, particularly detrimental to the mental development of children.

Lead is the most widely used non-ferrous metal and has a large number of industrial applications. Its single largest industrial use worldwide is in the manufacture of batteries and it is also used in paints, glazes, alloys, radiation shielding, tank lining and piping.

As tetraethyl lead, it has been used for many years as an additive in petrol; with the increasing use of unleaded petrol, however, emissions and concentrations in air have reduced steadily in recent years.

Climatic change

Human activities, particularly the combustion of fossil fuels, have made the blanket of greenhouse gases (water vapour, carbon dioxide, methane, ozone etc.) around the earth thicker. The resulting increase in global temperature is altering the complex web of systems that allow life to thrive on earth such as rainfall, wind patterns, ocean currents and distribution of plant and animal species.

Greenhouse Effect and the Carbon Cycle

Life on earth is made possible by energy from the sun, which arrives mainly in the form of visible light. About 30 percent of the sunlight is scattered back into space by outer atmosphere and the balance 70 percent reaches the earth's surface, which reflects it in form of infrared radiation. The escape of slow moving infrared radiation is delayed by the green house gases. A thicker blanket of greenhouse gases traps more infrared radiation and increase the earth's temperature (Refer Figure 1.11).

Greenhouse gases makeup only 1 percent of the atmosphere, but they act as a blanket around the earth, or like a glass roof of a greenhouse and keep the earth 30 degrees warmer than it would be otherwise - without greenhouse gases, earth would be too cold to live. Human activities that are responsible for making the greenhouse layer thicker are emissions of carbon dioxide from the combustion of coal, oil and natural gas; by additional methane and nitrous oxide from farming activities and changes in land use; and by several man made gases that have a long life in the atmosphere.

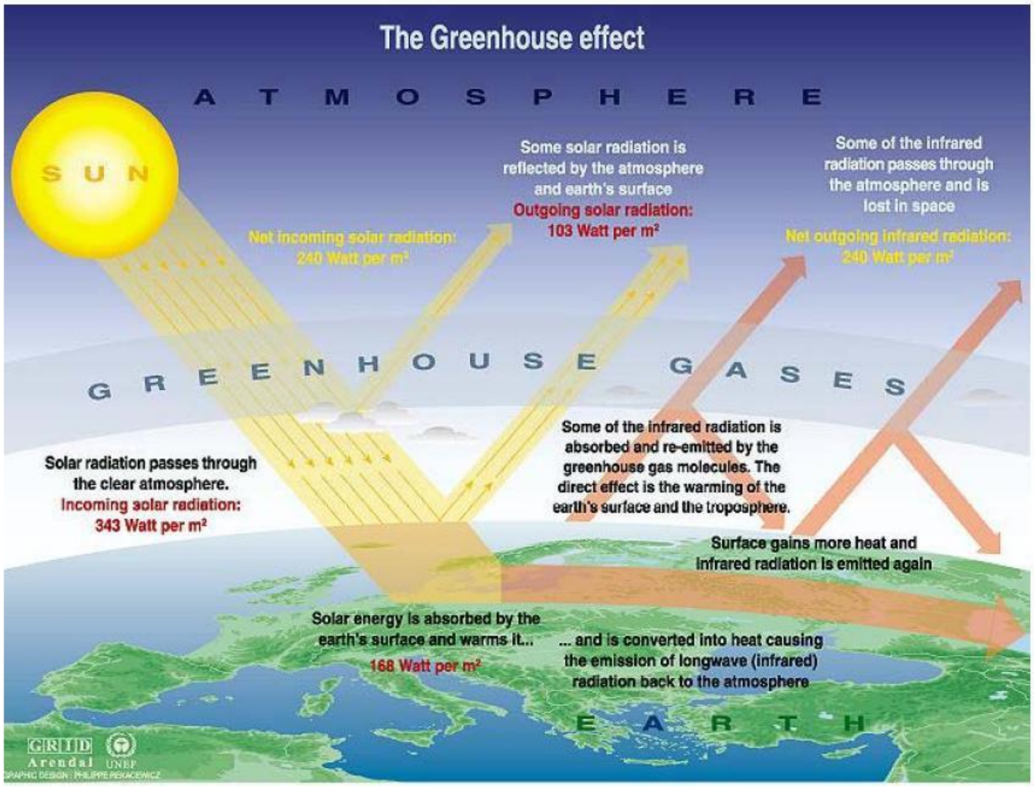


Figure 1.11 The Greenhouse Effect

The increase in greenhouse gases is happening at an alarming rate. If greenhouse gases emissions continue to grow at current rates, it is almost certain that the atmospheric levels of carbon dioxide will increase twice or thrice from pre-industrial levels during the 21^{st} century.

Even a small increase in earth's temperature will be accompanied by changes in climate- such as cloud cover, precipitation, wind patterns and duration of seasons. In an already highly crowded and stressed earth, millions of people depend on weather patterns, such as monsoon rains, to continue as they have in the past. Even minimum changes will be disruptive and difficult.

Carbon dioxide is responsible for 60 percent of the "enhanced greenhouse effect". Humans are burning coal, oil and natural gas at a rate that is much faster than the rate at which these fossil fuels were created. This is releasing the carbon stored in the fuels into the atmosphere and upsetting the carbon cycle (a precise balanced system by which carbon is exchanged between the air, the oceans and land vegetation taking place over millions of years). Currently, carbon dioxide levels in the atmospheric are rising by over 10 percent every 20 years.

Current Evidence of Climatic Change

Cyclones, storm, hurricanes are occurring more frequently and floods and draughts are more intense than before. This increase in extreme weather events cannot be explained away as random events.

This trend toward more powerful storms and hotter, longer dry periods is predicted by computer models. Warmer temperatures mean greater evaporation, and a warmer atmosphere is able to hold more moisture and hence there is more water aloft that can fall as precipitation. Similarly, dry regions are prone to lose still more moisture if the weather is hotter and hence this leads to more severe droughts and desertification.

Future Effects

Even the minimum predicted shifts in climate for the 21st century are likely to be significant and disruptive. Predictions of future climatic changes are wide-ranging. The global temperature may climb from 1.4 to 5.8 degrees C; the sea level may rise from 9 to 88 cm. Thus, increases in sea level this century are expected to range from significant to catastrophic. This uncertainty reflects the complexity, interrelatedness, and sensitivity of the natural systems that make up the climate.

Severe Storms and Flooding

The minimum warming forecast for the next 100 years is more than twice the 0.6 degree C increase that has occurred since 1900 and that earlier increase is already having marked consequences. Extreme weather events, as predicted by computer models, are striking more often and can be expected to intensify and become still more frequent. A future of more severe storms and floods along the world's increasingly crowded coastlines is likely.

Food shortages

Although regional and local effects may differ widely, a general reduction is expected in potential crop yields in most tropical and sub-tropical regions. Mid-continental areas such as the United States' "grain belt" and vast areas of Asia are likely to become dry. Sub-Saharan Africa where dryland agriculture relies solely on rain, the yields would decrease dramatically even with minimum increase in temperature. Such changes could cause disruptions in food supply in a world is already afflicted with food shortages and famines.

Dwindling Freshwater supply

Salt-water intrusion from rising sea levels will reduce the quality and quantity of freshwater supplies. 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.

Loss of biodiversity

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.

Increased diseases

Higher temperatures are expected to expand the range of some dangerous "vector-borne" diseases, such as malaria, which already kills 1 million people annually, most of them children.

A world under stress

Ongoing environmentally damaging activities such as overgrazing, deforestation, and denuded agricultural soils means that nature will be more vulnerable than previously to changes in climate.

Similarly, the world's vast human population, much of it poor, is vulnerable to climate stress. Millions live in dangerous places such as floodplains or in slums around the big cities of the developing world. Often there is nowhere else for population to move. In the distant past, man and his ancestors migrated in response to changes in habitat. There will be much less room for migration in future.

Global warming almost certainly will be unfair. The industrialized countries of North America and Western Europe, and other countries such as Japan, are responsible for the vast amount of past and current greenhouse-gas emissions. These emissions are incurred for the high standards of living enjoyed by the people in those countries.

Yet those to suffer most from climate change will be in the developing world. They have fewer resources for coping with storms, with floods, with droughts, with disease outbreaks, and with disruptions to food and water supplies. They are eager for economic development themselves, but may find that this already difficult process has become more difficult because of climate change. The poorer nations of the world have done almost nothing to cause global warming yet is most exposed to its effects.

Acid Rain

Acid rain is caused by release of SO_X and NO_X from combustion of fossil fuels, which then mix with water vapour in atmosphere to form sulphuric and nitric acids respectively (Refer Figure 1.12). 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)

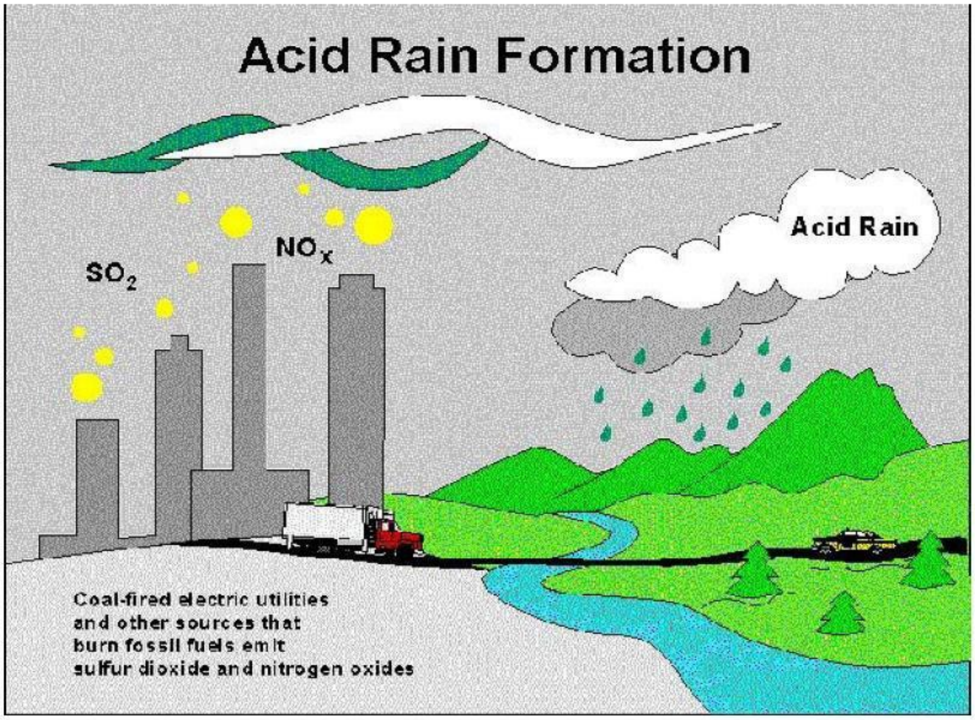


Figure 1.12 Acid Rain Formation

1.12 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.

India will continue to experience an energy supply shortfall throughout the forecast period. This gap has widened since 1985, when the country became a net importer of coal. India has been unable to raise its oil production substantially in the 1990s. Rising oil demand of close to 10 percent per year has led to sizable oil import bills. In addition, the government subsidises refined oil product prices, thus compounding the overall monetary loss to the government.

Imports of oil and coal have been increasing at rates of 7% and 16% per annum respectively during the period 1991–99. The dependence on energy imports is projected to increase in the future. Estimates indicate that oil imports will meet 75% of total oil consumption requirements and coal imports will meet 22% of total coal consumption requirements in 2006. The imports of gas and LNG (liquefied natural gas) are likely to increase in the coming years. This energy import dependence implies vulnerability to external price shocks and supply fluctuations, which threaten the energy security of the country.

Increasing dependence on oil imports means reliance on imports from the Middle East, a region susceptible to disturbances and consequent disruptions of oil supplies. 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.

Some of the strategies that can be used to meet future challenges to their energy security are

- Building stockpiles
- Diversification of energy supply sources
- Increased capacity of fuel switching
- Demand restraint,
- Development of renewable energy sources.
- Energy efficiency
- Sustainable development

Although all these options are feasible, their implementation will take time. Also, for countries like India, reliance on stockpiles would tend to be slow because of resource constraints. Besides, the market is not sophisticated enough or the monitoring agencies experienced enough to predict the supply situation in time to take necessary action. Insufficient storage capacity is another cause for worry and needs to be augmented, if India has to increase its energy stockpile.

However, out of all these options, the simplest and the most easily attainable is reducing demand through persistent energy conservation efforts.

1.13 Energy Conservation and its Importance

Coal and other fossil fuels, which have taken three million 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 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 1.13).

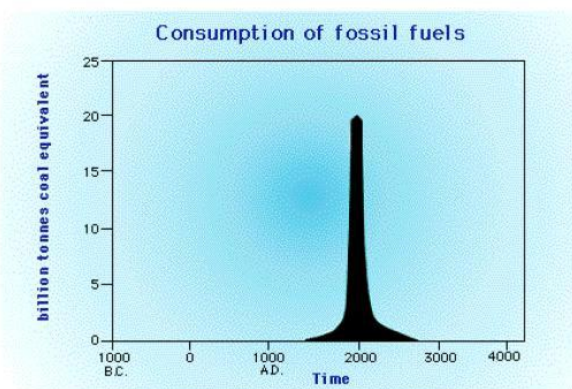


Figure 1.13

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, measured in physical terms. Energy Conservation can, therefore, be 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.

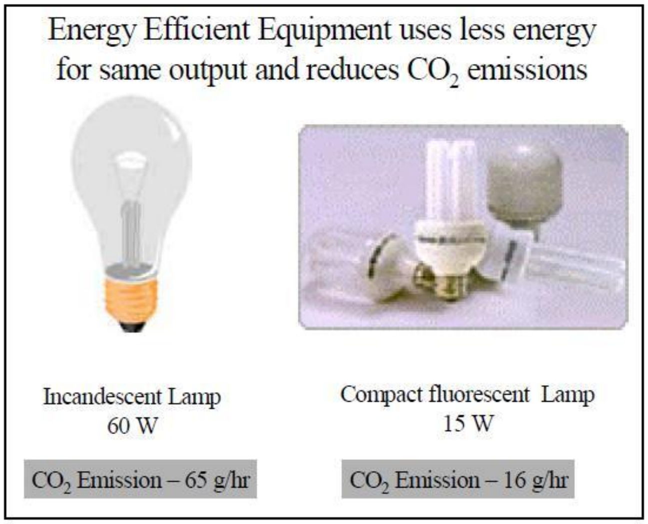


Figure 1.14

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 traditional light bulbs with Compact Fluorescent Lamps (CFLs) means you will use only 1/4th of the energy to light a room. Pollution levels also reduce by the same amount (refer Figure 1.14).

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.

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 control of future CO_2 emissions through even more energy efficiency improvements than have occurred in the past. The industrial sector accounts for some 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 1.15.

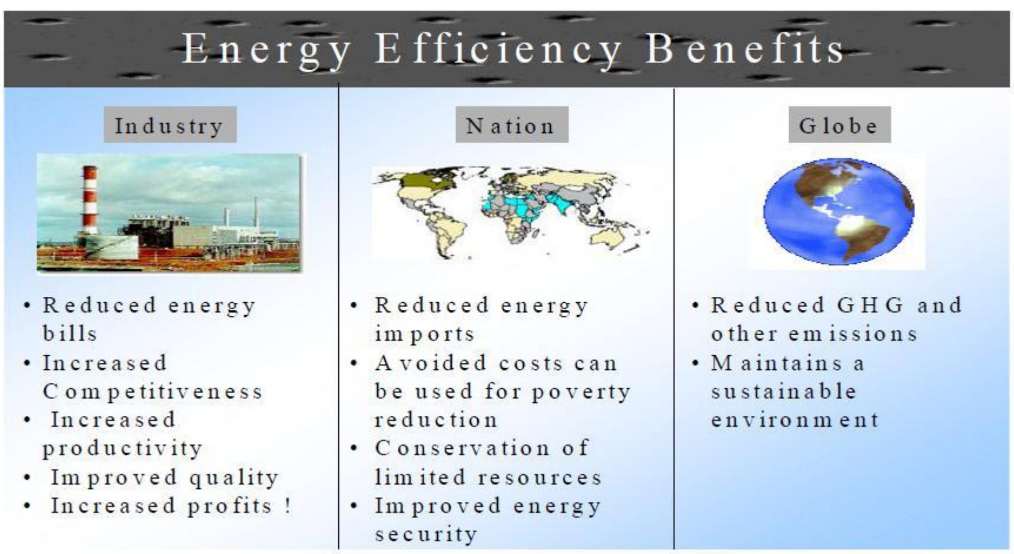


Figure 1.15

1.14 Energy Strategy for the Future

The energy strategy for the future could be classified into immediate, medium-term and long-term strategy. The various components of these strategies are listed below:

Immediate-term strategy:

- Rationalizing the tariff structure of various energy products.
- Optimum utilization of existing assets
- Efficiency in production systems and reduction in distribution losses, including those in traditional energy sources.
- Promoting R&D, transfer and use of technologies and practices for environmentally sound energy systems, including new and renewable energy sources.

Medium-term strategy:

- Demand management through greater conservation of energy, optimum fuel mix, structural changes in the economy, an appropriate model mix in the transport sector, i.e. greater dependence on rail than on road for the movement of goods and passengers and a shift away from private modes to public modes for passenger transport; changes in design of different products to reduce the material intensity of those products, recycling, etc.
- There is need to shift to less energy-intensive modes of transport. This would include measures to improve the transport infrastructure viz. roads, better design of vehicles, use of compressed natural gas (CNG) and synthetic fuel, etc. Similarly, better urban planning would also reduce the demand for energy use in the transport sector.
- There is need to move away from non-renewable to renewable energy sources viz. solar, wind, biomass energy, etc.

Long-term strategy:

- Efficient generation of energy resources
  - Efficient production of coal, oil and natural gas
  - Reduction of natural gas flaring
- Improving energy infrastructure
  - Building new refineries
  - Creation of urban gas transmission and distribution network
  - Maximizing efficiency of rail transport of coal production.
  - Building new coal and gas fired power stations.
- Enhancing energy efficiency
  - Improving energy efficiency in accordance with national, socio-economic, and environmental priorities
  - Promoting of energy efficiency and emission standards
  - Labeling programmes for products and adoption of energy efficient technologies in large industries

- Deregulation and privatization of energy sector
  - Reducing cross subsidies on oil products and electricity tariffs
  - Decontrolling coal prices and making natural gas prices competitive
  - Privatization of oil, coal and power sectors for improved efficiency.
- Investment legislation to attract foreign investments.
  - Streamlining approval process for attracting private sector participation in power generation, transmission and distribution .

1.15 The Energy Conservation Act, 2001 and its Features

Policy Framework – Energy Conservation Act – 2001

With the background of high energy saving potential and its benefits, bridging the gap between demand and supply, reducing environmental emissions through energy saving, and to effectively overcome the barrier, the Government of India has enacted the Energy Conservation Act – 2001. The Act provides the much-needed legal framework and institutional arrangement for embarking on an energy efficiency drive.

Under the provisions of the Act, Bureau of Energy Efficiency has been established with effect from 1st March 2002 by merging erstwhile Energy Management Centre of Ministry of Power. The Bureau would be responsible for implementation of policy programmes and coordination of implementation of energy conservation activities.

Important features of the Energy Conservation Act are:

Standards and Labeling

Standards and Labeling (S & L) has been identified as a key activity for energy efficiency improvement. The S & L program, when in place would ensure that only energy efficient equipment and appliance would be made available to the consumers.

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

- Evolve minimum energy consumption and performance standards for notified equipment and appliances.
- Prohibit manufacture, sale and import of such equipment, which does not conform to the standards.
- Introduce a mandatory labeling scheme for notified equipment appliances to enable consumers to make informed choices
- Disseminate information on the benefits to consumers

Designated Consumers

The main provisions of the EC Act on designated consumers are:

- The government would notify energy intensive industries and other establishments as designated consumers;

- Schedule to the Act provides list of designated consumers which covered basically energy intensive industries, Railways, Port Trust, Transport Sector, Power Stations, Transmission & Distribution Companies and Commercial buildings or establishments;
- The designated consumer to get an energy audit conducted by an accredited energy auditor;
- Energy managers with prescribed qualification are required to be appointed or designated by the designated consumers;
- Designated consumers would comply with norms and standards of energy consumption as prescribed by the central government.

Certification of Energy Managers and Accreditation of Energy Auditing Firms

The main activities in this regard as envisaged in the Act are:

A cadre of professionally qualified energy managers and auditors with expertise in policy analysis, project management, financing and implementation of energy efficiency projects would be developed through Certification and Accreditation programme. BEE to design training modules, and conduct a National level examination for certification of energy managers and energy auditors.

Energy Conservation Building Codes:

The main provisions of the EC Act on Energy Conservation Building Codes are:

- The BEE would prepare guidelines for Energy Conservation Building Codes (ECBC);
- These would be notified to suit local climate conditions or other compelling factors by the respective states for commercial buildings erected after the rules relating to energy conservation building codes have been notified. In addition, these buildings should have a connected load of 500 kW or contract demand of 600 kVA and above and are intended to be used for commercial purposes;
- Energy audit of specific designated commercial building consumers would also be prescribed.

Central Energy Conservation Fund:

The EC Act provisions in this case are:

- The fund would be set up at the centre to develop the delivery mechanism for large-scale adoption of energy efficiency services such as performance contracting and promotion of energy service companies. The fund is expected to give a thrust to R & D and demonstration in order to boost market penetration of efficient equipment and appliances. It would support the creation of facilities for testing and development and to promote consumer awareness.

Bureau of Energy Efficiency (BEE):

- The mission of Bureau of Energy Efficiency is to institutionalize energy efficiency services, enable delivery mechanisms in the country and provide leadership to energy efficiency in all sectors of economy. The primary objective would be to reduce energy intensity in the Indian Economy.

- The general superintendence, directions and management of the affairs of the Bureau is vested in the Governing Council with 26 members. The Council is headed by Union Minister of Power and consists of members represented by Secretaries of various line Ministries, the CEOs of technical agencies under the Ministries, members representing equipment and appliance manufacturers, industry, architects, consumers and five power regions representing the states. The Director General of the Bureau shall be the ex-officio member-secretary of the Council.
- The BEE will be initially supported by the Central Government by way of grants through budget, it will, however, in a period of 5-7 years become self-sufficient. It would be authorized to collect appropriate fee in discharge of its functions assigned to it. The BEE will also use the Central Energy Conservation Fund and other funds raised from various sources for innovative financing of energy efficiency projects in order to promote energy efficient investment.

Role of Bureau of Energy Efficiency

- The role of BEE would be to prepare standards and labels of appliances and equipment, develop a list of designated consumers, specify certification and accreditation procedure, prepare building codes, maintain Central EC fund and undertake promotional activities in co-ordination with center and state level agencies. The role would include development of Energy service companies (ESCOs), transforming the market for energy efficiency and create awareness through measures including clearing house.

Role of Central and State Governments:

The following role of Central and State Government is envisaged in the Act

- **Central** - to notify rules and regulations under various provisions of the Act, provide initial financial assistance to BEE and EC fund, Coordinate with various State Governments for notification, enforcement, penalties and adjudication.
- **State** - to amend energy conservation building codes to suit the regional and local climatic condition, to designate state level agency to coordinate, regulate and enforce provisions of the Act and constitute a State Energy Conservation Fund for promotion of energy efficiency.

Enforcement through Self-Regulation:

E.C. Act would require inspection of only two items. The following procedure of self-regulation is proposed to be adopted for verifying areas that require inspection of only two items that require inspection.

- The certification of energy consumption norms and standards of production process by the Accredited Energy Auditors is a way to enforce effective energy efficiency in Designated Consumers.
- For energy performance and standards, manufacturer's declared values would be checked in Accredited Laboratories by drawing sample from market. Any manufacturer or consumer or consumer association can challenge the values of the other manufacturer and bring to the notice of BEE. BEE can recognize for challenge testing in disputed cases as a measure for self-regulation.

Penalties and Adjudication:

- Penalty for each offence under the Act would be in monetary terms i.e. Rs.10,000 for each offence and Rs.1,000 for each day for continued non Compliance.

- The initial phase of 5 years would be promotional and creating infrastructure for implementation of Act. No penalties would be effective during this phase.
- The power to adjudicate has been vested with state Electricity Regulatory Commission which shall appoint any one of its member to be an adjudicating officer for holding an enquiry in connection with the penalty imposed.

Features Extracted from The Energy Conservation Act, 2001.

CHAPTER -I

Definitions

In this Act, unless the context otherwise requires: —

(a) "accredited energy auditor" means an auditor possessing qualifications specified under clause (p) of sub-section (2) of section 13;

(b) " Appellate Tribunal" means Appellate Tribunal for Energy Conservation established under section 30;

(c) "building" means any structure or erection or part of a structure or erection, after the rules relating to energy conservation building codes have been notified under clause (a) of section 15 of clause (l) of sub-section (2) of section 56, which is having a connected load of 500kW or contract demand of 600 kVA and above and is intended to be used for commercial purposes;

(d) "Bureau" means the Bureau of Energy Efficiency established under subsection (l) of section 3;

(e) "Chairperson" means the Chairperson of the Governing council;

(f) "designated agency" means any agency designated under clause (d) of section 15;

(g) "designated consumer" means any consumer specified under clause (e) of section 14;

(h) "energy" means any form of energy derived from fossil fuels, nuclear substances or materials, hydro-electricity and includes electrical energy or electricity generated from renewable sources of energy or bio-mass connected to the grid;

(i) "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;

(j) "energy conservation building codes" means the norms and standards of energy consumption expressed in terms of per square meter of the area wherein energy is used and includes the location of the building;

(k) "energy consumption standards" means the norms for process and energy consumption standards specified under clause (a) of section 14;

(l) "Energy Management Centre" means the Energy Management Centre set up under the Resolution of the Government of India in the erstwhile Ministry of Energy, Department of Power No. 7(2)/87-EP (Vol. IV), dated the 5th July, 1989 and registered under the Societies Registration Act, 1860; (21 of 1860)

(m) "energy manager" means any individual possessing the qualifications prescribed under clause (m) of section 14;

(n) " Governing Council" means the Governing Council referred to in section 4;

(o) "member" means the member of the Governing Council and includes the Chairperson;

(p) "notification" means a notification in the Gazette of India or, as the case may be, the Official Gazette of a State;

(q) "prescribed" means prescribed by rules made under this Act;

(r) "regulations" means regulations made by the Bureau under this Act;

(s) "schedule" means the Schedule of this Act;

(t) "State Commission" means the State Electricity Regulatory Commission established under sub-section (l) of section 17 of the Electricity Regulatory Commissions Act, 1998; (14 of 1998)

(u) words and expression used and not defined in this Act but defined in the Indian Electricity Act, 1910 or the Electricity (Supply) Act, 1948 or the Electricity Regulatory Commissions Act, 1998 shall have meanings respectively assigned to them in those Acts. (9 of 1940, 54 of 1948,14 of 1998)

CHAPTER IV, SECTION 13
Powers and Functions of Bureau

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

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

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

(b) recommend to the Central Government the particulars required to be displayed on label on equipment or on appliances and manner of their display under clause *(d)* of section 14;

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

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

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

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

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

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

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

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

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

(l) promote innovative financing of energy efficiency projects;

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

(n) levy fee, as may be determined by regulations, for services provided for promoting efficient use of energy and its conservation;

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

(p) specify, by regulations, qualifications for the accredited energy auditors;

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

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

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

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

(u) perform such other functions as may be prescribed.

CHAPTER V, SECTION 14

Power of Central Government to Facilitate and Enforce Efficient use of Energy and its Conservation

The Central Government may, by notification, in consultation with the Bureau, —

(a) specify the norms for processes and energy consumption standards for any equipment, appliances which consumes, generates, transmits or supplies energy;

(b) specify equipment or appliance or class of equipments or appliances, as the case may be, for the purposes of this Act;

(c) prohibit manufacture or sale or purchase or import of equipment or appliance specified under clause (b) unless such equipment or appliances conforms to energy consumption standards;

Provided that no notification prohibiting manufacture or sale or purchase or import or equipment or appliance shall be issued within two years from the date of notification issued under clause (a) of this section;

(d) direct display of such particulars on label on equipment or on appliance specified under clause (b) and in such manner as may be specified by regulations;

(e) specify, having regarding to the intensity or quantity of energy consumed and the amount of investment required for switching over to energy efficient equipments and capacity or industry to invest in it and availability of the energy efficient machinery and equipment required by the industry, any user or class of users of energy as a designated consumer for the purposes of this Act;

(f) alter the list of Energy Intensive Industries specified in the Schedule;

(g) establish and prescribe such energy consumption norms and standards for designated consumers as it may consider necessary:
Provided that the Central Government may prescribe different norms and standards for different designated consumers having regard to such factors as may be prescribed;

(h) direct, having regard to quantity of energy consumed or the norms and standards of energy consumption specified under clause (a) the energy intensive industries specified in the Schedule to get energy audit conducted by an accredited energy auditor in such manner and intervals of time as may be specified by regulations;

(i) direct, if considered necessary for efficient use of energy and its conservation, any designated consumer to get energy audit conducted by an accredited energy auditor;

(j) specify the matters to be included for the purposes of inspection under sub-section (2) of section 17;

(k) direct any designated consumer to furnish to the designated agency, in such form and manner and within such period, as may be prescribed, the information with regard to the energy consumed and action taken on the recommendation of the accredited energy auditor;

(l) direct any designated consumer to designate or appoint energy manger in charge of activities for efficient use of energy and its conservation and submit a report, in the form and manner as may be prescribed, on the status of energy consumption at the end of the every financial year to designated agency;

(m) prescribe minimum qualification for energy managers to be designated or appointed under clause *(l);*

(n) direct every designated consumer to comply with energy consumption norms and standards;

(o) direct any designated consumer, who does not fulfil the energy consumption norms and standards prescribed under clause (g), to prepare a scheme for efficient use of energy and its conservation and implement such scheme keeping in view of the economic viability of the investment in such form and manner as may be prescribed;

(p) prescribe energy conservation building codes for efficient use of energy and its conservation in the building or building complex;

(q) amend the energy conservation building codes to suit the regional and local climatic conditions;

(r) direct every owner or occupier of the building or building complex, being a designated consumer to comply with the provisions of energy conservation building codes for efficient use of energy and its conservation;

(s) direct, any designated consumer referred to in clause *(r)*, if considered necessary, for efficient use of energy and its conservation in his building to get energy audit conducted in respect of such building by an accredited energy auditor in such manner and intervals of time as may be specified by regulations;

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

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

(v) take steps to encourage preferential treatment for use of energy efficient equipment or appliances:

Provided that the powers under clauses (p) and (s) shall be exercised in consultation with the concerned State.

CHAPTER VI, SECTION 15

Power Of State Government To Facilitate And Enforce Efficient Use Of Energy And Its Conservation

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

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

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

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

(d) designate any agency as designated agency to coordinate, regulate and enforce provisions of this Act within the State;

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

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

(g) take steps to encourage preferential treatment for use of energy efficient equipment or appliances;

(h) direct, any designated consumer to furnish to the designated agency, in such form and manner and within such period as may be specified by rules made by it, information with regard to the energy consumed by such consumer;

(i) specify the matters to be included for the purposes of inspection under sub-section (2) of section 17;

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

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

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

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

(1) The designated agency may appoint, after the expiry of five years from the date of commencement of this Act, as many inspecting officers as may be necessary for the purpose of ensuring compliance with energy consumption standard specified under clause (a) of section 14 or ensure display of particulars on label on equipment or appliances specified under clause (b) of section 14 or for the purpose of performing such other functions as may be assigned to them.

(2) Subject to any rules made under this Act, an inspecting officer shall have power to -

(a) inspect any operation carried on or in connection with the equipment or appliance specified under clause (b) of section 14 or in respect of which energy standards under clause (a) of section 14 have been specified;

(b) enter any place of designated consumer at which the energy is used for any activity and may require any proprietor, employee, director, manager or secretary or any other person who may be attending in any manner to or helping in, carrying on any activity with the help of energy -

(i) to afford him necessary facility to inspect -

(A) any equipment or appliance as he may require and which may be available at such place;

(B) any production process to ascertain the energy consumption norms and standards;

(ii) to make an inventory of stock of any equipment or appliance checked or verified by him;

(iii) to record the statement of any person which may be useful for, or relevant to, for efficient use of energy and its conservation under this Act.

(3) An inspecting officer may enter any place of designated consumer -

(a) where any activity with the help of energy is carried on; and

(b) where any equipment or appliance notified under clause (b) of section 14 has been kept, during the hours at which such places is open for production or conduct of business connected therewith.

(4) An inspecting officer acting under this section shall, on no account, remove or cause to be removed from the place wherein he has entered, any equipment or appliance or books of accounts or other documents.

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

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

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

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

CHAPTER VIII, SECTION 26
Penalties and Adjudication

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

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

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

(1) For the purpose of adjudging section 26, the State Commission shall appoint any of its members to be an adjudicating officer for holding an inquiry in such manner as may be prescribed by the Central Government, after giving any person concerned a reasonable opportunity of being heard for the purpose of imposing any penalty.

(2) While holding an inquiry the adjudicating officer shall have power to summon and enforce the attendance of any person acquainted with the facts and circumstances of the case of give evidence or produce any document which in the opinion of the adjudicating officer, may be useful for or relevant to the subject-matter of the inquiry, and if, on such inquiry, he is satisfied that the person has failed to comply with the provisions of any of the clauses of the sections specified in section 26, he may impose such penalty as he thinks fit in accordance with the provisions of any of those clauses of that section:

Provided that where a State Commission has not been established in a State, the Government of that State shall appoint any of its officer not below the rank equivalent to a Secretary dealing with legal affairs in that State to be an adjudicating officer for the purposes of this section and such officer shall cease to be an adjudicating officer immediately on the appointment of an adjudicating officer by the State Commission on its establishment in that State:

Provided further that where an adjudicating officer appointed by a State Government ceased to be an adjudicating officer, he shall transfer to the adjudicating officer appointed by the State Commission all matters being adjudicated by him and thereafter the adjudicating officer appointed by the State Commission shall adjudicate the penalties on such matters.

While adjudicating the quantum of penalty under section 26, the adjudicating officer shall have due regard to the following factors, namely:-

(a) the amount of disproportionate gain or unfair advantage, wherever quantifiable, made as a result of the default;

(b) the repetitive nature of the default.

No civil court shall have jurisdiction to entertain any suit or proceeding in respect of any matter which an adjudicating officer appointed under this Act or the Appellate Tribunal is empowered by or under this Act to determine and no injunction shall be granted by any court or other authority in respect of any action taken or to be taken in pursuance of any power conferred by or under this Act.

CHAPTER IX, SECTION 30

Appellate Tribunal for Energy Conservation

The Central Government shall, by notification, establish an Appellate Tribunal to be known as the Appellate Tribunal for Energy Conservation to hear appeals against the orders of the adjudicating officer or the Central Government or the State Government or any other authority under this Act

CHAPTER X,
Miscellaneous

SECTION 61

The provisions of this Act shall not apply to the Ministry or Department of the Central Government dealing with Defence, Atomic Energy or such other similar Ministries or Departments undertakings or Boards or institutions under the control of such Ministries or Departments as may be notified by the Central Government.

THE SCHEDULE

[See section 2 (s)]

List of Energy Intensive Industries and other establishments specified as designated consumers

1. Aluminium;
2. Fertilizers;
3. Iron and Steel;
4. Cement;
5. Pulp and paper;
6. Chlor Akali;
7. Sugar;
8. Textile;
9. Chemicals;
10. Railways;
11. Port Trust;
12. Transport Sector (industries and services);
13. Petrochemicals, Gas Crackers, Naphtha Crackers and Petroleum Refineries;
14. Thermal Power Stations, hydel power stations, electricity transmission companies and distribution companies;
15. Commercial buildings or establishments;

Full version of this act may be obtained from www.bee-india.nic.in

QUESTIONS	
1.	Define the following terms with three examples for each – a) Primary and Secondary Energy. b) Commercial and Non-commercial Energy. c) Renewable and Non-renewable Energy
2.	In terms of coal reserve India's position in the world is (a) 10^{th} (b) 17^{th} (c) 4^{th} (d) 26^{th}
3.	The world oil reserves is expected to last another (a) 300 years (b) 45 years (c) 600 years (d) forever
4.	Of the total primary energy consumption in India coal accounts for (a) 35% (b) 46% (c) 55% (d) 75%
5.	List atleast five States where coal deposits are concentrated in India.
6.	How much % of our Country's oil consumption is imported and how much does it cost (approximately) per year?
7.	Name any three places of oil reserves located in India.
8.	What is the hydro power generation potential available in India, and how much is exploited so far?
9.	What are the % shares of commercial energy consumption in industrial and agricultural sectors?
10.	How is economic growth linked to energy consumption?
11.	What do you think of strategies required for long-term management of energy in India?
12.	Discuss the subsidies and cross subsidies in oil sector in India.
13.	Write in few words about the various reforms in the energy sector.
14.	Though Plant Respiration and Decomposition release more than ten times CO_2 released by human activities, explain why CO_2 is regarded as a potential threat to the planet.
15.	The contribution of CO_2 to the green house gases is (a) 23% (b) 95% (c) 54% (d) 0%
16.	What are the implications of Global warming?
17.	Describe the Greenhouse effect.
18.	The excess of which gas in the atmosphere is the main cause for greenhouse effect?
19.	Name three greenhouse gases. Which one of them produces the maximum greenhouse effect?
20.	What are the major pollutants in burning fossil fuels?

21.	Differentiate between energy conservation and energy efficiency.
22.	What are the benefits for industry through implementing energy efficiency programme?
23.	Why energy conservation is important in the prevailing energy scenario?
24.	The energy conservation act requires that all designated energy consumers should get energy audits conducted by (a) Energy manager (b) accredited energy auditor (c) managing director (d) chartered accountant
25.	Name five designated consumers under the energy conservation act.
26.	Name any three main provisions of the EC act, 2001 as applicable to the designated consumers.
27.	List the incorrect statement and correct the same. The Energy Conservation Act, 2001 requires that a) designated consumer to furnish to the designated agency, in such form and manner and within such period as may be prescribed the information with regard to the energy purchased and action taken on the recommendation of energy auditor. b) direct, if consider necessary, for efficient use of energy and its conservation, to get energy audit conducted by a certified energy auditor.

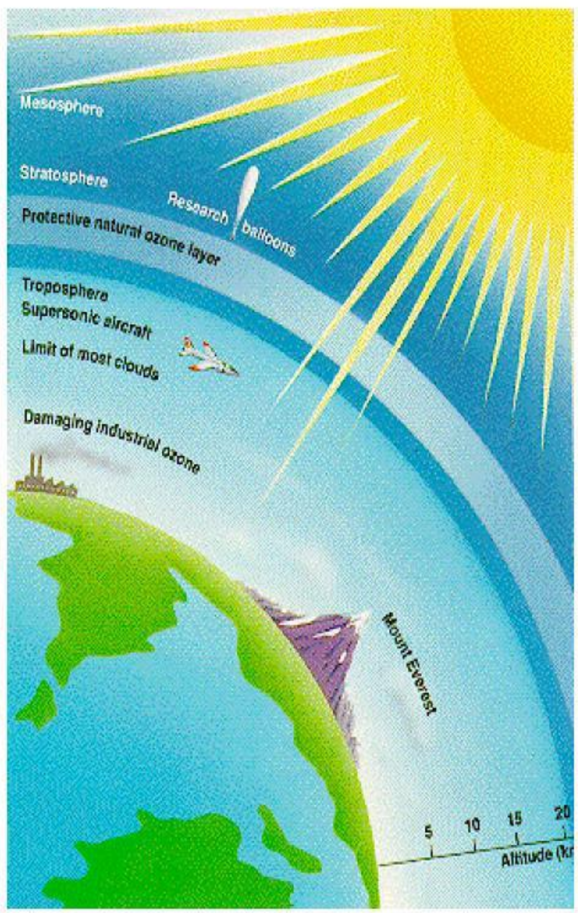
9.1 Global Environmental Issues

As early as 1896, the Swedish scientist Svante Arrhenius had predicted that human activities would interfere with the way the sun interacts with the earth, resulting in global warming and climate change. His prediction has become true and climate change is now disrupting global environmental stability. The last few decades have seen many treaties, conventions, and protocols for the cause of global environmental protection.

Few examples of environmental issues of global significance are:

- Ozone layer depletion
- Global warming
- Loss of biodiversity

One of the most important characteristics of this environmental degradation is that it affects all mankind on a global scale without regard to any particular country, region, or race. The whole world is a stakeholder and this raises issues on who should do what to combat environmental degradation.



9.2 Ozone Layer Depletion

Earth's atmosphere is divided into three regions, namely troposphere, stratosphere and mesosphere (see Figure 9.1). The stratosphere extends from 10 to 50 kms from the Earth's surface. This region is concentrated with slightly pungent smelling, light bluish ozone gas. The ozone gas is made up of molecules each containing three atoms of oxygen; its chemical formula is O_3. The ozone layer, in the stratosphere acts as an efficient filter for harmful solar Ultraviolet B (UV-B) rays

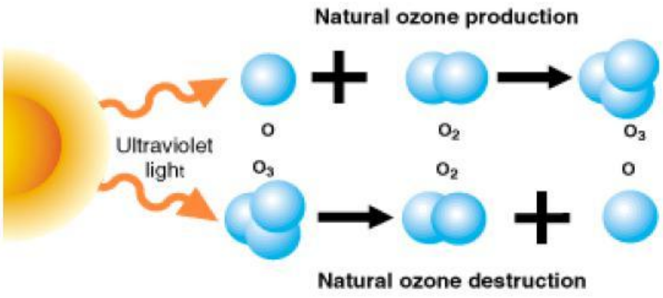


Figure 9.2 Ozone Production and Destruction Process

Ozone is produced and destroyed naturally in the atmosphere and until recently, this resulted in a well-balanced equilibrium (see Figure 9.2). 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. 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 hole.

9.2.1 Ozone Depletion Process

Ozone is highly reactive and easily broken down by man-made chlorine and bromine compounds. These compounds are found to be most responsible for most of ozone layer depletion.

The ozone depletion process begins when CFCs (used in refrigerator and air conditioners) and other ozone-depleting substances (ODS) are emitted into the atmosphere. Winds efficiently mix and evenly distribute the ODS in the troposphere. These ODS compounds do not dissolve in rain, are extremely stable, and have a long life span. After several years, they reach the stratosphere by diffusion.

Strong UV light breaks 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 (UV) 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. The 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 9.3.

* CFC - chlorofluorocarbon: it contains chlorine, fluorine and carbon atoms.
** UV radiation breaks oxygen molecules (O_2) into single oxygen atoms.

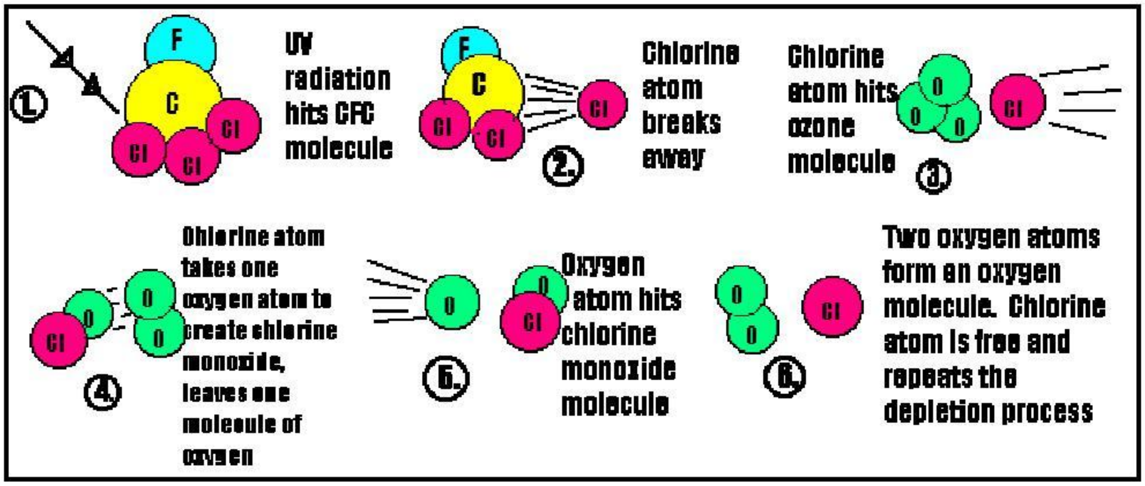


Figure 9.3 Chemistry of Ozone Depletion Process

Chemical equation is

$$CFCl_3 + \text{UV Light} ==> CFCl_2 + Cl$$
$$Cl + O_3 ==> ClO + O_2$$
$$ClO + O ==> Cl + O_2$$

The free chlorine atom is then free to attack another ozone molecule

$$Cl + O_3 ==> ClO + O_2$$
$$ClO + O ==> Cl + O_2$$

and again ...

$$Cl + O_3 ==> ClO + O_2$$
$$ClO + O ==> Cl + O_2$$

and again... for thousands of times.

Scientist measure ozone layer thickness by measuring how much ultraviolet radiation reaches the ground, using a Dobson ozone spectrophotometer. Ozone layer thickness is measured in Dobson units. The higher the number, the thicker the ozone layer. Since the 1970s, gases produced for commercial purposes have been destroying the ozone layer, upsetting the natural equilibrium that existed. It is planned that by 2005 in developed countries and by 2015 in developing countries, the use of ozone depleting gases, such as CFCs, will be phased out.

9.2.2 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: In forests and grasslands, increased radiation is likely to change species composition 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.

The ozone layer, therefore, is highly beneficial to plant and animal life on earth filtering out the dangerous part of sun's radiation and allowing only the beneficial part to reach earth. Any disturbance or depletion of this layer would result in an increase of harmful radiation reaching the earth's surface leading to dangerous consequences.

9.2.3 Ozone Depletion Counter Measures

- International cooperation, agreement (Montreal Protocol) to phase out ozone depleting chemicals since 1974
- Tax imposed for ozone depleting substances
- Ozone friendly substitutes- HCFC (less ozone depleting potential and shorter life)
- Recycle of CFCs and Halons

9.3 Global Warming

Before the Industrial Revolution, human activities released very few gases into the atmosphere and all climate changes happened naturally. After the Industrial Revolution, through fossil fuel combustion, changing agricultural practices and deforestation, the natural composition of gases in the atmosphere is getting affected and climate and environment began to alter significantly.

Over the last 100 years, it was found out that the earth is getting warmer and warmer, unlike previous 8000 years when temperatures have been relatively constant. The present temperature is 0.3 - 0.6 ^{o}C warmer than it was 100 years ago.

The key greenhouse gases (GHG) causing global warming is carbon dioxide. CFC's, even though they exist in very small quantities, are significant contributors to global warming. Carbon dioxide, one of the most prevalent greenhouse gases in the atmosphere, has two major anthropogenic (human-caused) sources: the combustion of fossil fuels and changes in land use. Net releases of carbon dioxide from these two sources are believed to be contributing to the rapid rise in atmospheric concentrations since Industrial Revolution. Because estimates indicate that approximately 80 percent of all anthropogenic carbon dioxide emissions currently come from fossil fuel combustion, world energy use has emerged at the center of the climate change debate.

9.3.1 Sources of Greenhouse Gases

Some greenhouse gases occur naturally in the atmosphere, while others result from human activities. Naturally occurring greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone (refer Figure 9.4). Certain human activities, however, add to the levels of most of these naturally occurring gases.

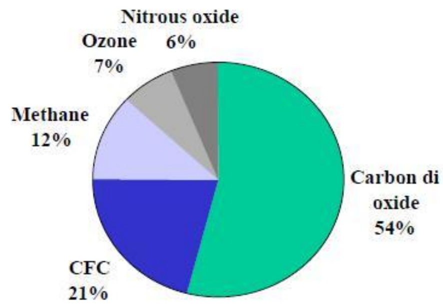


Figure 9.4 %Share of Greenhouse Gases

Carbon dioxide is released to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), and wood and wood products are burned.

Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from the decomposition of organic wastes in municipal solid waste landfills, and the raising of livestock. Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.

Very powerful greenhouse gases that are not naturally occurring include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6), which are generated in a variety of industrial processes.

Often, estimates of greenhouse gas emissions are presented in units of millions of metric tons of carbon equivalents (MMTCE), which weights each gas by its Global Warming Potential or GWP value.

9.3.2 Global Warming Potentials

Although there are a number of ways of measuring the strength of different greenhouse gases in the atmosphere, the Global Warming Potential (GWP) is perhaps the most useful.

GWPs measure the influence greenhouse gases have on the natural greenhouse effect, including the ability of greenhouse gas molecules to absorb or trap heat and the length of time, greenhouse gas molecules remain in the atmosphere before being removed or broken down. In this way, the contribution that each greenhouse gas has towards global warming can be assessed.

Each greenhouse gas differs in its ability to absorb heat in the atmosphere. HFCs and PFCs are the most heat-absorbent. Methane traps over 21 times more heat per molecule than carbon dioxide, and nitrous oxide absorbs 270 times more heat per molecule than carbon dioxide. Conventionally, the GWP of carbon dioxide, measured across all time horizons, is 1. The GWPs of other greenhouse gases are then measured relative to the GWP of carbon dioxide. Thus GWP of methane is 21 while GWP of nitrous oxide is 270.

Other greenhouse gases have much higher GWPs than carbon dioxide, but because their concentration in the atmosphere is much lower, carbon dioxide is still the most important greenhouse gas, contributing about 60% to the enhancement of the greenhouse effect.

9.3.3 Global Warming (Climate Change) Implications

Rise in global temperature
Observations show that global temperatures have risen by about 0.6 °C over the 20th century. 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.

Rise in sea level
In general, the faster the climate change, the greater will be the risk of damage. The mean sea level is expected to rise 9 - 88 cm by the year 2100, causing flooding of low lying areas and other damages.

Food shortages and hunger
Water resources will be affected as precipitation and evaporation patterns change around the world. This will affect agricultural output. Food security is likely to be threatened and some regions are likely to experience food shortages and hunger.

India could be more at risks than many other countries
Models predict an average increase in temperature in India of 2.3 to 4.8°C for the benchmark doubling of Carbon-dioxide scenario. Temperature would rise more in Northern India than in Southern India. It is estimated that 7 million people would be displaced, 5700 km^2 of land and 4200 km of road would be lost, and wheat yields could decrease significantly.

9.4 Loss of Biodiversity

Biodiversity refers to the variety of life on earth, and its biological diversity. The number of species of plants, animals, micro organisms, the enormous diversity of genes in these species, the different ecosystems on the planet, such as deserts, rainforests and coral reefs are all a part of a biologically diverse earth. Biodiversity actually boosts ecosystem productivity where each species, no matter how small, all have an important role to play and that it is in this combination that enables the ecosystem to possess the ability to prevent and recover from a variety of disasters.

It is now believed that human activity is changing biodiversity and causing massive extinctions. The *World Resource Institute* reports that *there is a link between biodiversity* and *climate change*. Rapid global warming can affect ecosystems chances to adapt naturally. Over the past 150 years, deforestation has contributed an estimated 30 percent of the atmospheric build-up of CO_2. It is also a significant driving force behind the loss of genes, species, and critical ecosystem services.

Link between Biodiversity and Climate change

- Climate change is affecting species already threatened by multiple threats across the globe. Habitat fragmentation due to colonization, logging, agriculture and mining etc. are all contributing to further destruction of terrestrial habitats.
- Individual species may not be able to adapt. Species most threatened by climate change have small ranges, low population densities, restricted habitat requirements and patchy distribution.
- Ecosystems will generally shift northward or upward in altitude, but in some cases they will run out of space – as 1^0C change in temperature correspond to a 100 Km change in latitude, hence, average shift in habitat conditions by the year 2100 will be on the order of 140 to 580 Km.
- Coral reef mortality may increase and erosion may be accelerated. Increase level of carbon dioxide adversely impact the coral building process (calcification).
- Sea level may rise, engulfing low-lying areas causing disappearance of many islands, and extinctions of endemic island species.
- Invasive species may be aided by climate change. Exotic species can out-compete native wildlife for space, food, water and other resources, and may also prey on native wildlife.
- Droughts and wildfires may increase. An increased risk of wildfires due to warming and drying out of vegetation is likely.
- Sustained climate change may change the competitive balance among species and might lead to forests destruction

9.5 Climatic Change Problem and Response

9.5.1 The United Nations Framework Convention on Climate Change, UNFCCC

In June 1992, the "United Nations Framework Convention on Climate Change" (UNFCCC) was signed in Rio de Janeiro by over 150 nations. The climate convention is the base for international co-operation within the climate change area. In the convention the climate problem's seriousness is stressed. There is a concern that human activities are enhancing the natural greenhouse effect, which can have serious consequences on human settlements and ecosystems.

The convention's overall objective is the stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

The principle commitment applying to parties of the convention is the adoption of policies and measures on the mitigation of climate change, by limiting anthropogenic emissions of greenhouse gases and protecting and enhancing greenhouse gas sinks and reservoirs. The commitment includes the preparation and communication of national inventories of greenhouse gases. The Climate convention does not have any quantitative targets or timetables for individual nations. However, the overall objective can be interpreted as stabilization of emissions of greenhouse gases by year 2000 at 1990 levels.

The deciding body of the climate convention is the Conference of Parties (COP). At the COP meetings, obligations made by the parties are examined and the objectives and implementation of the climate convention are further defined and developed. The first COP was held in Berlin, Germany in 1995 and the latest (COP 10) was held in December 2004, Buenos Aires, Argentina.

9.5.2 The Kyoto Protocol

There is a scientific consensus that human activities are causing global warming that could result in significant impacts such as sea level rise, changes in weather patterns and adverse health effects. As it became apparent that major nations such as the United States and Japan would not meet the voluntary stabilization target by 2000, Parties to the Convention decided in 1995 to enter into negotiations on a protocol to establish legally binding limitations or reductions in greenhouse gas emissions. It was decided by the Parties that this round of negotiations would establish limitations only for the developed countries, including the former Communist countries (called annex A countries).

Negotiations on the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) were completed December 11, 1997, committing the industrialized nations to specify, legally binding reductions in emissions of six greenhouse gases. The 6 major greenhouse gases covered by the protocol are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

Emissions Reductions

The United States would be obligated under the Protocol to a cumulative reduction in its greenhouse gas emissions of 7% below 1990 levels for three greenhouse gases (including carbon dioxide), and below 1995 levels for the three man-made gases, averaged over the commitment period 2008 to 2012.

The Protocol states that developed countries are committed, individually or jointly, to ensuring that their aggregate anthropogenic carbon dioxide equivalent emissions of greenhouse gases do not exceed amounts assigned to each country with a view to reducing their overall emissions of such gases by at least 5% below 1990 levels in the commitment period 2008 to 2012.

The amounts for each country are listed as percentages of the base year, 1990 and range from 92% (a reduction of 8%) for most European countries--to 110% (an increase of 10%) for Iceland.

Developing Country Responsibilities

Another problematic area is that the treaty is ambiguous regarding the extent to which developing nations will participate in the effort to limit global emissions. The original 1992 climate treaty made it clear that, while the developed nations most responsible for the current buildup of greenhouse gases in the atmosphere should take the lead in combating climate change, developing nations also have a role to play in protecting the global climate. Per Capita CO_2 emissions are small in developing countries and developed nations have altered the atmosphere the most as shown in the Figure 9.5 & Figure 9.6.

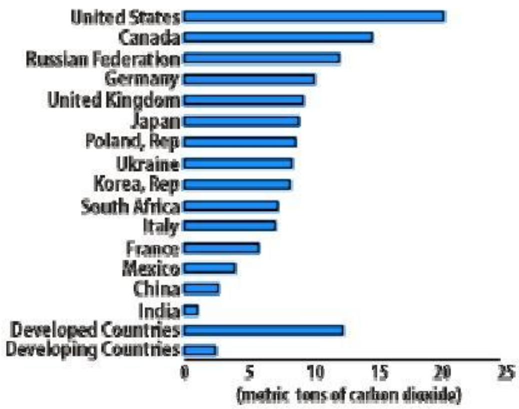


Figure 9.5 Per Capita CO_2 Emissions for the 15 Countries With the Highest Total Industrial Emissions, 1995

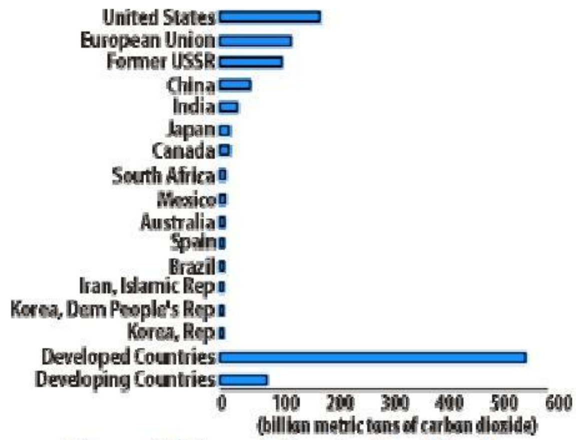


Figure 9.6 Cumulative Carbon-Dioxide Emissions, 1950-95

Developing countries, including India and China, do not have to commit to reductions in this first time period because their per-capita emissions are much lower than those of developed countries, and their economies are less able to absorb the initial costs of changing to cleaner fuels. They have not contributed significantly to today's levels of pollution that has been the product of the developed world's Industrial Revolution. The idea is that developing countries will be brought more actively into the agreement as new energy technologies develops and as they industrialize further.

Annex I and Annex II Parties

Annex I parties are countries which have commitments according to the Kyoto protocol. The entire Annex I parties are listed in the Table 9.1 below. Further Annex I parties shown in bold are also called Annex II parties. These Annex II parties have a special obligation to provide "new and additional financial sources" to developing countries (non Annex I) to help them tackle climate change, as well as to facilitate the transfer of climate friendly technologies to both developing countries and to economies in transition. Commitments are presented as percentage of base year emission levels to be achieved during between 2008 – 2012.

Table 9.1 Annex I and Annex II Parties

European Union	%	Economies in transition to a market economy	%
Austria	92	Bulgaria	92
Belgium	92	Croatia	95
Denmark	92	Czech Republic	92
Finland	92	Estonia	92
France	92	Hungary	94
Germany	92	Latvia	92
Greece	92	Lithuania	92
Ireland	92	Poland	94
Italy	92	Romania	92
Luxembourg	92	Russian Federation	100
Netherlands	92	Slovakia	92
Portugal	92	Slovenia	92
Spain	92	Ukraine	100
Sweden	92		
United Kingdom	92		
Other Europe		Other Annex I	
Iceland	110	**Australia**	108
Liechtenstein	92	**Canada**	94
Monaco	92	**Japan**	94
Norway	101	**New Zealand**	100
Switzerland	92	**United States of America**	93

Base year is 1990 for all countries except those economies in transition, who may chose an alternative base year or multi-year period.

Actions required from developed and developing Nations

The Kyoto Protocol does call on all Parties (developed and developing) to take a number of steps to formulate national and regional programs to improve "local emission factors," activity data, models, and national inventories of greenhouse gas emissions and sinks that remove these gases from the atmosphere. All Parties are also committed to formulate, publish, and update climate change mitigation and adaptation measures, and to cooperate in promotion and transfer of environmentally sound technologies and in scientific and technical research on the climate system.

Who is bound by the Kyoto Protocol?

The Kyoto Protocol has to be signed and ratified by 55 countries (including those responsible for at least 55% of the developed world's 1990 carbon dioxide emissions) before it can enter into force. Now that Russia has ratified, this been achieved and the Protocol will enter into force on 16 February 2005.

9.5.3 India's Greenhouse Gas Emissions

India has experienced a dramatic growth in fossil fuel CO_2 emissions, and the data compiled by various agencies shows an increase of nearly 5.9 % since 1950. At present India is rated as the 6^{th} largest contributor of CO_2 emissions behind China, the 2^{nd} largest contributor. However, our per capita CO_2 of 0.93 tons per annum is well below the world average of 3.87 tons per annum. Fossil fuel emissions in India continue to result largely from coal burning. India is highly vulnerable to climate change as its economy is heavily reliant on climate sensitive sectors like agriculture and forestry. The vast low-lying and densely populated coastline is susceptible to rise in sea level.

The energy sector is the largest contributor of carbon dioxide emissions in India. The national inventory of greenhouse gases indicates that 55% of the total national emissions come from energy sector. These include emissions from road transport, burning of traditional bio-mass fuels, coal mining, and fugitive emissions from oil and natural gas.

Agriculture sector constitutes the next major contributor, accounting for nearly 34%. The emissions under this sector include those from enteric fermentation in domestic animals, manure management, rice cultivation, and burning of agriculture residues. Emissions from Industrial sector mainly came from cement production.

Indian Response to Climatic Change

Under the UNFCCC, developing countries such as India do not have binding GHG mitigation commitments in recognition of their small contribution to the greenhouse problem as well as low financial and technical capacities. The Ministry of Environment and Forests is the nodal agency for climate change issues in India. It has constituted Working Groups on the UNFCCC and Kyoto Protocol. Work is currently in progress on India's initial National Communication (NATCOM) to the UNFCCC. India ratified the Kyoto Protocol in 2002

9.6 The Conference of the Parties (COP)

The Conference of the Parties is the supreme body of the Climate Change Convention. The vast majority of the world's countries are members (185 as of July 2001). The Convention enters into force for a country 90 days after that country ratifies it. The COP held its first session in 1995 and will continue to meet annually unless decided otherwise. However, various subsidiary bodies that advise and support the COP meet more frequently.

The Convention states that the COP must periodically examine the obligations of the Parties and the institutional arrangements under the Convention. It should do this in light of the Convention's objective, the experience gained in its implementation, and the current state of scientific knowledge.

Exchange of Information

The COP assesses information about policies and emissions that the Parties share with each other through their national communications. It also promotes and guides the development and periodic refinement of comparable methodologies, which are needed for quantifying net greenhouse gas emissions and evaluating the effectiveness of measures to limit them. Based on the information available, the COP assesses the Parties efforts to meet their treaty commitments and adopts and publishes regular reports on the Convention's implementation.

Support for Developing countries

Developing countries need support so that they can submit their national communications, adapt to the adverse effects of climate change, and obtain environmentally sound technologies. The COP therefore oversees the provision of new and additional resources by developed countries.

The third session of the Conference of the Parties adopted the Kyoto Protocol.

9.6.1 The Flexible Mechanisms

The Kyoto protocol gives the Annex I countries the option to fulfill a part of their commitments through three "flexible mechanisms". Through these mechanisms, a country can fulfill a part of their emissions reductions in another country or buy emission allowances from another country. There are three flexible mechanisms:

i. Emissions trading
ii. Joint implementation
iii. Clean development mechanism

i) Emissions trading

Article 17 of the Kyoto protocol opens up for emissions trading between countries that have made commitments to reduce greenhouse gas emissions. The countries have the option to delegate this right of emissions trading to companies or other organisations.

In a system for emissions trading, the total amount of emissions permitted is pre-defined. The corresponding emissions allowances are then issued to the emitting installations through auction or issued freely. Through trading, installations with low costs for reductions are stimulated to make reductions and sell their surplus of emissions allowances to organisations where reductions are more expensive. Both the selling and buying company wins on this flexibility that trade offers with positive effects on economy, resource efficiency and climate. The environmental advantage is that one knows, in advance, the amount of greenhouse gases that will be emitted. The economical advantage is that the reductions are done where the reduction costs are the lowest. The system allows for a cost effective way to reach a pre-defined target and stimulates environmental technology development.

ii) Joint Implementation, JI

Under article 6 of the Kyoto protocol an Annex I country that has made a commitment for reducing greenhouse gases, can offer to, or obtain from another Annex I country greenhouse gas emissions reductions. These emissions reductions shall come from projects with the objectives to reduce anthropogenic emissions from sources or increase the anthropogenic uptake in sinks. In order to be accepted as JI-projects, the projects have to be accepted by both parties in advance. It also has to be proven that the projects will lead to emissions reductions that are higher than what otherwise would have been obtained. JI-projects are an instrument for one industrial country to invest in another industrial country and in return obtain emissions reductions. These reductions can be used to help fulfill their own reduction commitments at a lower cost than if they had to do the reductions in their own country.

iii) Clean Development Mechanism (CDM)

Article 12 of the Kyoto protocol defines the Clean Development Mechanism, CDM. The purpose of CDM is to:

a) contribute to sustainable development in developing countries;
b) help Annex I-countries under the Kyoto Protocol to meet their target.

With the help of CDM, countries which have set themselves an emission reduction target under the Kyoto Protocol (Annex I countries) can contribute to the financing of projects in developing countries (non-Annex I countries) which do not have a reduction target. These projects should reduce the emission of greenhouse gases while contributing to the sustainable development of the host country involved. The achieved emission reductions can be purchased by the Annex I country in order to meet its reduction target.

In order to be accepted as CDM-projects, the projects have to be accepted by both parties in advance. It also has to be proven that the projects will lead to emissions reductions that are higher than what otherwise would have been obtained. The difference between JI-projects and CDM-projects is that JI-projects are done between countries that both have commitments, while the CDM-projects is between one country that has commitments and another country that does not have commitments. Emissions reductions that have been done through CDM-projects during the period 2000 to 2007, can be used for fulfilling commitments in Annex I countries for the period 2008-2012.

How CDM works?

An investor from a developed country, can invest in, or provide finance for a project in a developing country that reduces greenhouse gas emissions so that they are lower than they would have been without the extra investment – i.e. compared to what would have happened without the CDM under a business as usual outcome. The investor then gets credits – carbon credits - for the reductions and can use those credits to meet their Kyoto target. If the CDM works perfectly it will not result in more or less emission reductions being achieved than were agreed under the Kyoto Protocol, it will simply change the location in which some of the reductions will happen.

For example, a French company needs to reduce its emissions as part of its contribution to meeting France's emission reduction target under the Kyoto Protocol. Instead of reducing emissions from its own activities in France, the company provides funding for the construction of a new biomass plant in India that would not have been able to go ahead without this investment. This, they argue, prevents the construction of new fossil-fueled plants in India, or displaces consumption of electricity from existing ones, leading to a reduction in greenhouse gas emissions in India. The French investor gets credit for those reductions and can use them to help meet their reduction target in France.

Requirements for Participating in CDM

Criteria

All Annex I and non-Annex I nations must meet three requirements for participation in CDM.

- Voluntary participation
- Establishment of National CDM Authority
- Ratification of Kyoto Protocol

In addition Annex I nations must establish:

- the assigned amount under Article 3 of the Protocol
- a national system for the estimation of GHG
- a national registry
- an annual inventory and
- an accounting system for the sale and purchase of emission reductions.

Eligible Projects

The CDM can include projects the following projects:

- End-use energy efficiency improvements
- Supply-side energy efficiency improvement
- Renewable energy
- Fuel switching
- Agriculture (reduction of CH4 and N2o emissions)
- Industrial processes (CO2 from cement etc., HFCs, PFCs, SF6
- Sinks projects (only afforestation and reforestation)

Note: Annex I nations must refrain from using CERs generated through nuclear energy to meet their targets

Project cycle for CDM

The project cycle for CDM is shown in Figure 9.7. There are seven basic stages; the first four stages are performed prior to the implementation of the project, while the last three stages are performed during the lifetime of the project.

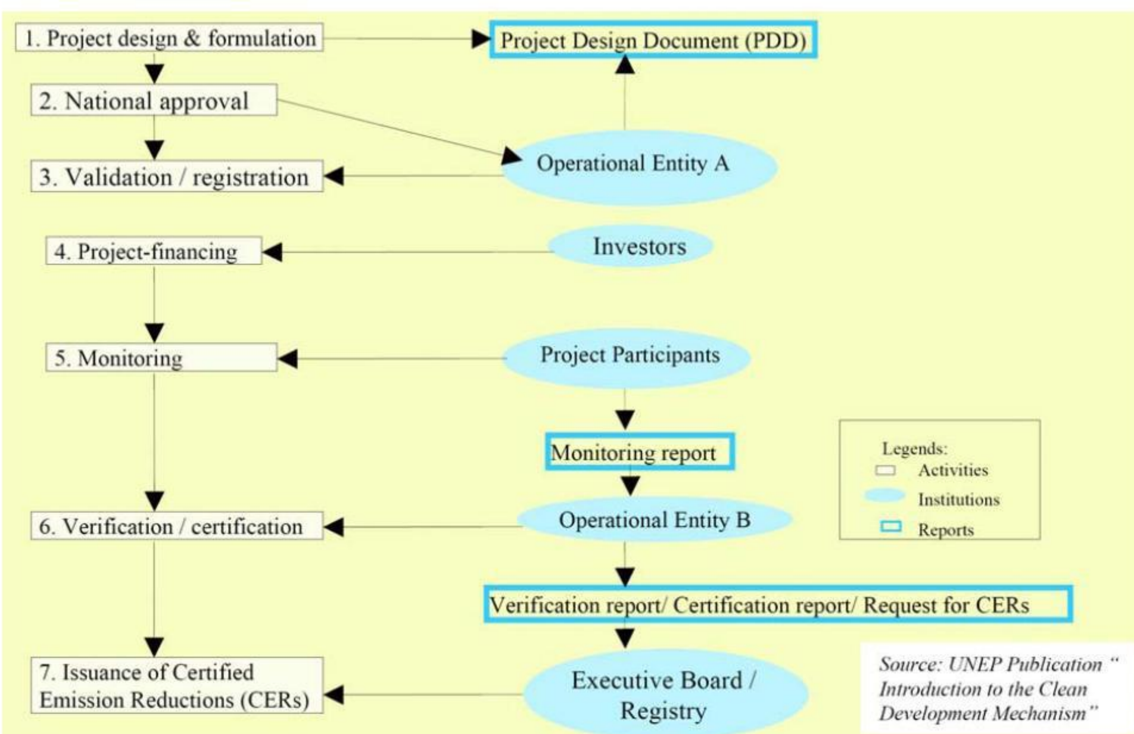


Figure 9.7 Project Cycle for CDM

While investors profit from CDM projects by obtaining reductions at costs lower than in their own countries, the gains to the developing country host parties are in the form of finance, technology, and sustainable development benefits.

Projects starting in the year 2000 are eligible to earn Certified Emission Reductions (CERs) if they lead to "real, measurable, and long-term" GHG reductions, which are additional to any that would occur in the absence of the CDM project. This includes afforestation and reforestation projects, which lead to the sequestration of carbon dioxide.

At COP-7, it was decided that the following types of projects would qualify for fast-track approval procedures:

- Renewable energy projects with output capacity up to 15 MW
- Energy efficiency improvement projects which reduce energy consumption on the supply and/or demand side by up to 15 GWh annually
- Other project activities that both reduce emissions by sources and directly emit less than 15 kilotons CO_2 equivalent annually.

The CDM will be supervised by an executive board, and a share of the proceeds from project activities will be used to assist developing countries in meeting the costs of adaptation to climate change.

Indian Initiatives on CDM

Government of India has been willing to fulfill its responsibility under the CDM. It has developed an interim criterion for approval of CDM project activities, which is now available to stakeholders. It has undertaken various capacity building activities like holding of workshops, initiation of various studies, and briefing meeting with the stakeholders. India has been actively participating in the CDM regime and has already approved projects for further development.

Under CDM, projects such as energy efficient hydrocarbon refrigerators, modernization of small scale foundry units and renovation, modernization of thermal power stations etc. are being taken up.

Case Example

In a power plant renovation and modernization programme by replacing plant equipment which are prone to wear and tear over a period of time, such as boilers and auxiliaries, turbine blades, HP governor valves and station auxiliaries which include material handling equipment, water treatment, pulverisers, ash handling plant, ESP etc resulted in CO2 emission reduction from 1.20 kg/kWh to 1.11 kg/kWh. The details are shown in the Table 9.2:

Table 9.2 Efficiency Improvement And Emission Reduction in a Power Plant Modernisation Programme

Parameters	Before the programme	After the programme
Gross heat rate (kcal/KWh)	2700	2500
Net efficiency (%)	28	30
Specific coal consumption	0.77	0.71
Total CO_2 emissions (tones/year)	1435336	1329015
CO_2 emissions (kg/ kWh)	1.20	1.11

9.7 Prototype Carbon Fund (PCF)

Recognizing that global warming will have the most impact on its borrowing client countries, the World Bank approved the establishment of the Prototype Carbon Fund (PCF). The PCF is intended to invest in projects that will produce high quality greenhouse gas emission reductions that could be registered with the United Nations Framework Convention on Climate Change (UNFCCC) for the purposes of the Kyoto Protocol. To increase the likelihood that the reductions will be recognized by the Parties to the UNFCCC, independent experts will follow validation, verification and certification procedures that respond to UNFCCC rules as they develop.

The PCF will pilot production of emission reductions within the framework of Joint Implementation (JI) and the Clean Development Mechanism (CDM). The PCF will invest contributions made by companies and governments in projects designed to produce emission reductions fully consistent with the Kyoto Protocol and the emerging framework for JI and the CDM. Contributors, or "Participants" in the PCF, will receive a pro rata share of the emission reductions, verified and certified in accordance with agreements reached with the respective countries "hosting" the projects.

9.7.1 Size of Market for Emissions Reductions

- All estimates of market volume are speculative at this early stage in the market's development.
- One way of looking at the potential size of the market is to assume that about one billion tonnes of carbon emissions must be reduced per year during the commitment period of 2008-2012 in order for the industrialized countries to meet their obligations of a 5% reduction in their 1990 levels of emissions.

Under Prototype carbon fund programme of the World Bank. Government of India has approved a municipal solid waste energy project for implementation in Chennai, which proposes to use the state of art technology for extracting energy from any solid waste irrespective of the energy content. Many industrial organisations in the private sector have also sought assistance under this fund.

9.8 Sustainable Development

9.8.1 What is Sustainable Development?

Sustainable development is often defined as 'development that meets the needs of the present, without compromising the ability of future generations to meet their own needs'.

Sustainable development encompasses three basic and inter-related objectives:

- Economic security and prosperity
- Social development and advancement
- Environmental sustainability

Figure 9.8 Sustainable Development

Sustainable development demands that we seek ways of living, working and being that enable all people of the world to lead healthy, fulfilling, and economically secure lives without destroying the environment and without endangering the future welfare of people and the planet.

Sustainable development as applied to energy and environment should consider the following:

- inputs - such as fuels and energy sources, land and raw materials - are non-renewable they should be used up only as far as they can be substituted in future
- where they are renewable they should be used up at a rate within which they can be renewed,
- outputs - in production and consumption - should not overstrain ecosystems or the assimilation capacity of the ecosphere.

UNIT II

ENERGY CONSERVATION

.ENERGY SURVEYING & AUDITING

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 an effective tool in defining and pursuing comprehensive energy management programme.

Need for Energy Audit

In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker, and thus energy management function constitutes a strategic area for cost reduction.

Energy Audit will help to understand more about the ways energy and fuel are used in any industry, and help in identifying the areas where waste can occur and where scope for improvement exists. The Energy Audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the 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 lending technically feasible solutions with economic and other organizational considerations within a specified time frame. The primary objective of Energy Audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy Audit provides a " bench-mark" (Reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

Type of Energy Audit

The type of Energy Audit to be performed depends on:

- Function and type of industry
- Depth to which final audit is needed, and
- Potential and magnitude of cost reduction desired

Thus Energy Audit can be classified into the following two types.

i) Preliminary Audit

ii) Detailed Audit

Preliminary Energy Audit Methodology

Preliminary energy audit is a relatively quick exercise to:

- Establish energy consumption in the organization
- Estimate the scope for saving
- Identify the most likely (and the easiest areas for attention
- Identify immediate (especially no-/low-cost) improvements/ savings
- Set a 'reference point'
- Identify areas for more detailed study/measurement
- Preliminary energy audit uses existing, or easily obtained data

Detailed Energy Audit Methodology

A comprehensive audit provides a detailed energy project implementation plan for a facility, since it evaluates all major energy using systems.

This type of audit offers the most accurate estimate of energy savings and cost. It considers the interactive effects of all projects, accounts for the energy use of all major equipment, and includes detailed energy cost saving calculations and project cost.

In a comprehensive audit, one of the key elements is the energy balance. This is based on an inventory of energy using systems, assumptions of current operating conditions and calculations of energy use. This estimated use is then compared to utility bill charges.

Detailed energy auditing is carried out in three phases: Phase I, II and

III. Phase I - Pre Audit Phase

Phase II - Audit Phase

Phase III - Post Audit Phase

Ten Steps Methodology for 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	• Resource planning, Establish/organize a Energy audit team • Organize Instruments & time frame • Macro Data collection (suitable to type of industry.) • Familiarization of process/plant activities • First hand observation & Assessment of current level operation and practices
Step 2	• Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.)	• Building up cooperation • Issue questionnaire for each department • Orientation, awareness creation
	Phase II –Audit Phase	
Step 3	• Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	• Historic data analysis, Baseline data collection • Prepare process flow charts • All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution. • Design, operating data and schedule of operation • Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step 4	• Conduct survey and monitoring	• Measurements : Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.
Step 5	• Conduct of detailed trials /experiments for selected energy guzzlers	• Trials/Experiments: - 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 experiments etc
Step6	• Analysis of energy use	• Energy and Material balance & energy loss/waste analysis
Step 7	• Identification and development of Energy Conservation (ENCON) opportunities	• Identification & Consolidation ENCON measures • Conceive, develop, and refine ideas • Review the previous ideas suggested by unit personal • Review the previous ideas suggested by energy audit 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
Step9	• Reporting & Presentation to the Top Management	• Documentation, Report Presentation to the top Management.
	Phase III –Post Audit phase	
Step10	• Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance • Action plan, Schedule for implementation • Follow-up and periodic review

The information to be collected during the detailed audit includes: -

1. Energy consumption by type of energy, by department, by major items of process equip ment, by end-use

2. 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.)

3. Energy cost and tariff data

4. Process and material flow diagrams

5. Generation and distribution of site services (eg.compressed air, steam).

6. Sources of energy supply (e.g. electricity from the grid or self-generation)

7. Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and power generation).

8. Energy Management procedures and energy awareness training programs within the establishment. Existing baseline information and reports are useful to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs. The audit team should collect the following baseline data:

- Technology, processes used and equipment details
- Capacity utilisation
- Amount & type of input materials used
- Water consumption
- Fuel Consumption
- Electrical energy consumption
- Steam consumption
- Other inputs such as compressed air, cooling water etc
- Quantity & type of wastes generated
- Percentage rejection / reprocessing
- Efficiencies / yield

TABLE 3.1 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 Reporting Format

After successfully carried out energy audit energy manager/energy auditor should report to the top management for effective communication and implementation. A typical energy audit reporting contents and format are given below. The following format is applicable for most of the industries. However the format can be suitably modified for specific requirement applicable for a particular type of industry.

Report on

DETAILED ENERGY AUDIT

TABLE OF CONTENTS

i. **Acknowledgement**

ii. **Executive Summary**

Energy Audit Options at a glance & Recommendations

1.0 Introduction about the plant

1.1 General Plant details and descriptions

1.2 Energy Audit Team

1.3 Component of production cost (Raw materials, energy, chemicals, manpower, overhead, others)

1.4 Major Energy use and Areas

2.0 Production Process Description

2.1 Brief description of manufacturing process

2.2 Process flow diagram and Major Unit operations

2.3 Major Raw material Inputs, Quantity and Costs

3.0 Energy and Utility System Description

3.1 List of Utilities

3.2 Brief Description of each utility

3.2.1 Electricity
3.2.2 Steam
3.2.3 Water
3.2.4 Compressed air
3.2.5 Chilled water
3.2.6 Cooling water

4.0 Detailed Process flow diagram and Energy& Material balance

4.1 Flow chart showing flow rate, temperature, pressures of all input-output streams

4.2 Water balance for entire industry

5.0 Energy efficiency in utility and process systems

5.1 Specific Energy consumption

5.2 Boiler efficiency assessment

5.3 Thermic Fluid Heater performance assessment

5.4 Furnace efficiency Analysis

5.5 Cooling water system performance assessment

5.6 DG set performance assessment

5.7 Refrigeration system performance

5.8 Compressed air system performance

5.9 Electric motor load analysis

5.10 Lighting system

6.0 Energy Conservation Options & Recommendations

6.1 List of options in terms of No cost/ Low Cost, Medium cost and high investment Cost, Annual Energy & Cost savings, and payback

6.2 Implementation plan for energy saving measures/Projects

ANNEXURE

A1. List of Energy Audit Worksheets

A2. List of instruments

A3. List of Vendors and Other Technical details

The following Worksheets (refer Table 3.2 & Table 3.3) can be used as guidance for energy audit assessment and reporting.

TABLE 3.2 SUMMARY OF ENERGY SAVING RECOMMENDATIONS

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

TABLE 3.3 TYPES AND PRIORITY OF ENERGY SAVING MEASURES

	Type of Energy Saving Options	Annual Electricity /Fuel savings	Annual Savings	Priority
		KWh/MT or kl/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			

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 m^3/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 m^3/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 (240x1000 x 1x 5)	=	1200,000 K.Cal/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	=	40kWx 8400hr = 3,36,000 Units/Year
Annual Cost Savings	=	3,36,000 xRs.4.00 = Rs.13.4 Lakh per year
Investment (Only cost of piping)	=	Rs 1.5Lakhs
Simple Pay back Period	=	**Less than 2 months**

ENERGY CONSERVATION SCHEMES

It is generally considered that investment for energy conservation should be judged by exactly the same criteria as for any other form of capital investment. Energy conservation measures may be classified on an economic basis and fall into the following three categories:

(a) *Short term* — These measures usually involve changes in operating practices resulting in little or no capital expenditure.
(b) *Medium term* — Low-cost modifications and improvements to existing equipment where the pay-back period is less than two years and often under one year.
(c) *Long term* — Modifications involving high capital costs and which frequently involve the implementation of new techniques and new technologies.

While the first two categories together can achieve savings of the order of 5–10 per cent, capital expenditure using existing and new technology may achieve a further 10–15 per cent. It is impossible to give a comprehensive list of all items in each category but selected examples are given for each section.

Understanding Energy Costs

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 base-line 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. Few are listed below:

- Fuel oil
- Low Sulphur Heavy Stock (LSHS)
- Light Diesel Oil (LDO)
- Liquefied Petroleum Gas (LPG)
- COAL
- LIGNITE
- WOOD ETC.

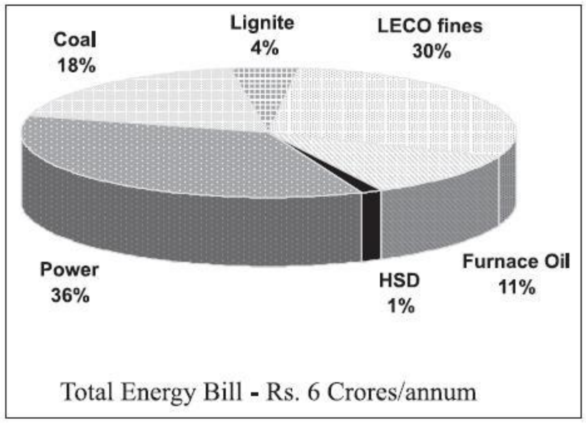


Figure 3.2 Annual Energy Bill

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

Example: Purchased energy Bill

A typical summary of energy purchased in an industry based on the invoices

TABLE 3.4

Type of energy	Original units	Unit Cost	Monthly Bill Rs.
Electricity	5,00,000 kWh	Rs.4.00/kWh	20,00,000
Fuel oil	200 kL	Rs.10,000/ kL	20,00,000
Coal	1000 tons	Rs.2,000/ton	20,00,000
Total			60,00,000

Unfortunately the different forms of energy are sold in different units e.g. kWh of electricity, liters of fuel oil, tonne of coal. To allow comparison of energy quantities these must be converted to a common unit of energy such as kWh, Giga joules, kCals etc.

Electricity (1 kWh) = 860 kCal/kWh (0.0036 GJ)
Heavy fuel oil (Gross calorific value, GCV) =10000 kCal/litre (0.0411 GJ/litre)
Coal (Gross calorific value, GCV) =4000 kCal/kg (28 GJ/ton)

ENERGY CONSERVATION IN THERMAL SYSTEMS, BUILDINGS, ENGINEERING & PROCESS INDUSTRIES

THERMAL UTILITIES

Boilers

- Preheat combustion air with waste heat
  (22 ^{0}C reduction in flue gas temperature increases boiler efficiency by 1%).
- Use variable speed drives on large boiler combustion air fans with variable flows.
- Burn wastes if permitted.
- Insulate exposed heated oil tanks.
- Clean burners, nozzles, strainers, etc.
- Inspect oil heaters for proper oil temperature.
- Close burner air and/or stack dampers when the burner is off to minimize heat loss up the stack.
- Improve oxygen trim control (e.g. -- limit excess air to less than 10% on clean fuels).
  (5% reduction in excess air increases boiler efficiency by 1% or: 1% reduction of residual oxygen in stack gas increases boiler efficiency by 1%.)
- Automate/optimize boiler blowdown. Recover boiler blowdown heat.
- Use boiler blowdown to help warm the back-up boiler.
- Optimize deaerator venting.
- Inspect door gaskets.
- Inspect for scale and sediment on the water side
  (A 1 mm thick scale (deposit) on the water side could increase fuel consumption by 5 to 8%).
- Inspect for soot, flyash, and slag on the fire side
  (A 3 mm thick soot deposition on the heat transfer surface can cause an increase in fuel consumption to the tune of 2.5%.)
- Optimize boiler water treatment.
- Add an economizer to preheat boiler feedwater using exhaust heat.
- Recycle steam condensate.
- Study part-load characteristics and cycling costs to determine the most-efficient mode for operating multiple boilers.
- Consider multiple or modular boiler units instead of one or two large boilers.
- Establish a boiler efficiency-maintenance program. Start with an energy audit and follow-up, then make a boiler efficiency-maintenance program a part of your continuous energy management program.

Steam System

- Fix steam leaks and condensate leaks
  (A 3 mm diameter hole on a pipe line carrying 7 kg/cm^2 steam would waste 33 kilo litres of fuel oil per year).
- Accumulate work orders for repair of steam leaks that can't be fixed during the heating season due to system shutdown requirements. Tag each such leak with a durable tag with a good description.
- Use back pressure steam turbines to produce lower steam pressures.
- Use more-efficient steam desuperheating methods.
- Ensure process temperatures are correctly controlled.
- Maintain lowest acceptable process steam pressures.
- Reduce hot water wastage to drain.

- Remove or blank off all redundant steam piping.
- Ensure condensate is returned or re-used in the process
  (6 ^{0}C raise in feed water temperature by economiser/condensate recovery corresponds to a 1% saving in fuel consumption, in boiler).
- Preheat boiler feed-water.
- Recover boiler blowdown.
- Check operation of steam traps.
- Remove air from indirect steam using equipment
  (0.25 mm thick air film offers the same resistance to heat transfer as a 330 mm thick copper wall.)
- Inspect steam traps regularly and repair malfunctioning traps promptly.
- Consider recovery of vent steam (e.g. -- on large flash tanks).
- Use waste steam for water heating.
- Use an absorption chiller to condense exhaust steam before returning the condensate to the boiler.
- Use electric pumps instead of steam ejectors when cost benefits permit
- Establish a steam efficiency-maintenance program. Start with an energy audit and follow-up, then make a steam efficiency-maintenance program a part of your continuous energy management program.

Buildings

- Seal exterior cracks/openings/gaps with caulk, gasketing, weatherstripping, etc.
- Consider new thermal doors, thermal windows, roofing insulation, etc.
- Install windbreaks near exterior doors.
- Replace single-pane glass with insulating glass.
- Consider covering some window and skylight areas with insulated wall panels inside the building.
- If visibility is not required but light is required, consider replacing exterior windows with insulated glass block.
- Consider tinted glass, reflective glass, coatings, awnings, overhangs, draperies, blinds, and shades for sunlit exterior windows.
- Use landscaping to advantage.
- Add vestibules or revolving doors to primary exterior personnel doors.
- Consider automatic doors, air curtains, strip doors, etc. at high-traffic passages between conditioned and non-conditioned spaces. Use self-closing doors if possible.
- Use intermediate doors in stairways and vertical passages to minimize building stack effect.
- Use dock seals at shipping and receiving doors.
- Bring cleaning personnel in during the working day or as soon after as possible to minimize lighting and HVAC costs.

NON CONVENTIONAL ENERGY SOURCE SCHEMES

The contemporary non-conventional sources of energy like wind, tidal, solar etc. were the conventional sources until James Watt invented the steam engine in the eighteenth century. In fact, the New World was explored by man using wind-powered ships only. The nonconventional sources are available free of cost, are pollution-free and inexhaustible. Man has used these sources for many centuries in propelling ships, driving windmills for grinding corn and pumping water, etc. Because of the poor technologies then existing, the cost of harnessing energy from these sources was quite high. Also because of uncertainty of period of availability and the difficulty of transporting this form of energy, to the place of its use are some of the factors which came in the way of its adoption or development. The use of fossil fuels and nuclear energy replaced totally the non-conventional methods because of inherent advantages of transportation and certainty of availability; however these have polluted the atmosphere to a great extent. In fact, it is feared that nuclear energy may prove to be quite hazardous in case it is not properly controlled.

1. Wind Energy

   The evolution of windmills into wind turbines did not happen overnight and attempts to produce electricity with windmills date back to the beginning of the century. It was Denmark which erected the first batch of steel windmills specially built for generation of electricity. After World War II, the development of wind turbines was totally hampered due to the installation of massive conventional power stations using fossil fuels available at low cost. But the oil crisis of 1973 heralded a definite break through in harnessing wind energy. Many European countries started pursuing the development of wind turbine technology seriously and their development efforts are continuing even today. The technology involves generation of electricity using turbines, which converts mechanical energy created by the rotation of blades into electrical energy, some times the mechanical energy from the mills is directly used for pumping water from well also. The wind power programme in India was started during 1983-84 with the efforts of the Ministry of Non-Conventional Energy Sources. In India the total installed capacity from wind mills is 1612 MW, of which, Tamilnadu has an installed capacity of 858 MW as on 31.03.2002.

Tamil Nadu is endowed with lengthy mountain ranges on its Western side with three prominent passes in its length. These are with wind-potentials: (1) Palghat Pass in Coimbatore District-1200 MW, (2) Shengottah Pass in Tirunelveli District-500MW and (3) Aralvoymozhi Pass in Kanniyakumari District- 300 MW (Total potential-2000 MW). The mountainous areas close to Cumbum Valley are observed to be having high potential and, though coastal areas, central plains and hilly areas have been observed unsuitable for wind power projects, Rameshwaram is found suitable.

2. Bio Energy Biomass is yet another important source of energy with potential to generate power to the extent of more than 50% of the country's requirements. India is predominantly an agricultural economy, with huge quantity of biomass available in the form of husk, straw, shells of coconuts wild bushes etc. With an estimated production of 350 million tons of agricultural waste every year, biomass is capable of supplementing coal to the tune of about 200 million tonnes producing 17,000 MW of power and resulting in a saving of about Rs.20,000 crores every year. Biomass available in India comprises of rice husk, rice straw, bagasse, coconut shell, jute, cotton, husk etc. Biomass can be obtained by raising energy farms or may be obtained from organic waste. The biomass resources including large quantities of cattle dung can be used in bio-energy technologies viz., biogas, gasifier, biomass combustion, cogeneration etc., to produce energy-thermal or electricity. Biomass can be used in three ways – one in the form of gas through gasifiers for thermal applications, second in the form of methane gas to run gas engines and produce power and the third through combustion to produce steam and thereby power.

3. Solar Energy Solar Power was once considered, like nuclear power, 'too cheap to meter' but this proved illusory because of the high cost of photovoltaic cells and due to limited demand. Experts however believe that with mass production and improvement in technology, the unit price would drop and this would make it attractive for the consumers in relation to thermal or hydel power. The Solar Photo Voltaic (SPV) technology which enables the direct conversion of sun light into electricity can be used to run pumps, lights, refrigerators, TV sets, etc., and it has several distinct advantages, since it does not have

moving parts, produces no noise or pollution, requires very little maintenance and can be installed anywhere. These advantages make them an ideal power source for use especially in remote and isolated areas which are not served by conventional electricity making use of ample sunshine available in India, for nearly 300 days in a year. A Solar Thermal Device, on the other hand captures and transfers the heat energy available in solar radiation. The energy generated can be used for thermal applications in different temperature ranges. The heat can be used directly or further converted into mechanical or electrical energy. 4. Other Sources The other sources of renewable energy are geothermal, ocean, hydrogen and fuel cells. These have immense energy potential, though tapping this potential for power generation and other applications calls for development of suitable technologies.

Recommendations/ Suggestions

a) A consistent and long term policy may be formulated and adopted to promote harnessing of renewable energy sources in the State.

b) A Single Window Agency may be established under TEDA to act as a forum for speedy clearance of projects.

c) Tariff may be restructured and power purchase policy revised suitably to make investment in renewable energy attractive for investors taking into account not just the economic cost but also the social/ environmental costs associated with conventional power sources.

d) The grant of suitable fiscal and financial incentives may be considered for investment in renewable sources of energy taking into account the clean and green nature of the energy source such as exemption from sales tax or sales tax deferral for investment in renewable energy projects

e) Merger of NBDP and IREP schemes along with staff may be undertaken so as to create field outfits to promote renewable energy projects/ schemes

Ninth Five Year Plan Performance

An outlay of Rs.19.95 crores was approved for Non- Conventional Energy sector for the Ninth Plan. But, the actual allocation by the State Government was Rs.8.73 crores which is 44% of the outlay, of which Rs.8.57 crores was spent. The over all financial and physical performance is shown below:

Financial Performance

		Rs. in lakhs			Rs. in lakhs	
Sl. No.	**Scheme**	**Ninth Plan outlay 1997-2002**	**Ninth Plan actual funds allocated by State Govt.**	**% of funds allotted to total outlay**	**Total 9th Plan performance**	**% Performance to total funds allotted**
1.	Wind Energy	374.40	15.22	4.1%	14.42	94.7%
2.	Solar Energy	283.60	210.42	74.2%	208.92	99.3%
3.	Bio Energy	531.40	43.45	8.2%	36.49	84.0%
4.	IREP	459.00	300.87	65.5%	298.42	96.0%
5.	Others	346.70	302.88	87.4%	298.87	98.5%
	Total	1995.10	872.84	43.8%	857.12	98.2%

Physical Performance

Sl. No.	**Scheme**	**Unit**	**9th Five Year Plan**	
			Target	Achievement
1.	Windmill for Water Pump	Nos.	22	18
2.	Wind Resource Monitoring Station	Nos.	11	11
3.	Wind Energy Project	MW		
	Public		-	-
	Private		-	181
4.	Biogas plant	Nos.	14	6
5.	Gasifier	Nos.	13	16
6.	Taluka Level Biomass Assessment Study	Nos.	4	4
7.	Assessment Study on Municipal Waste	Nos.	5	5
8.	Biomass Based Power Project	MW	-	-
9	Co-generation in sugar mill	MW	-	69(private)
10.	Solar Thermal	Nos.	1250	1370
	Domestic	Sq.m	1240	1280
	Industrial	Nos.	12	12
	Government Institutions			
11.	Solar Still	Sq.M.	400	-
12.	Solar Photovoltaic			
	Street Light	Nos.	60	60
	Pump	Nos.	95	95
	Lantern	Nos.	1000	1000
	Roof Top Power Plant	KW	11	9*

*Includes 4 KW installed in TEDA office at Chennai.

1. *Wind Energy*

The total wind potential in the State is around 2000 MW of which about 40% only has been tapped so far. The installation of 119 Wind electric generators for a total capacity of 19 MW as part of demonstration programmes has motivated and encouraged private sector to install 3003 Wind electric generators for a total capacity of 838 MW. The Wind Mills have a total capacity of 857 MW, of which, 181 MW capacity was added during the Ninth Plan and have generated and fed into the grid (6816.379 Mu.)

Installation of windmill for water pumping was taken up by providing subsidy ranging from Rs.20,000 to Rs.32,000 from State Government besides MNES subsidy of Rs.30,000 to Rs.45,000 against the total cost of Rs.80,000 for gear type and Rs.1,45,000 for AV55 type Wind Mills. During Ninth plan period, 18 gear type Wind Mills were installed from 1997 to 2000 and another 4 mills were also installed by the end of 2002. Wind monitoring stations were set up in 11 centres in Coimbatore, Erode, Kanyakumari and Tuticorin to conduct Wind Resource Assessment study which helps to identify potential locations for wind mills.

2. *Bio-Energy*

It is technically possible and economically feasible to generate biogas from cattle dung and certain agro and industrial waste. During Ninth Plan, 12 Biogas plants were installed in livestock farms, educational institutions, agricultural farms, central prisons and sugar mills. 24 Gasifier systems i.e., 23 thermal gasifiers and one electrical gasifier were also installed during Ninth Plan with financial assistance from the Ministry of Non-conventional Energy Sources.

Resource Assessment studies were carried out in 35 Taluks under MNES Programme and 4 Taluks under State programme during Ninth Plan. This will be useful for private entrepreneurs to evolve suitable power projects.

The sugar mills go in for co-generation projects by upgrading their boilers and other accessories suitably so as to supply excess electricity to Tamilnadu Electricity Board. Government of India extends financial assistance up to Rs.45 lakh per MW of surplus power to Co-operative sugar mills and interest subsidy to the Private Sugarmills. At present, the installed capacity through co-generation in sugarmills is 142 MW. Other potential sectors for co-generation are cement, paper, caustic soda, textiles, iron and steel etc., with a total potential of 5600 MW in the country.

The Ministry of Non-conventional Energy Sources sanctioned a scheme for establishing a 1.2 MW Power plant at Sarkar Uduppam Village in Namakkal District under private sector for energy recovery from poultry wastes as a demonstration project with an assistance of Rs.3.5 crores which will be commissioned during the year 2002. Another demonstration High Biomethnation Project has also been sanctioned under MNES for setting up of a sub-project under UNDP/GEF assisted project for processing of tapioca wastes water for generation of power (500 Kw) and manure in Pappireddipatti of Dharmapuri district under private sector. The project cost is Rs.3.59 crores which will be shared equally by MNES and the beneficiary and the project will be commissioned during the year 2002.

3. Solar Energy

(a) Solar Water Heating System

Several designs and capacities of Solar Water Heating System (SWHS) are available to suit the users' needs. The Government of Tamilnadu provided a subsidy of Rs.2000/- to Rs.3000/- for domestic Water Heating System from 1993 to 1998. The Government also sanctioned the full cost of SWHS in 12 Government buildings, mostly hostels and hospitals, in addition to which during the Ninth Plan, 1370 domestic and 58 Industrial Water Heaters were installed in Tamil Nadu.

(b) Solar Air Heating Systems

Tamilnadu has taken a lead role in the country to promote the use of Solar Air Heating technology for Tea/ Fruit processing and Grain drying. 14 systems were installed in Tamil Nadu with MNES subsidy. This process of pre-heating using solar energy saves nearly 25% of fossil fuels or firewood. The concept of solar air heating was evolved only in Tamilnadu for the first time in the country. The air gets heated when passed through the solar air heating system, which is used for bringing down the moisture content in the materials to be dried. In the process, it provides substantial fuel savings to the Industries. During Ninth Plan, 14 solar air heating Systems were installed in Tamilnadu with the research experience of Planters Energy Network, an associate of the Madurai Kamaraj University.

(c) Solar Photovoltaic Systems

Solar Photovoltaic pump is a system which produces electricity from sunlight and operates the pump to lift water from wells. A 900 watts pump can deliver about 50,000 litres of water per day over a total head of 30 feet. It can irrigate one to two acres. Under these conditions, the SPV pumps offer a reliable alternative for small farmers. The cost of a 900 watts pump is Rs.2.24 lakhs. IREDA, Government of India and GOTN provide a subsidy of Rs.1,12,500/- at Rs.125/- per watt and Rs.59,000/- per pump respectively and the remaining is the farmer's contribution. During Ninth Plan period, 95 numbers of SPV pumps were installed.

SPV lantern is a portable lighting device which provides light equivalent to a 60 watt bulb for about 4 hours per day. This is very useful in remote areas where there is no electricity or where there is frequent failure of electricity. MNES, Government of India provides subsidy of Rs.1500 per lantern. During the Ninth Plan period, 1000 SPV lanterns were distributed.

SPV Street light is a stand-alone street light system with a 11 W CFL Lamp. It provides lighting for 12 hours. The cost of each light is around Rs.30,000/-. Tamilnadu Government provided a subsidy of Rs.12000/- per light. During the Ninth Plan period 60 SPV Street Lights were installed.

4. Integrated Rural Energy Planning (IREP)

The Objectives of the IREP Programme are:

(i) To provide for minimum domestic energy needs for cooking, heating and lighting purposes to rural people.

(ii) To provide the most cost effective mix of various energy sources and options for meeting the requirements of sustainable agriculture and rural development with due environmental considerations.

(iii) To ensure people's participation in planning and implementation.

(iv) To develop and strengthen mechanisms and co-ordination arrangements for linking micro level planning for rural energy with national and State level planning and programmes.

The IREP Programme is being implemented by the Tamilnadu Energy Development Agency in 21 selected blocks all over Tamilnadu. Under this programme, the optimum mix of all types of energy locally available is provided to the rural public for meeting their lighting, cooking and heating needs. The programme is funded by Government of India which meets the staff cost and the State Government bears the scheme cost. The programmes implemented in the Ninth Plan period with subsidies ranging from 25% to 100% are:

1) Improved Chulah (100% subsidy)
2) Frictionless footvalves (75% subsidy)
3) Solar Cookers (25%) subsidy.
4) Windmills for pumping water for community use (100% subsidy)
5) Other energy saving devices (25% subsidy)

5. Energy Conservation and Audit

Energy Audit is a systematic approach for effecting energy conservation in an industry. Energy audit helps in identifying and assessing potential areas where energy could be conserved.

TEDA is co-ordinating with TNEB for implementation of Energy Audit in power intensive industries in Tamil Nadu.

The Government has made Energy Audit mandatory for the industrial sector and commercial sector with high tension power consumption with maximum demand exceeding 200 kVA under Phase I and between 1000 kVA to 2000 kVA under Phase II. (The new HT services covered under mandatory Energy Audit programmes are exempted from conducting energy audit for a period of 3 years from the date of service connection).

TNEB received Energy Audit Reports on 181 HT industries (having a demand of more than 2000 kVA) covered under Phase I from the registered Energy Auditors. Out of these, implementation schedule for 102 Nos. has been received. Savings in energy achieved so far is 1494 lakh units / annum. The total projected saving is 2198 units, i.e. a capacity equivalent of 25 MW of Rs.125 crores.

6. Publicity

Tamilnadu Energy Development Agency conducts seminars, exhibitions, business meets etc. using press and media and also participates in the seminars, meets, exhibitions sponsored by various Agencies in order to propagate the usefulness of the Non conventional Sources of Energy. It is very essential to create awareness of the benefits derived by the use of NCES to reach the urban public and also to be taken to the root level in rural areas by organising energy fairs and exhibitions. One Mobile Exhibition Van is available in Tamilnadu Energy Development Agency, which is sent to exhibitions, Government functions like inaugural functions, festivals and meetings for publicity purposes throughout State.

7. Evaluation Studies

To evaluate the working of these systems and to bring forth the bottlenecks and to find out remedy to make the systems work successfully, periodical evaluation studies were conducted by TEDA to prove the success or failure of the programme so as to decide the continuance or discontinuance of the programme. During the Ninth Plan period the following Evaluation Studies were conducted by TEDA:

(i) Biogas Plants 117 Nos.

(ii) SPV Pumps 100 Nos.

(iii) Wind mill for Water Pumping 108 Nos.

(iv) Wind Electric Generators – 2599 Nos.(711 MW)

(v) SPV Street Lights – 108 Nos. Solar Water Heating Systems: Domestic –100 Nos.; Industrial – 10 Nos.; and Government Buildings – 14 Nos.

Bottlenecks and Constraints

While the performance under the renewable energy sources programmes upto Eighth Five Year Plan was relatively good, the pace of implementation suffered during the Ninth Plan period due to various constraints, some of which are as follows:

(i) Renewable Energy Technologies are capital intensive and require high initial investment which investors could not mobilize in the absence of financial support including capital subsidy from the Central Government/ State Government.

(ii) The power purchase policy has not been encouraging for private entrepreneurs and suitable policy initiatives in the form of wheeling, and banking facilities, evacuation, arrangements, land allotment etc., need to be considered to boost investment.

(iii) Technologies for several renewable energy sources have not fully stabilized which has hampered the development and hence more intensive R&D efforts are called for with special focus on partnership with industry.

(iv) Since the cost of renewable energy gadgets/ devices such as solar cooker, biogas, solar geysers, solar lanterns etc., is high, it is not possible to generate sufficient demand for these items though the people are aware of the advantages. Hence, the cost needs to be reduced through suitable support to manufacturers.

(v) Fiscal incentives namely 100% depreciation attracted several private investors. But it has been diluted to a considerable extent by the imposition of Minimum Alternative Tax.

(vi) Adequate number of professionally skilled manpower has not been developed in the renewable energy sector and hence training programmes may be organized to develop required manpower.

Tenth Five Year Plan

Vision

- Provide and promote "clean and green energy" on much wider scale covering villages and towns to meet the decentralized energy requirements in agriculture, small scale industries, commercial establishments and households with priority for remote habitations which do not enjoy grid power.
- Enhance the generation of grid quality power through private investment for harnessing various renewable energy sources.
- Encourage energy efficient buildings which will conserve energy to meet energy requirements from naturally available resources.
- Promote energy efficiency and energy conservation in industries domestic use etc.

Goals and Objectives

The national goal of meeting 10% of grid capacity from renewable sources by 2010 has been achieved by Tamil Nadu (12.5%) even as on 31.3.02. Under the Tenth Plan, the goal is to consolidate and stabilize the share of grid connected power with addition of 550 MW and also achieve decentralized power generation to meet the local energy needs in agriculture, agro- processing, households etc., especially in remote areas and expand the use of renewable energy sources and promote energy efficiency and thereby energy saving.

Strategies

i. Encourage and promote private investments in renewable energy through suitable policy initiatives at State level.

ii. Involve local bodies in developing decentralized power and its use in agriculture, household sectors etc.

iii. Establish field units to promote renewable energy at local levels by integrating existing programme staff.

iv. Enable suitable revision of power purchase rate for grid connected power to make it attractive for the investors.

v. Encourage research and development to improve efficiency of the devices and bring down the cost.

vi. Undertake awareness campaigns in Districts through seminars, exhibition, etc.

New initiatives

The following new initiatives are proposed during the Tenth Plan:

i) Undertake further studies for micrositing for setting up of Wind Mills by identifying proper and suitable locations

ii) Undertake Biomass potential assessment studies at Taluk level and make data on Biomass potential available for prospective investors

iii) Merge the staff under Centrally sponsored schemes like IREP and National Biogas Development programme and create field outfits to provide guidance and support to local bodies in tapping renewable energy.

iv) Popularise and propagate renewable energy use among industries and households in rural and urban areas

v) Secure proper and reasonable price for grid connected power through State Electricity Regulatory Commission

vi) Arrange for suitable adjustments in wheeling and banking facilities, and third party sale to attract further investment in renewable energy sector and

vii) Designate TEDA as single window agency to facilitate smooth clearance for projects upto certain capacity say 25 MW.

Programmes for Tenth Five Year Plan (2002-07)

A. Wind Energy

i. Wind Power Generation - It is proposed to add 250 MW wind power generation through private sector during Tenth Plan period, if policy measures, especially power purchase price, are taken in accordance with the guidelines of the Ministry of Non-conventional Energy Sources (MNES).

ii. Micro-Level Study- To provide accurate data to the entrepreneurs, it is proposed to conduct micro-level study through C-WET in some of the unexplored regions in the State particularly in hilly terrains. An outlay of Rs.10 lakhs is proposed for the Tenth Plan at Rs. 2 lakhs each for 5 locations.

iii. Maintenance of Wind Monitoring Stations - An amount of Rs.32,000/- per annum is proposed for the maintenance of 3 existing permanent wind monitoring stations in Tamil Nadu by Tamil Nadu Energy Development Agency (TEDA). An outlay of Rs.1.60 lakhs is proposed for the above purpose for five years.

iv. Wind mills for Water Pumping - It is proposed to provide Rs.20,000/- per windmill as additional subsidy over and above the Central Subsidy for installing 20 Nos. of Wind Mill for water pumps in the State during Tenth Plan. An outlay of Rs. 4 lakhs is proposed this scheme.

v. Wind – Solar Hybrid Systems - In order to promote the new concept of wind – solar hybrid system in the case of private investors, it is proposed to give an additional subsidy of Rs.50,000/- per KW over and above Central Subsidy for a total of 40 KW in multiples of 1 KW. during the Tenth Plan. An outlay of Rs.20 lakhs is proposed for this scheme.

During Tenth Plan, a total outlay of Rs.35.60 lakhs has been proposed for Wind Power generation programmes.

B. Bio-Energy

i. Bio-Gas Plant - The Bio-Gas development is being undertaken as a State Level Programme for community and institutional set up. It is proposed to instal 10 numbers of Bio-Gas Plants in Sugar Mills using pressmud with 60 cum capacity. A provision of Rs. 11.50 lakhs has been proposed as State Subsidy Component during the Tenth Five Year Plan.

ii. Community Bio-gas Plants (CBP)- TEDA has installed 9 Community Biogas Plants under State Funding. It is proposed to maintain these plants at an annual cost of Rs.12,000/- per year per plant through Non-Governmental organizations such as Rotary Club, etc. An outlay of Rs.5.40 lakhs is proposed for this scheme. A total outlay of Rs.16.90 lakhs has been proposed for the Bio-Gas Plants Programme during Tenth Plan.

iii. Gasifier - It is proposed to install 50 Nos. of Gasifiers of 100 Kwe capacity with a State subsidy at 20% of the cost of Rs. 5 lakhs each. The Gasifiers are proposed to be installed in Educational Institutions for cooling applications. An outlay of Rs. 50 lakhs is proposed for this scheme during the Tenth Plan.

iv. Energy Park - The establishment of Energy Parks in various institutions will be continued under MNES programme. It is proposed to establish a State Level Energy Park at Chennai with financial assistance upto Rs. 1 Crore from Ministry of Non-conventional Energy Sources and the State Government's share of Rs. 60 lakhs towards the cost of civil works in buildings etc., and a minimum of 3 to 5 acres of land in TEDA's name, having easy access to Public. Further seminar halls etc. can also be built in these in order to generate sufficient revenue component for maintaining the energy park as self supporting. The objectives of the Energy Park will include generating awareness amongst common people about renewable and non-conventional resources of energy, energy conservation practices and to attract entrepreneurs towards renewable energy based projects.

A total outlay of Rs.126.90 lakhs has been proposed for the Bio-Energy Programmes during the Tenth Plan period.

C.1. Solar Energy

(i) Solar Photovoltaic Lantern - During Tenth Plan, it is proposed to distribute 1,000 lanterns per year to the poor people like fishermen. The above SPV Lanterns will emit light covering 360 degrees and will be capable of lighting for 3 hours for a CFL 7 watts lantern or 4 hours for a CFL 5 watts lantern with an average daily solar radiation of 5 kwhr / sq.mt. of horizontal surface. The cost of a lantern is Rs.4,000/- which includes the cost of module, electronics and lamp accessories. It is proposed to provide 100% State subsidy for this scheme. The total cost will be Rs. 40 lakhs / annum.

The number of beneficiaries during Tenth Plan will be 5,000. An outlay of Rs. 200 lakhs is proposed for this scheme during the Tenth Plan.

(ii) Solar Photovoltaic Pump - Against a back log of 4,70,000 applications for service connection for agricultural pump-sets with TNEB, only 40,000 could be covered per year. The Board is also suffering commercial losses due to free supply of power to them apart from the line losses of around 20%. Hence SPV pump is the most reliable and cost effective alternative option. It has no battery and easy to maintain and the life of solar module which converts solar energy directly into electricity is more than 10 years. A 900 watt pump cost Rs.2.24 lakhs, of which Rs.50,000/- will be borne by the beneficiary, Rs.99,000/- (at Rs.110/- per watt) by MNES and Rs.75,000/- is proposed as State subsidy. It is proposed to instal 70 SPV pumps every year with a total outlay of Rs.53.20 lakh/ year including Rs.1000/- per pump as service charges to TEDA. The total outlay for Tenth Plan is Rs.266 lakhs.

(iii) SPV Street Lights - Like other SPV programmes, it is proposed to install 100 SPV Street Lights per year in selected areas in consultation with District Collectors in the industrial premises, parks, gardens, educational, charitable institutions etc. The cost of each Street Light is Rs.30,000. The subsidy component is Rs.11,000/- per light and Rs.500 will be charged by TEDA as service charge. The balance cost will be met by the beneficiary organization. During the Tenth Plan, it is proposed to instal 500 SPV Street Lights. An outlay of Rs.57.50 lakhs is proposed for this scheme.

(iv) SPV Home Lighting - It is proposed to instal SPV Home Lights in selected buildings in consultation with District Collectors in industrial premises, tourist places etc. During Tenth Plan, it is proposed to instal 200 Home lights per year with a subsidy of Rs.5500/- per system and Rs.200/- each as service charges to TEDA. The balance cost will be met by the beneficiary organization. This scheme provides easy and quick method for electrification of households in remote and difficult villages and hamlets in the State. During Tenth Plan it is proposed to instal 1000 numbers of SPV Home Lighting Systems. An outlay of Rs.57 lakhs is proposed for this programme during Tenth Plan.

(v) Repayment of IREDA Loan - During 1993-94, the Government of Tamilnadu sanctioned installation of 50 SPV pumps, for which Government has undertaken to repay the IREDA loan of Rs.40 lakhs at the rate of Rs.80,000/- per pump and interest at 2.5% thereon over a period of ten years. All the 50 SPV pumps have been installed. Up to Ninth Plan, eight instalments have been paid and the remaining 2 instalments will have to be paid during Tenth Plan, which works out to Rs.8.28 lakhs. An evaluation study of the above 100 SPV pumps conducted by Anna University during 1998-99 showed that 73% of the pumps are working satisfactorily and the rest were having minor problems due to non-maintenance of the pumps. A provision of Rs.8.28 lakhs is proposed for this scheme as loan component.

(vi) Electrification for remote habitations (matching grant by State Govt.) - TNEB has identified 122 Nos. of remote hamlets spread over 11 districts in Tamilnadu, which could not be electrified by conventional grid supply. Electrification of the above hamlets is proposed during the Tenth Five

Annexure – I
Yearwise Tenth Plan (2002-07) -Financial Outlay

(Rs in lakhs)

Scheme	2002-03	2003-04	2004-05	2005-06	2006-07	Outlay
I.WIND ENERGY Micro Study of remaining Windy Station and further Wind Monitoring Stations through C-WET	2.00	2.00	2.00	2.00	2.00	10.00
2. Maintenance of 3 permanent Wind Monitoring Stations	0.32	0.32	0.32	0.32	0.32	1.60
3. Installation of Wind Mills for water pumping		1.00	1.00	1.00	1.00	4.00
4. Wind Solar Hybrid System		5.00	5.00	5.00	5.00	20.00
Total –I Wind Energy	**2.32**	**8.32**	**8.32**	**8.32**	**8.32**	**35.60**
II. SOLAR ENERGY 1. SPV Lanterns	40.00	40.00	40.00	40.00	40.00	200.00
2. SPV Pumps	53.20	53.20	53.20	53.20	53.20	266.00
3. SPV Street Lights	11.50	11.50	11.50	11.50	11.50	57.50
4. Repayment of IREDA loan	4.19	4.09	--	--	--	8.28
5. SPV Home Light Systems	11.40	11.40	11.40	11.40	11.40	57.00
6. Electrification of hamlets	--	61.00	61.00	--	-	122.00
Total –II –Solar Energy	**120.29**	**181.19**	**177.10**	**116.10**	**116.10**	**710.78**

Scheme	2002-03	2003-04	2004-05	2005-06	2006-07	Outlay
III. SOLAR THERMAL ENERGY 1. Domestic Solar Water Heating Systems	23.10	23.10	23.10	23.10	23.10	115.50
2. Industrial Solar Water Heating Systems	7.70	7.70	7.70	7.70	7.70	38.50
3. Installation of Solar Water Heating Systems in Government Hospitals/ Institutions	40.00	40.00	40.00	40.00	40.00	200.00
4. Installation of solar stills	0.30	0.30	0.30	0.30	0.30	1.50
5. Solar Passive Architecture System	12.25	12.25	12.25	12.25	12.25	61.25
6.Solar Air Heating Systems	10.50	10.50	10.50	10.50	10.50	52.50
7. Solar Cooker *	4.10	4.10	4.10	4.10	4.10	20.50
III.Total - Solar Thermal Energy	**97.95**	**97.95**	**97.95**	**97.95**	**97.95**	**489.75**
IV. BIO – ENERGY - **1. Biogas** Industries Sugar Mills	2.30	2.30	2.30	2.30	2.30	11.50
Maintenance of 9 CBPs	1.08	1.08	1.08	1.08	1.08	5.40
2.Gassifier Cooking application for Education Institutions	10.00	10.00	10.00	10.00	10.00	50.00
3. State Level Energy Park	0.00	0.00	60.00	0.00	0.00	60.00
Total – IV- Bio-Energy	**13.38**	**13.38**	**73.38**	**13.38**	**13.38**	**126.90**

Scheme	2002-03	2003-04	2004-05	2005-06	2006-07	Outlay
V. INTEGRATED RURAL ENERGY PROGRAMME 1. Continuance of IREP in 21 blocks – for devices - for staff	105.00 30.58	105.00 30.58	105.00 30.58	105.00 30.58	105.00 30.58	525.00 152.90 *
Sub - Total	**135.58**	**135.58**	**135.58**	**135.58**	**135.58**	**677.90**
2. Matching grant (10%) for IREP under International funding Assistance	50.00	50.00	50.00	50.00	50.00	250.00
Total – V – IREP	**185.38**	**185.38**	**185.38**	**185.38**	**185.38**	**927.90**
VI. Publicity	**10.00**	**10.00**	**10.00**	**10.00**	**10.00**	**50.00**
VII. Evaluation studies	**0.00**	**6.00**	**6.00**	**6.00**	**6.00**	**24.00**
VIII.Research and Devp	**20.00**	**20.00**	**20.00**	**20.00**	**20.00**	**100.00**
IX. Establish-ment cost	**70.00**	**80.00**	**100.00**	**120.00**	**130.00**	**500.00**
GRAND TOTAL	**499.52**	**607.42**	**683.33**	**582.33**	**592.33**	**2964.93 or 2965.00**

* Funded by Government of India

Annexure – III
Specific Monitorable Targets

The following specific targets are envisaged for the tenth plan for propagating non-conventional renewal sources of energy.

Sl. No	Scheme	Units	Targets
1.	Micro Study of Remaining Wind Stations	Nos.	24
2.	Wind Mill Water Pumps	Nos.	20
3.	Wind Solar Hybrid System	KW	40
4.	SPV Lantern	Nos.	5000
5.	SPV Pumps	Nos.	350
6.	SPV Street Lights	Nos.	500
7.	SPV Home Lights	Nos.	1000
8.	Electrification of Remote Areas	Habitates in Numbers.	122
9.	Domestic Solar Water Heaters	Nos.	3500
10.	Industrial Solar Water Heaters	Nos.	175
11.	Solar Water Heating System (Govt. Buildings)	Nos.	50
12.	Solar Stills	LPD	25
13.	Solar Passive Architecture System	DRPs Buildings	25 10
14.	Solar Air Heating Systems	Sq.M	5000
15.	Solar Cooker (Box Type) (Dish Type)	Nos. Nos.	500 100
16.	Bio Gas Plant	Nos.	10
17.	Gasifiers (100 KW)	Nos.	50
18.	State Level Energy Park	Nos.	1
19.	IREP – Continuance of IREP in 21 Blocks: Rural Energy Programme with International Funding Assistance.	Nos.	21

UNIT III

ENERGY TECHNOLOGIES

This section briefly describes the Boiler and various auxiliaries in the Boiler Room.

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred to water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process. Water is a useful and inexpensive medium for transferring heat to a process. When water at atmospheric pressure is boiled into steam its volume increases about 1,600 times, producing a force that is almost as explosive as gunpowder. This causes the boiler to be an equipment that must be treated with utmost care.

The boiler system comprises of: a feed water system, steam system and fuel system. The **feed water system** provides water to the boiler and regulates it automatically to meet the steam demand. Various valves provide access for maintenance and repair. The **steam system** collects and controls the steam produced in the boiler. Steam is directed through a piping system to the point of use. Throughout the system, steam pressure is regulated using valves and checked with steam pressure gauges. The **fuel system** includes all equipment used to provide fuel to generate the necessary heat. The equipment required in the fuel system depends on the type of fuel used in the system.

The water supplied to the boiler that is converted into steam is called **feed water**. The two sources of feed water are: (1) **Condensate** or condensed steam returned from the processes and (2) **Makeup water** (treated raw water) which must come from outside the boiler room and plant processes. For higher boiler efficiencies, an economizer preheats the feed water using the waste heat in the flue gas.

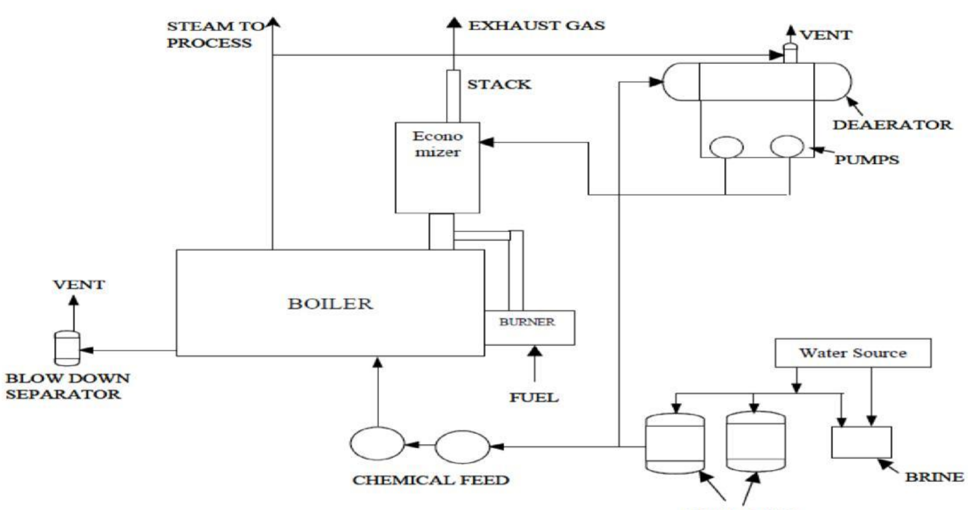


Figure 1. Schematic diagram of a Boiler Room

2. TYPE OF BOILERS

This section describes the various types of boilers: Fire tube boiler, Water tube boiler, Packaged boiler, Fluidized bed combustion boiler, Stoker fired boiler, Pulverized fuel boiler, Waste heat boiler and Thermic fluid heater.

2.1 Fire Tube Boiler

In a fire tube boiler, hot gases pass through the tubes and boiler feed water in the shell side is converted into steam. Fire tube boilers are generally used for relatively small steam capacities and low to medium steam pressures. As a guideline, fire tube boilers are competitive for steam rates up to 12,000 kg/hour and pressures up to 18 kg/cm^2. Fire tube boilers are available for operation with oil, gas or solid fuels. For economic reasons, most fire tube boilers are of "packaged" construction (i.e. manufacturer erected) for all fuels.

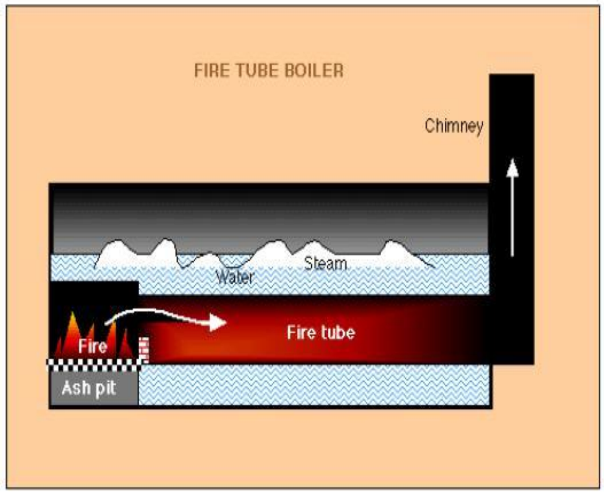


Figure 2. Sectional view of a Fire Tube Boiler
(Light Rail Transit Association)

2.2 Water Tube Boiler

In a water tube boiler, boiler feed water flows through the tubes and enters the boiler drum. The circulated water is heated by the combustion gases and converted into steam at the vapour space in the drum. These boilers are selected when the steam demand as well as steam pressure requirements are high as in the case of process cum power boiler / power boilers.

Most modern water boiler tube designs are within the capacity range 4,500 – 120,000 kg/hour of steam, at very high pressures. Many water tube boilers are of "packaged" construction if oil and /or gas are to be used as fuel. Solid fuel fired water tube designs are available but packaged designs are less common.

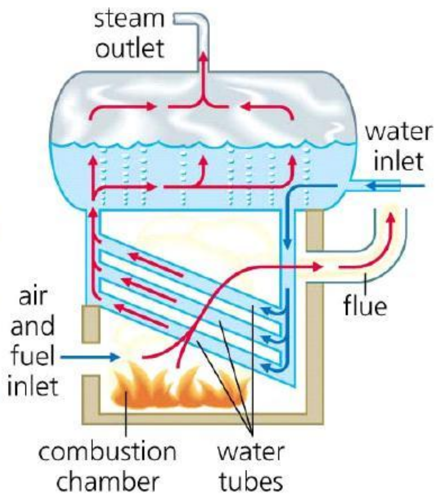


Figure 3. Simple Diagram of Water Tube Boiler (YourDictionary.com)

The features of water tube boilers are:

- Forced, induced and balanced draft provisions help to improve combustion efficiency.
- Less tolerance for water quality calls for water treatment plant.
- Higher thermal efficiency levels are possible

2.3 Packaged Boiler

The packaged boiler is so called because it comes as a complete package. Once delivered to a site, it requires only the steam, water pipe work, fuel supply and electrical connections to be made to become operational. Package boilers are generally of a shell type with a fire tube design so as to achieve high heat transfer rates by both radiation and convection.

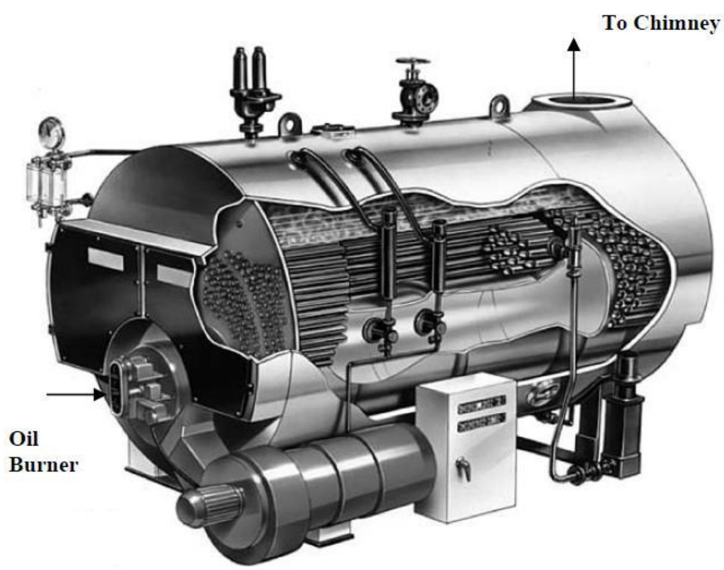


Figure 4. A typical 3 Pass, Oil fired packaged boiler
(BIB Cochran, 2003)

The features of packaged boilers are:

- Small combustion space and high heat release rate resulting in faster evaporation.
- Large number of small diameter tubes leading to good convective heat transfer.
- Forced or induced draft systems resulting in good combustion efficiency.
- Number of passes resulting in better overall heat transfer.
- Higher thermal efficiency levels compared with other boilers.

These boilers are classified based on the number of passes - the number of times the hot combustion gases pass through the boiler. The combustion chamber is taken, as the first pass after which there may be one, two or three sets of fire-tubes. The most common boiler of this class is a three-pass unit with two sets of fire-tubes and with the exhaust gases exiting through the rear of the boiler.

2.4 Fluidized Bed Combustion (FBC) Boiler

Fluidized bed combustion (FBC) has emerged as a viable alternative and has significant advantages over a conventional firing system and offers multiple benefits – compact boiler design, fuel flexibility, higher combustion efficiency and reduced emission of noxious pollutants such as SOx and NOx. The fuels burnt in these boilers include coal, washery rejects, rice husk, bagasse & other agricultural wastes. The fluidized bed boilers have a wide capacity range- 0.5 T/hr to over 100 T/hr.

When an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on a fine mesh, the particles are undisturbed at low velocity. As air velocity is gradually increased, a stage is reached when the individual particles are suspended in the air stream – the bed is called "fluidized".

With further increase in air velocity, there is bubble formation, vigorous turbulence, rapid mixing and formation of dense defined bed surface. The bed of solid particles exhibits the properties of a boiling liquid and assumes the appearance of a fluid – "bubbling fluidized bed".

If sand particles in a fluidized state are heated to the ignition temperatures of coal, and coal is injected continuously into the bed, the coal will burn rapidly and the bed attains a uniform temperature. The fluidized bed combustion (FBC) takes place at about $840^{O}C$ to $950^{O}C$. Since this temperature is much below the ash fusion temperature, melting of ash and associated problems are avoided.

The lower combustion temperature is achieved because of high coefficient of heat transfer due to rapid mixing in the fluidized bed and effective extraction of heat from the bed through in-bed heat transfer tubes and walls of the bed. The gas velocity is maintained between minimum fluidization velocity and particle entrainment velocity. This ensures stable operation of the bed and avoids particle entrainment in the gas stream.

2.4.1 Atmospheric Fluidized Bed Combustion (AFBC) Boiler

Most operational boiler of this type is of the Atmospheric Fluidized Bed Combustion. (AFBC). This involves little more than adding a fluidized bed combustor to a conventional shell boiler. Such systems have similarly being installed in conjunction with conventional water tube boiler.

Coal is crushed to a size of 1 – 10 mm depending on the rank of coal, type of fuel fed to the combustion chamber. The atmospheric air, which acts as both the fluidization and combustion air, is delivered at a pressure, after being preheated by the exhaust fuel gases. The in-bed tubes carrying water generally act as the evaporator. The gaseous products of combustion pass over the super heater sections of the boiler flowing past the economizer, the dust collectors and the air pre-heater before being exhausted to atmosphere.

2.4.2 Pressurized Fluidized Bed Combustion (PFBC) Boiler

In Pressurized Fluidized Bed Combustion (PFBC) type, a compressor supplies the Forced Draft (FD) air and the combustor is a pressure vessel. The heat release rate in the bed is proportional to the bed pressure and hence a deep bed is used to extract large amounts of heat. This will improve the combustion efficiency and sulphur dioxide absorption in the bed. The steam is generated in the two tube bundles, one in the bed and one above it. Hot flue gases drive a power generating gas turbine. The PFBC system can be used for cogeneration (steam and electricity) or combined cycle power generation. The combined cycle operation (gas turbine & steam turbine) improves the overall conversion efficiency by 5 to 8 percent.

2.4.3 Atmospheric Circulating Fluidized Bed Combustion Boilers (CFBC)

In a circulating system the bed parameters are maintained to promote solids elutriation from the bed. They are lifted in a relatively dilute phase in a solids riser, and a down-comer with a cyclone provides a return path for the solids. There are no steam generation tubes immersed in the bed. Generation and super heating of steam takes place in the convection section, water walls, at the exit of the riser.

CFBC boilers are generally more economical than AFBC boilers for industrial application requiring more than 75 – 100 T/hr of steam. For large units, the taller furnace characteristics of CFBC boilers offers better space utilization, greater fuel particle and sorbent residence time for efficient combustion and SO_2 capture, and easier application of staged combustion techniques for NO_x control than AFBC steam generators.

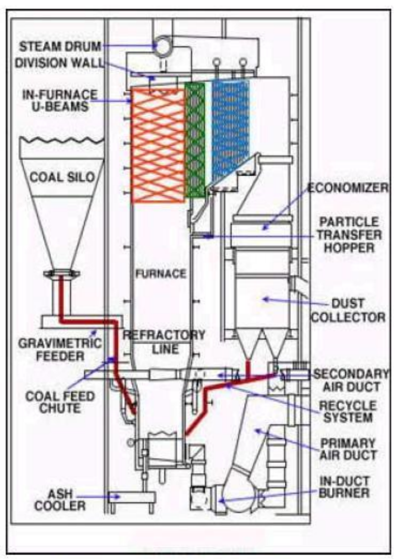


Figure 5. CFBC Boiler
(Thermax Babcock & Wilcox Ltd, 2001)

2.5 Stoker Fired Boilers

Stokers are classified according to the method of feeding fuel to the furnace and by the type of grate. The main classifications are spreader stoker and chain-gate or traveling-gate stoker.

2.5.1 Spreader stokers

Spreader stokers utilize a combination of suspension burning and grate burning. The coal is continually fed into the furnace above a burning bed of coal. The coal fines are burned in suspension; the larger particles fall to the grate, where they are burned in a thin, fast-burning coal bed. This method of firing provides good flexibility to meet load fluctuations, since ignition is almost instantaneous when the firing rate is increased. Due to this, the spreader stoker is favored over other types of stokers in many industrial applications.

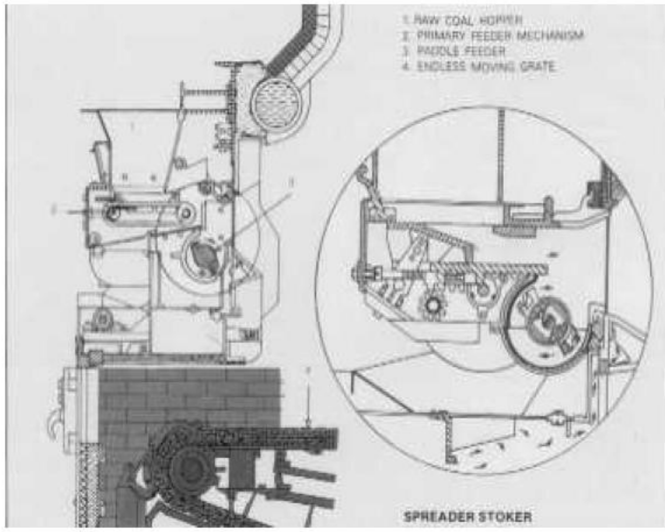


Figure 6. Spreader Stoker Boiler
(Department of Coal, 1985)

2.5.2 Chain-grate or traveling-grate stoker

Coal is fed onto one end of a moving steel grate. As the grate moves along the length of the furnace, the coal burns before dropping off at the end as ash. Some degree of skill is required, particularly when setting up the grate, air dampers and baffles, to ensure clean combustion leaving the minimum of unburnt carbon in the ash.

The coal-feed hopper runs along the entire coal-feed end of the furnace. A coal gate is used to control the rate at which coal is fed into the furnace by controlling the thickness of the fuel bed. Coal must be uniform in size as large lumps will not burn out completely by the time they reach the end of the grate.

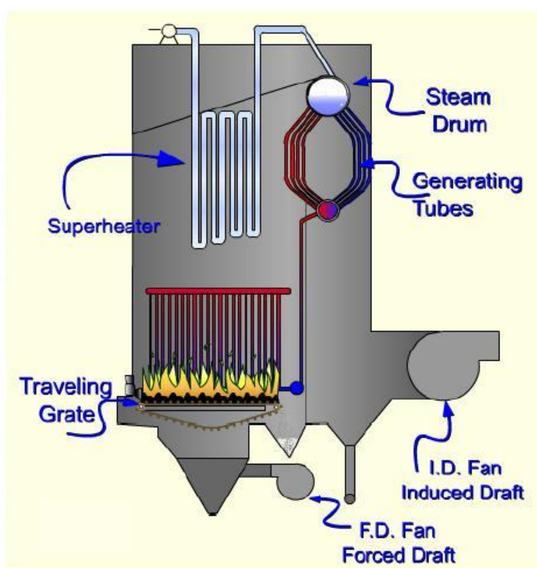


Figure 7. View of Traveling Grate Boiler
(University of Missouri, 2004)

2.6 Pulverized Fuel Boiler

Most coal-fired power station boilers use pulverized coal, and many of the larger industrial water-tube boilers also use this pulverized fuel. This technology is well developed, and there are thousands of units around the world, accounting for well over 90 percent of coal-fired capacity.

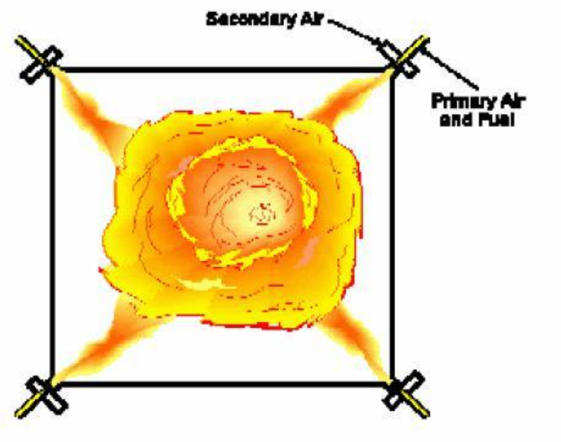


Figure 8: Tangential firing for pulverized fuel (Reference unknown)

The coal is ground (pulverized) to a fine powder, so that less than 2 percent is +300 micrometer (μm) and 70-75 percent is below 75 microns, for a bituminous coal. It should be noted that too fine a powder is wasteful of grinding mill power. On the other hand, too coarse a powder does not burn completely in the combustion chamber and results in higher unburnt losses.
The pulverized coal is blown with part of the combustion air into the boiler plant through a series of burner nozzles. Secondary and tertiary air may also be added. Combustion takes place at temperatures from 1300-1700 °C, depending largely on coal grade. Particle residence time in the boiler is typically 2 to 5 seconds, and the particles must be small enough for complete combustion to have taken place during this time.

This system has many advantages such as ability to fire varying quality of coal, quick responses to changes in load, use of high pre-heat air temperatures etc.

One of the most popular systems for firing pulverized coal is the tangential firing using four burners corner to corner to create a fireball at the center of the furnace.

2.7 Waste Heat Boiler

Wherever the waste heat is available at medium or high temperatures, a waste heat boiler can be installed economically. Wherever the steam demand is more than the steam generated during waste heat, auxiliary fuel burners are also used. If there is no direct use of steam, the steam may be let down in a steam turbine-generator set and power produced from it. It is widely used in the heat recovery from exhaust gases from gas turbines and diesel engines.

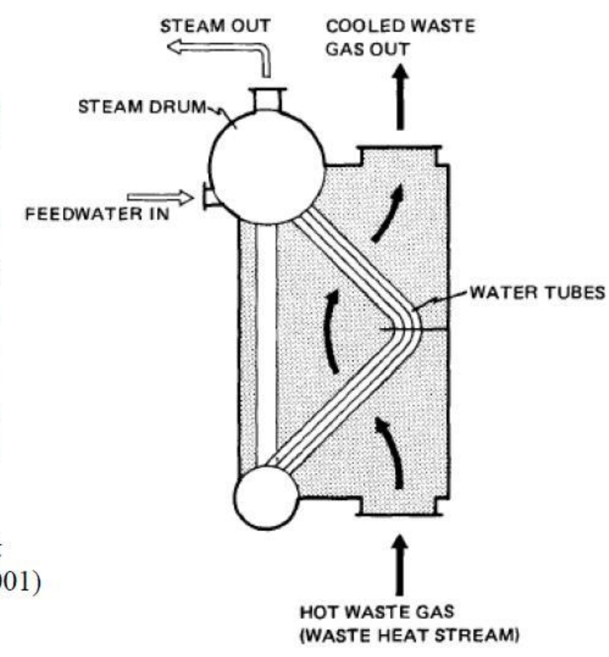


Figure 9: A simple schematic of Waste Heat Boiler (Agriculture and Agri-Food Canada, 2001)

2.8 Thermic Fluid Heater

In recent times, thermic fluid heaters have found wide application for indirect process heating. Employing petroleum - based fluids as the heat transfer medium, these heaters provide constantly maintainable temperatures for the user equipment. The combustion system comprises of a fixed grate with mechanical draft arrangements.

The modern oil fired thermic fluid heater consists of a double coil, three pass construction and fitted a with modulated pressure jet system. The thermic fluid, which acts as a heat carrier, is heated up in the heater and circulated through the user equipment. There it transfers heat for the process through a heat exchanger and the fluid is then returned to the heater. The flow of thermic fluid at the user end is controlled by a pneumatically operated control valve, based on the operating temperature. The heater operates on low or high fire depending on the return oil temperature, which varies with the system load.

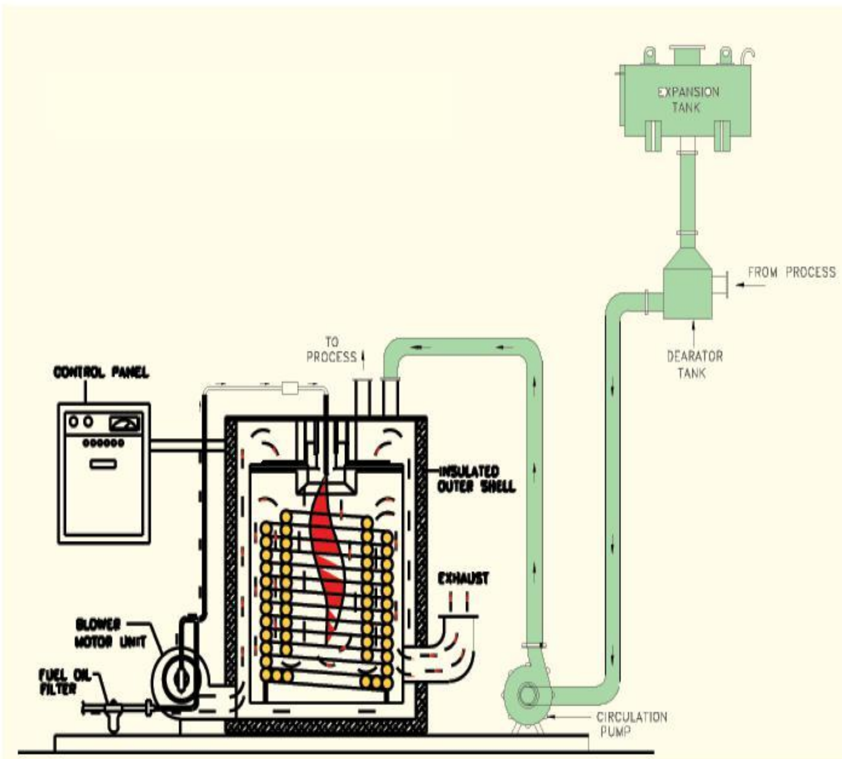


Figure 10. A typical configuration of Thermic Fluid Heater
(Energy Machine India)

The advantages of these heaters are:

- Closed cycle operation with minimum losses as compared to steam boilers.
- Non-Pressurized system operation even for temperatures around 250 ^{0}C as against 40 kg/cm^2 steam pressure requirement in a similar steam system.
- Automatic control settings, which offer operational flexibility.
- Good thermal efficiencies as losses due to blow down, condensate drain and flash steam do not exist in a thermic fluid heater system.

The overall economics of the thermic fluid heater will depend upon the specific application and reference basis. Coal fired thermic fluid heaters with a thermal efficiency range of 55-65 percent may compare favorably with most boilers. Incorporation of heat recovery devices in the flue gas path enhances the thermal efficiency levels further.

3. ASSESSMENT OF A BOILER

This section describes the Performance evaluation of boilers (through the direct and indirect method including examples for efficiency calculations), boiler blow down, and boiler water treatment.

3.1 Performance Evaluation of a Boiler

The performance parameters of a boiler, like efficiency and evaporation ratio, reduces with time due to poor combustion, heat transfer surface fouling and poor operation and maintenance. Even for a new boiler, reasons such as deteriorating fuel quality and water quality can result in poor boiler performance. A heat balance helps us to identify avoidable and unavoidable heat losses. Boiler efficiency tests help us to find out the deviation of boiler efficiency from the best efficiency and target problem area for corrective action.

3.1.1 Heat balance

The combustion process in a boiler can be described in the form of an energy flow diagram. This shows graphically how the input energy from the fuel is transformed into the various useful energy flows and into heat and energy loss flows. The thickness of the arrows indicates the amount of energy contained in the respective flows.

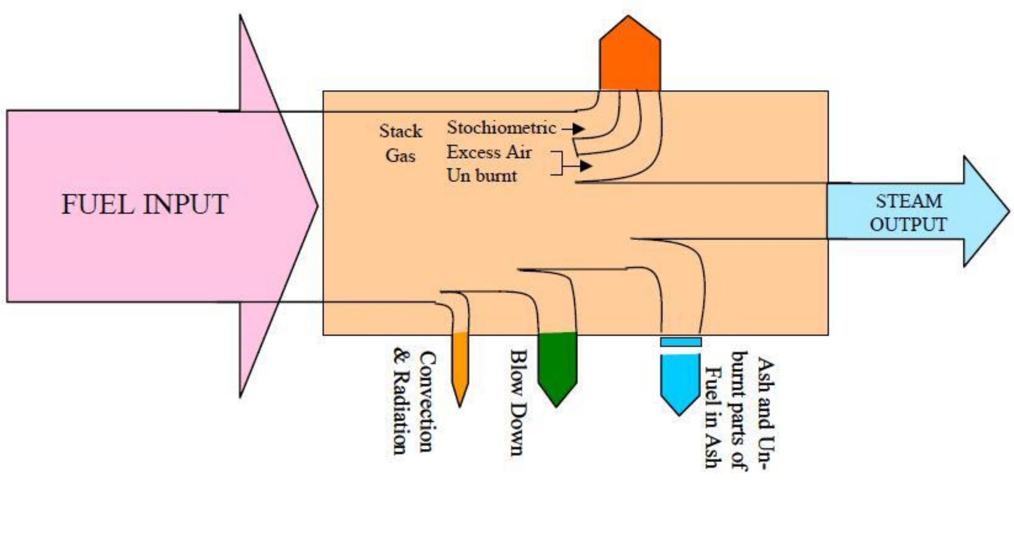


Figure 11. Energy balance diagram of a boiler

A heat balance is an attempt to balance the total energy entering a boiler against that leaving the boiler in different forms. The following figure illustrates the different losses occurring for generating steam.

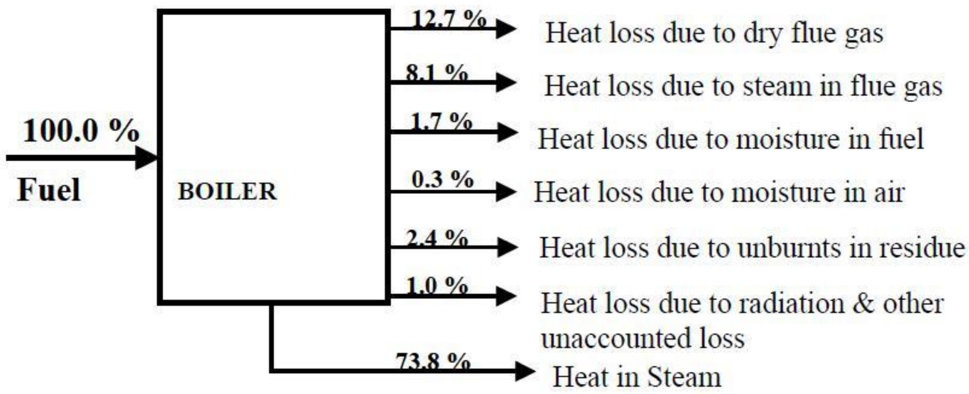


Figure 12. Typical Losses from Coal Fired Boiler

The energy losses can be divided in unavoidable and avoidable losses. The goal of a Cleaner Production and/or energy assessment must be to reduce the avoidable losses, i.e. to improve energy efficiency. The following losses can be avoided or reduced:

- Stack gas losses:
  - Excess air (reduce to the necessary minimum which depends from burner technology, operation, operation (i.e. control) and maintenance).
  - Stack gas temperature (reduce by optimizing maintenance (cleaning), load; better burner and boiler technology).
- Losses by unburnt fuel in stack and ash (optimize operation and maintenance; better technology of burner).
- Blow down losses (treat fresh feed water, recycle condensate)
- Condensate losses (recover the largest possible amount of condensate)
- Convection and radiation losses (reduced by better insulation of the boiler).

3.1.2 Boiler efficiency

Thermal efficiency of a boiler is defined as "the percentage of (heat) energy input that is effectively useful in the generated steam."

There are two methods of assessing boiler efficiency:

- The Direct Method: the energy gain of the working fluid (water and steam) is compared with the energy content of the boiler fuel
- The Indirect Method: the efficiency is the difference between the losses and the energy input

3.1.3 Direct method of determining boiler efficiency

Methodology

This is also known as 'input-output method' due to the fact that it needs only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency. This efficiency can be evaluated using the formula:

$$\text{Boiler Efficiency } (\eta) = \frac{\text{Heat Output}}{\text{Heat Input}} \times 100$$

$$\text{Boiler Efficiency } (\eta) = \frac{Q \times (h_g - h_f)}{q \times GCV} \times 100$$

Parameters to be monitored for the calculation of boiler efficiency by direct method are:

- Quantity of steam generated per hour (Q) in kg/hr.
- Quantity of fuel used per hour (q) in kg/hr.
- The working pressure (in kg/cm2(g)) and superheat temperature (oC), if any
- The temperature of feed water (oC)
- Type of fuel and gross calorific value of the fuel (GCV) in kcal/kg of fuel

And where

- h_g – Enthalpy of saturated steam in kcal/kg of steam
- h_f – Enthalpy of feed water in kcal/kg of water

Example

Find out the efficiency of the boiler by direct method with the data given below:

Type of boiler:	Coal fired
Quantity of steam (dry) generated:	10 TPH
Steam pressure (gauge) / temp:	10 kg/cm^2 (g)/ 180 ^{0}C
Quantity of coal consumed:	2.25 TPH
Feed water temperature:	85 ^{0}C
GCV of coal:	3200 kcal/kg
Enthalpy of steam at 10 kg/cm^2 pressure:	665 kcal/kg (saturated)
Enthalpy of feed water:	85 kcal/kg

$$\text{Boiler Efficiency } (\eta) = \frac{10 \times (665 - 85) \times 1000}{2.25 \times 3200 \times 1000} \times 100 = 80.56 \text{ percent}$$

Advantages of direct method

- Plant workers can evaluate quickly the efficiency of boilers
- Requires few parameters for computation

- Needs few instruments for monitoring
- Easy to compare evaporation ratios with benchmark figures

Disadvantages of direct method

- Does not give clues to the operator as to why efficiency of the system is lower
- Does not calculate various losses accountable for various efficiency levels

3.1.4 Indirect method of determining boiler efficiency

Methodology

The reference standards for Boiler Testing at Site using the indirect method are the *British Standard, BS 845:1987* and the *USA Standard ASME PTC-4-1 Power Test Code Steam Generating Units*.

The indirect method is also called the heat loss method. The efficiency can be calculated by subtracting the heat loss fractions from 100 as follows:

Efficiency of boiler (n) = 100 - (i + ii + iii + iv + v + vi + vii)

Whereby the principle losses that occur in a boiler are loss of heat due to:

i. Dry flue gas
ii. Evaporation of water formed due to H2 in fuel
iii. Evaporation of moisture in fuel
iv. Moisture present in combustion air
v. Unburnt fuel in fly ash
vi. Unburnt fuel in bottom ash
vii. Radiation and other unaccounted losses

Losses due to moisture in fuel and due to combustion of hydrogen are dependent on the fuel, and cannot be controlled by design.

The data required for calculation of boiler efficiency using the indirect method are:

- Ultimate analysis of fuel (H2, O2, S, C, moisture content, ash content)
- Percentage of oxygen or CO2 in the flue gas
- Flue gas temperature in °C (Tf)
- Ambient temperature in °C (Ta) and humidity of air in kg/kg of dry air
- GCV of fuel in kcal/kg
- Percentage combustible in ash (in case of solid fuels)
- GCV of ash in kcal/kg (in case of solid fuels)

A detailed procedure for calculating boiler efficiency using the indirect method is given below. However, practicing energy managers in industry usually prefer simpler calculation procedures.

Step 1: Calculate the theoretical air requirement

$$= [(11.43 \times C) + \{34.5 \times (H2 - O2/8)\} + (4.32 \times S)]/100 \text{ kg/kg of fuel}$$

Step 2: Calculate the percent excess air supplied (EA)

$$= \frac{O_2 \text{ percent} \times 100}{(21 - O_2 \text{ percent})}$$

Step 3: Calculate actual mass of air supplied/ kg of fuel (AAS)

$$= \{1 + EA/100\} \times \text{theoretical air}$$

Step 4: Estimate all heat losses

i. Percentage heat loss due to dry flue gas

$$= \frac{m \times C_p \times (T_f - T_a) \times 100}{\text{GCV of fuel}}$$

Where, m = mass of dry flue gas in kg/kg of fuel
m = (mass of dry products of combustion / kg of fuel) + (mass of N2 in fuel on 1 kg basis) + (mass of N2 in actual mass of air we are supplying).
Cp = Specific heat of flue gas (0.23 kcal/kg)

ii. Percentage heat loss due to evaporation of water formed due to H2 in fuel

$$= \frac{9 \times H_2 \{584 + C_p (T_f - T_a)\} \times 100}{\text{GCV of fuel}}$$

Where, H2 = percentage of H2 in 1 kg of fuel
Cp = specific heat of superheated steam (0.45 kcal/kg)

iii. Percentage heat loss due to evaporation of moisture present in fuel

$$= \frac{M\{584 + C_p (T_f - T_a)\} \times 100}{\text{GCV of fuel}}$$

Where, M – percent moisture in 1kg of fuel
Cp – Specific heat of superheated steam (0.45 kcal/kg)

iv. Percentage heat loss due to moisture present in air

$$= \frac{AAS \times \text{humidity factor} \times C_p (T_f - T_a)\} \times 100}{\text{GCV of fuel}}$$

Where, Cp – Specific heat of superheated steam (0.45 kcal/kg)

v. Percentage heat loss due to unburnt fuel in fly ash

$$= \frac{\text{Total ash collected/kg of fuel burnt x GCV of fly ash x 100}}{\text{GCV of fuel}}$$

vi. Percentage heat loss due to unburnt fuel in bottom ash

$$= \frac{\text{Total ash collected per Kg of fuel burnt x G.C.V of bottom ash x 100}}{\text{GCV of fuel}}$$

vii. Percentage heat loss due to radiation and other unaccounted loss

The actual radiation and convection losses are difficult to assess because of particular emissivity of various surfaces, its inclination, airflow patterns etc. In a relatively small boiler, with a capacity of 10 MW, the radiation and unaccounted losses could amount to between 1 percent and 2 percent of the gross calorific value of the fuel, while in a 500 MW boiler, values between 0.2 percent to 1 percent are typical. The loss may be assumed appropriately depending on the surface condition.

Step 5: Calculate boiler efficiency and boiler evaporation ratio

Efficiency of boiler (n) = 100 - (i + ii + iii + iv + v + vi + vii)

Evaporation Ratio = Heat utilized for steam generation/Heat addition to the steam

Evaporation ratio means kilogram of steam generated per kilogram of fuel consumed. Typical Examples are:

- Coal fired boiler: 6 (i.e. 1 kg of coal can generate 6 kg of steam)
- Oil fired boiler: 13 (i.e. 1 kg of oil can generate 13 kg of steam)

However, the evaporation ratio will depend upon type of boiler, calorific value of the fuel and associated efficiencies.

Example

- Type of boiler: Oil fired
- Ultimate analysis of Oil

C:	84 percent
H_2:	12.0 percent
S:	3.0 percent
O_2:	1 percent

- GCV of Oil: 10200 kcal/kg
- Percentage of Oxygen: 7 percent

- Percentage of CO_2: 11 percent
- Flue gas temperature (T_f): 220 ^{0}C
- Ambient temperature (T_a): 27 ^{0}C
- Humidity of air : 0.018 kg/kg of dry air

Step-1: Calculate the theoretical air requirement

= [(11.43 x C) + [{34.5 x (H2 – O2/8)} + (4.32 x S)]/100 kg/kg of oil
= [(11.43 x 84) + [{34.5 x (12 – 1/8)} + (4.32 x 3)]/100 kg/kg of oil
= 13.82 kg of air/kg of oil

Step-2: Calculate the percent excess air supplied (EA)

Excess air supplied (EA)
= (O2 x 100)/(21-O2)
= (7 x 100)/(21-7)
= 50 percent

Step 3: Calculate actual mass of air supplied/ kg of fuel (AAS)

AAS/kg fuel = [1 + EA/100] x Theo. Air (AAS)
= [1 + 50/100] x 13.82
= 1.5 x 13.82
= 20.74 kg of air/kg of oil

Step 4: Estimate all heat losses

i. Percentage heat loss due to dry flue gas

$$= \frac{m \times Cp \times (Tf - Ta) \times 100}{\text{GCV of fuel}}$$

m = mass of CO2 + mass of SO2 + mass of N2 + mass of O2

$$m = \frac{0.84 \times 44}{12} + \frac{0.03 \times 64}{32} + \frac{20.74 \times 77}{100} \quad (0.07 \times 32)$$

m = 21.35 kg / kg of oil

$$= \frac{21.35 \times 0.23 \times (220 - 27)}{10200} \times 100$$

= 9.29 percent

A simpler method can also be used: Percentage heat loss due to dry flue gas

$$= \frac{m \times Cp \times (Tf - Ta) \times 100}{GCV \text{ of fuel}}$$

m (total mass of flue gas)

= mass of actual air supplied + mass of fuel supplied

= 20.19 + 1 = 21.19

$$= \frac{21.19 \times 0.23 \times (220-27)}{10200} \times 100$$

= 9.22 percent

ii. Heat loss due to evaporation of water formed due to H2 in fuel

$$= \frac{9 \times H2 \{584+0.45 (Tf - Ta)\}}{GCV \text{ of fuel}}$$ where H2 = percentage of H2 in fuel

$$= \frac{9 \times 12 \{584+0.45(220-27)\}}{10200}$$

= 7.10 percent

iii. Heat loss due to moisture present in air

$$= \frac{AAS \times humidity \times 0.45 \times ((Tf - Ta) \times 100}{GCV \text{ of fuel}}$$

= [20.74 x 0.018 x 0.45 x (220-27) x 100]/10200

= 0.317 percent

iv. Heat loss due to radiation and other unaccounted losses

For a small boiler it is estimated to be 2 percent

Step 5: Calculate boiler efficiency and boiler evaporation ratio

Efficiency of boiler (n) = 100 - (i + ii + iii + iv + v + vi + vii)

i. Heat loss due to dry flue gas : 9.29 percent
ii. Heat loss due to evaporation of water formed due to H2 in fuel : 7.10 percent

iii. Heat loss due to moisture present in air : 0.317 percent
iv. Heat loss due to radiation and other unaccounted losses : 2 percent

= 100- [9.29+7.10+0.317+2]

= 100 – 17.024 = 83 percent (approximate)

Evaporation Ratio = Heat utilized for steam generation/Heat addition to the steam

= 10200 x 0.83 / (660-60)
= 14.11 (compared to 13 for a typical oil fired boiler)

Advantages of indirect method

- A complete mass and energy balance can be obtained for each individual stream, making it easier to identify options to improve boiler efficiency

Disadvantages of indirect method

- Time consuming
- Requires lab facilities for analysis

3.2 Boiler Blow Down

When water is boiled and steam is generated, any dissolved solids contained in the water remain in the boiler. If more solids are put in with the feed water, they will concentrate and may eventually reach a level where their solubility in the water is exceeded and they deposit from the solution. Above a certain level of concentration, these solids encourage foaming and cause carryover of water into the steam. The deposits also lead to scale formation inside the boiler, resulting in localized overheating and finally causing boiler tube failure.

It is therefore necessary to control the level of concentration of the solids in suspension and dissolved in the boiled water. This is achieved by the process of 'blowing down', where a certain volume of water is blown off and is automatically replaced by feed water - thus maintaining the optimum level of total dissolved solids (TDS) in the boiler water and removing those solids that have fallen out of solution and which tend to settle on the internal surfaces of the boiler. Blow down is necessary to protect the surfaces of the heat exchanger in the boiler. However, blow down can be a significant source of heat loss, if improperly carried out.

Since it is tedious and time consuming to measure TDS in a boiler water system, conductivity measurement is used for monitoring the overall TDS present in the boiler. A rise in conductivity indicates a rise in the "contamination" of the boiler water.

Boiler Water Sampling

A boiler water sample is only useful if it is representative of the conditions inside the boiler. Therefore samples taken from the level gauge glass, externally mounted level control chambers, or close to the feed water inlet connection are likely to be very inaccurate.

A sample taken from the boiler shell is unsafe and inaccurate because the water is under pressure and a significant proportion will flash into steam. Therefore higher TDS concentrations are measured in the sample than inside the boiler. Based on these sample analysis results, it is very common that more boiler water is blown down than necessary.

The solution is to use a sample cooler to extract water from a boiler. A sample cooler is a small heat exchanger that uses cold water to cool the sample being withdrawn, thereby eliminating any flashing and improving operator safety and sample accuracy. In some automatic systems, a conductivity sensor is mounted directly into the boiler shell to monitor the TDS levels continuously. Another reason for an automatic TDS control system is to avoid the influence of variability in steam load, rate of condensate return, and make-up water quality on the sample results.

3.2.1 Two types of blow down

Conventional methods for blowing down the boiler depend on two kinds of blow down: intermittent and continuous.

a) Intermittent blow down

The intermittent blown down is given by manually operating a valve fitted to a discharge pipe at the lowest point of the boiler shell to reduce parameters (TDS or conductivity, pH, Silica and Phosphates concentration) within prescribed limits so that steam quality is not likely to be affected. This type of blow down is also an effective method to remove solids that have fallen out of solution and have settled upon the fire tubes and the internal surface of the boiler shell. In intermittent blow down, a large diameter line is opened for a short period of time, the time being based on a general rule such as "once in a shift for 2 minutes".

Intermittent blow down requires l*arge* short-term increases in the amount of feed water put into the boiler, and hence may necessitate larger feed water pumps than if continuous blow down is used. Also, TDS level will vary, thereby causing fluctuations of the water level in the boiler due to changes in steam bubble size and distribution which accompany changes in concentration of solids. Also, a substantial amount of heat energy is lost with intermittent blow down.

b) Continuous blow down

There is a steady and constant dispatch of a small stream of concentrated boiler water, and replacement by steady and constant inflow of feed water. This ensures constant TDS and steam purity at a given steam load. Once a blow down valve is set for a given conditions, there is no need for regular operator intervention.

Even though large quantities of heat are removed from the boiler, opportunities exist for recovering this heat by blowing into a flash tank and generating flash steam. This flash steam can be used for pre-heating boiler feed water. This type of blow down is common in high-pressure boilers.

The residual blowdown which leaves the flash vessel still contains a good deal of heat energy and a significant proportion of this can also be recovered by introducing a heat exchanger to heat up cold make-up water. Complete blowdown heat recovery systems such as the one illustrated below which extract the flash steam and the energy content of the residual blowdown, can recover up to 80% of the energy contained in the blowdown. They can be applied to any size of steam boiler and an investment in such a system is often recovered in a matter of months.

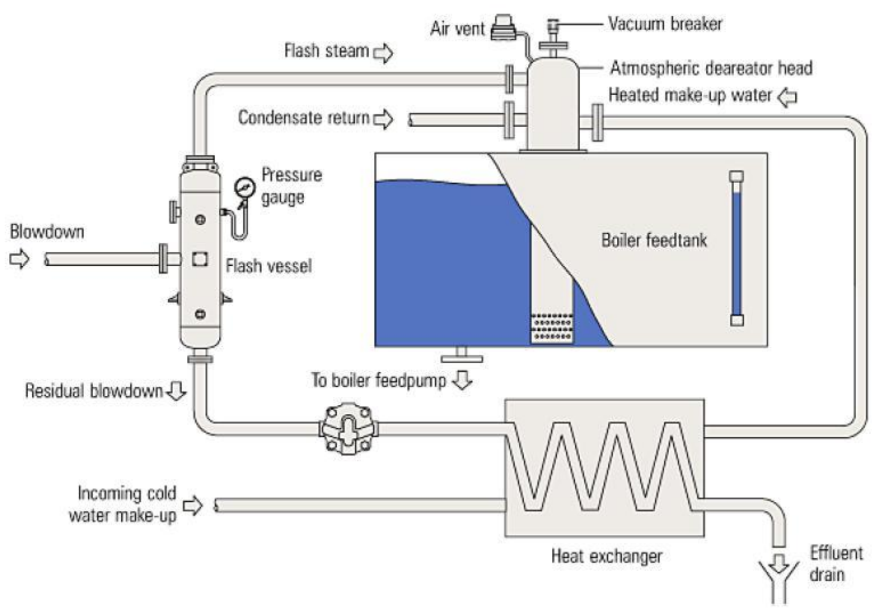


Figure 13. Schematic of Recovery of Heat from Boiler Blowdown (Spirax Sarco)

3.2.2 Blow down calculations

The quantity of blow down required to control boiler water solids concentration is calculated by using the following formula:

$$\text{Blow down (percent)} = \frac{\text{Make up water TDS x \% Make up water}}{\text{Maximum permissible TDS in boiler water}}$$

If the maximum permissible limit of TDS as in a package boiler is 3000 ppm, the percentage make up water is 10 percent and the TDS in make up water is 300 ppm, then the percentage blow down is given as:

= 300 x 10 / 3000
= 1 percent

If boiler evaporation rate is 3000 kg/hr then required blow down rate is:
= 3000 x 1 / 100
= 30 kg/hr

3.2.3 Benefits of blow down control

Good boiler blow down control can significantly reduce treatment and operational costs that include:

- Lower pretreatment costs
- Less make-up water consumption
- Reduced maintenance downtime
- Increased boiler life
- Lower consumption of treatment chemicals

3.3 Boiler Feed Water Treatment

Producing quality steam on demand depends on properly managed water treatment to control steam purity, deposits and corrosion. A boiler is the sump of the boiler system. It ultimately receives all of the pre-boiler contaminants. Boiler performance, efficiency, and service life are direct products of selecting and controlling feed water used in the boiler.

When feed water enters the boiler, the elevated temperatures and pressures cause the components of water to behave differently. Most of the components in the feed water are soluble. However, under heat and pressure most of the soluble components come out of solution as particulate solids, sometimes in crystallized forms and other times as amorphous particles. When solubility of a specific component in water is exceeded, scale or deposits develop. The boiler water must be sufficiently free of deposit forming solids to allow rapid and efficient heat transfer and it must not be corrosive to the boiler metal.

Deposit control is explain first, followed by the two major types of boiler water treatment: internal water treatment and external water treatment.

3.3.1 Deposit control

Deposits in boilers may result from hardness contamination of feed water and corrosion products from the condensate and feed water system. Hardness contamination of the feed water may arise due to a deficient softener system.

Deposits and corrosion result in efficiency losses and may result in boiler tube failures and inability to produce steam. Deposits act as insulators and slow heat transfer. Large amounts of deposits throughout the boiler could reduce the heat transfer enough to reduce the boiler efficiency significantly. Different types of deposits affect the boiler efficiency differently. Thus it may be useful to analyze the deposits for their characteristics. The insulating effect of deposits causes the boiler metal temperature to rise and may lead to tube-failure by overheating.

4. ENERGY EFFICIENCY OPPORTUNITIES

This section includes energy efficiency opportunities related to combustion, heat transfer, avoidable losses, auxiliary power consumption, water quality and blow down.

Energy losses and therefore energy efficiency opportunities in boilers can be related to combustion, heat transfer, avoidable losses, high auxiliary power consumption, water quality and blow down.

The various energy efficiency opportunities in a boiler system can be related to:

1. Stack temperature control
2. Feed water preheating using economizers
3. Combustion air pre-heating
4. Incomplete combustion minimization
5. Excess air control
6. Radiation and convection heat loss avoidance
7. Automatic blow down control
8. Reduction of scaling and soot losses
9. Reduction of boiler steam pressure
10. Variable speed control for fans, blowers and pumps
11. Controlling boiler loading
12. Proper boiler scheduling
13. Boiler replacement

These are explained in the sections below.

Internal treatment involves adding chemicals to a boiler to prevent the formation of scale. Scale-forming compounds are converted to free-flowing sludge, which can be removed by blow down. This method is limited to boilers, where feed water is low in hardness salts, where low pressure, high TDS content in boiler water is tolerated, and when only a small quantity of water is required to be treated. If these conditions are not met, then high rates of blow down are required to dispose off the sludge. They become uneconomical considering heat and water loss.

Different types of water sources require different chemicals. Sodium carbonate, sodium aluminate, sodium phosphate, sodium sulphite and compounds of vegetable or inorganic origin are all used for this purpose. Proprietary chemicals are available to suit various water conditions. A specialist must be consulted to determine the most suitable chemicals to use in each case. Internal treatment alone is not recommended.

3.3.3 External Water Treatment

External treatment is used to remove suspended solids, dissolved solids (particularly the calcium and magnesium ions which are major a cause of scale formation) and dissolved gases (oxygen and carbon dioxide).

The external treatment processes available are:

- Ion exchange
- De-aeration (mechanical and chemical)
- Reverse osmosis
- Demineralization

The stack temperature should be as low as possible. However, it should not be so low that water vapor in the exhaust condenses on the stack walls. This is important in fuels containing significant sulphur as low temperature can lead to sulphur dew point corrosion. Stack temperatures greater than 200°C indicates potential for recovery of waste heat. It also indicates the scaling of heat transfer/recovery equipment and hence the urgency of taking an early shut down for water / flue side cleaning.

4.2 Feed Water Preheating using Economizers

Typically, the flue gases leaving a modern 3-pass shell boiler are at temperatures of 200 to 300 °C. Thus, there is a potential to recover heat from these gases. The flue gas exit temperature from a boiler is usually maintained at a minimum of 200°C, so that the sulphur oxides in the flue gas do not condense and cause corrosion in heat transfer surfaces. When a clean fuel such as natural gas, LPG or gas oil is used, the economy of heat recovery must be worked out, as the flue gas temperature may be well below 200 °C.

The potential for energy savings depends on the type of boiler installed and the fuel used. For a typically older model shell boiler, with a flue gas exit temperature of 260 °C, an economizer could be used to reduce it to 200 °C, increasing the feed water temperature by 15 °C. Increase in overall thermal efficiency would be in the order of 3 percent. For a modern 3-pass shell boiler firing natural gas with a flue gas exit temperature of 140 °C a condensing economizer would reduce the exit temperature to 65 °C increasing thermal efficiency by 5 percent.

4.3 Combustion Air Preheating

Combustion air preheating is an alternative to feed water heating. In order to improve thermal efficiency by 1 percent, the combustion air temperature must be raised by 20 °C. Most gas and oil burners used in a boiler plant are not designed for high air-preheat temperatures.

Modern burners can withstand much higher combustion air preheat, so it is possible to consider such units as heat exchangers in the exit flue as an alternative to an economizer, when either space or a high feed water return temperature make it viable.

4.4 Incomplete Combustion

Incomplete combustion can arise from a shortage of air or surplus of fuel or poor distribution of fuel. It is usually obvious from the colour or smoke, and must be corrected immediately.

In the case of oil and gas fired systems, CO or smoke (for oil fired systems only) with normal or high excess air indicates burner system problems. A more frequent cause of incomplete combustion is the poor mixing of fuel and air at the burner. Poor oil fires can result from improper viscosity, worn tips, carbonization on tips and deterioration of diffusers or spinner plates.

With coal firing, unburned carbon can comprise a big loss. It occurs as grit carry-over or carbon-in-ash and may amount to more than 2 percent of the heat supplied to the boiler. Non-uniform fuel size could be one of the reasons for incomplete combustion. In chain grate stokers, large lumps will not burn out completely, while small pieces and fines may block the air passage, thus causing poor air distribution. In sprinkler stokers, stoker grate condition, fuel distributors, wind box air regulation and over-fire systems can affect carbon loss. Increase in the fines in pulverized coal also increases carbon loss.

4.5 Excess Air Control

The table below gives the theoretical amount of air required for combustion of various types of fuel.

Excess air is required in all practical cases to ensure complete combustion, to allow for the normal variations in combustion and to ensure satisfactory stack conditions for some fuels. The optimum excess air level for maximum boiler efficiency occurs when the sum of the losses due to incomplete combustion and loss due to heat in flue gases is minimized. This level varies with furnace design, type of burner, fuel and process variables. It can be determined by conducting tests with different air fuel ratios.

THEORETICAL COMBUSTION DATA – COMMON BOILER FUELS (National Productivity Council, field experience)		
Fuel	**kg of air req./kg of fuel**	**CO_2 percent in flue gas achieved in practice**
Solid Fuels		
Bagasse	3.3	10-12
Coal (bituminous)	10.7	10-13
Lignite	8.5	9 -13
Paddy Husk	4.5	14-15
Wood	5.7	11.13
Liquid Fuels		
Furnace Oil	13.8	9-14
LSHS	14.1	9-14

TYPICAL VALUES OF EXCESS AIR LEVELS FOR DIFFERENT FUELS (National Productivity Council, field experience)		
Fuel	**Type of Furnace or Burners**	**Excess Air (percent by wt)**
Pulverized coal	Completely water-cooled furnace for slag-tap or dry-ash removal	15-20
	Partially water-cooled furnace for dry-ash removal	15-40
Coal	Spreader stoker	30-60
	Water-cooler vibrating-grate stokers	30-60
	Chain-grate and traveling-grate stokers	15-50
	Underfeed stoker	20-50
Fuel oil	Oil burners, register type	15-20
	Multi-fuel burners and flat-flame	20-30
Natural gas	High pressure burner	5-7

Wood	Dutch over (10-23 percent through grates) and Hofft type	20-25
Bagasse	All furnaces	25-35
Black liquor	Recovery furnaces for draft and soda-pulping processes	30-40

Controlling excess air to an optimum level always results in reduction in flue gas losses; for every 1 percent reduction in excess air there is approximately 0.6 percent rise in efficiency.

Various methods are available to control the excess air:

- Portable oxygen analyzers and draft gauges can be used to make periodic readings to guide the operator to manually adjust the flow of air for optimum operation. Excess air reduction up to 20 percent is feasible.
- The most common method is the continuous oxygen analyzer with a local readout mounted draft gauge, by which the operator can adjust air flow. A further reduction of 10-15 percent can be achieved over the previous system.
- The same continuous oxygen analyzer can have a remote controlled pneumatic damper positioner, by which the readouts are available in a control room. This enables an operator to remotely control a number of firing systems simultaneously.

The most sophisticated system is the automatic stack damper control, whose cost is really justified only for large systems.

4.6 Radiation and Convection Heat Loss Minimization

The external surfaces of a shell boiler are hotter than the surroundings. The surfaces thus lose heat to the surroundings depending on the surface area and the difference in temperature between the surface and the surroundings.

The heat loss from the boiler shell is normally a fixed energy loss, irrespective of the boiler output. With modern boiler designs, this may represent only 1.5 percent on the gross calorific value at full rating, but will increase to around 6 percent, if the boiler operates at only 25 percent output.

Repairing or augmenting insulation can reduce heat loss through boiler walls and piping.

4.7 Automatic Blow down Control

Uncontrolled continuous blow down is very wasteful. Automatic blow down controls can be installed that sense and respond to boiler water conductivity and pH. A 10 percent blow down in a 15 kg/cm2 boiler results in 3 percent efficiency loss.

4.8 Reduction of Scaling and Soot Losses

In oil and coal-fired boilers, soot buildup on tubes acts as an insulator against heat transfer. Any such deposits should be removed on a regular basis. Elevated stack temperatures may indicate excessive soot buildup. Also same result will occur due to scaling on the water side. High exit gas temperatures at normal excess air indicate poor heat transfer performance. This condition can result from a gradual build-up of gas-side or waterside deposits. Waterside deposits require a review of water treatment procedures and tube cleaning to remove deposits. An estimated 1 percent efficiency loss occurs with every 22°C increase in stack temperature.

Stack temperature should be checked and recorded regularly as an indicator of soot deposits. When the flue gas temperature rises to about 20 °C above the temperature for a newly cleaned boiler, it is time to remove the soot deposits. It is therefore recommended to install a dial type thermometer at the base of the stack to monitor the exhaust flue gas temperature.

It is estimated that 3 mm of soot can cause an increase in fuel consumption by 2.5 percent due to increased flue gas temperatures. Periodic off-line cleaning of radiant furnace surfaces, boiler tube banks, economizers and air heaters may be necessary to remove stubborn deposits.

4.9 Reduction of Boiler Steam Pressure

This is an effective means of reducing fuel consumption, if permissible, by as much as 1 to 2 percent. Lower steam pressure gives a lower saturated steam temperature and without stack heat recovery, a similar reduction in the temperature of the flue gas temperature results.

Steam is generated at pressures normally dictated by the highest pressure / temperature requirements for a particular process. In some cases, the process does not operate all the time, and there are periods when the boiler pressure could be reduced. But it must be remembered that any reduction of boiler pressure reduces the specific volume of the steam in the boiler, and effectively derates the boiler output. If the steam load exceeds the derated boiler output, carryover of water will occur. The energy manager should therefore consider the possible consequences of pressure reduction carefully, before recommending it. Pressure should be reduced in stages, and no more than a 20 percent reduction should be considered.

4.10 Variable Speed Control for Fans, Blowers and Pumps

Variable speed control is an important means of achieving energy savings. Generally, combustion air control is affected by throttling dampers fitted at forced and induced draft fans. Though dampers are simple means of control, they lack accuracy, giving poor control characteristics at the top and bottom of the operating range. In general, if the load characteristic of the boiler is variable, the possibility of replacing the dampers by a VSD should be evaluated.

4.11 Controlling Boiler Loading

The maximum efficiency of the boiler does not occur at full load, but at about two-thirds of the full load. If the load on the boiler decreases further, efficiency also tends to decrease. At zero output, the efficiency of the boiler is zero, and any fuel fired is used only to supply the losses. The factors affecting boiler efficiency are:

- As the load falls, so does the value of the mass flow rate of the flue gases through the tubes. This reduction in flow rate for the same heat transfer area reduces the exit flue gas temperatures by a small extent, reducing the sensible heat loss.
- Below half load, most combustion appliances need more excess air to burn the fuel completely. This increases the sensible heat loss.

In general, efficiency of the boiler reduces significantly below 25 percent of the rated load and operation of boilers below this level should be avoided as far as possible.

4.12 Proper Boiler Scheduling

Since, the optimum efficiency of boilers occurs at 65-85 percent of full load, it is usually more efficient, on the whole, to operate a fewer number of boilers at higher loads, than to operate a large number at low loads.

4.13 Boiler Replacement

The potential savings from replacing a boiler depend on the anticipated change in overall efficiency. A change in a boiler can be financially attractive if the existing boiler is:

- Old and inefficient
- Not capable of firing cheaper substitution fuel
- Over or under-sized for present requirements
- Not designed for ideal loading conditions

The feasibility study should examine all implications of long-term fuel availability and company growth plans. All financial and engineering factors should be considered. Since boiler plants traditionally have a useful life of well over 25 years, replacement must be carefully studied.

ENERGY PERFORMANCE ASSESSMENT OF FURNACES

Industrial Heating Furnaces

Furnace is by definition a device for heating materials and therefore a user of energy. Heating furnaces can be divided into batch-type (Job at stationary position) and continuous type (large volume of work output at regular intervals). The types of batch furnace include box, bogie, cover, etc. For mass production, continuous furnaces are used in general. The types of continuous furnaces include pusher-type furnace (Figure 2.1), walking hearth-type furnace, rotary hearth and walking beam-type furnace.(Figure 2.2)

The primary energy required for reheating / heat treatment (say annealing) furnaces are in the form of Furnace oil, LSHS, LDO or electricity

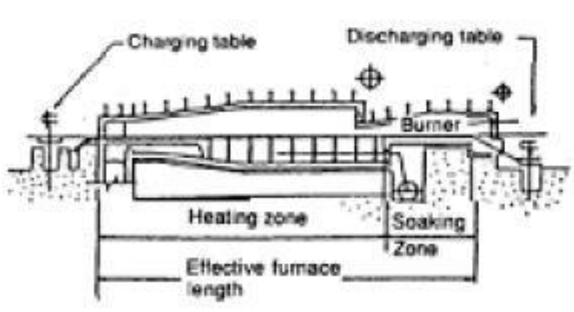


Figure 2.1: Pusher-Type 3-Zone Reheating Furnace

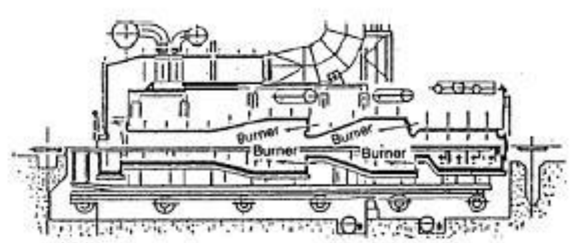


Figure 2.2: Walking Beam-Type Reheating Furnace

Purpose of the Performance Test

- To find out the efficiency of the furnace
- To find out the Specific energy consumption

The purpose of the performance test is to determine efficiency of the furnace and specific energy consumption for comparing with design values or best practice norms. There are many factors affecting furnace performance such as capacity utilization of furnaces, excess air ratio, final heating temperature etc. It is the key for assessing current level of performances and finding the scope for improvements and productivity.

Heat Balance of a Furnace

Heat balance helps us to numerically understand the present heat loss and efficiency and improve the furnace operation using these data. Thus, preparation of heat balance is a pre-requirement for assessing energy conservation potential.

Performance Terms and Definitions

1. Furnace Efficiency, η

$$= \frac{Heat\ output}{Heat\ input} x100$$

$$= \frac{Heat\ in\ stock\ (material)\ (kCals)}{Heat\ in\ fuel\ /\ electricity\ (kCals)} x100$$

2. Specific Energy Consumption

$$= \frac{Quantity\ of\ fuel\ or\ energy\ consumed}{Quantity\ of\ material\ processed}$$

Reference Standards

In addition to conventional methods, Japanese Industrial Standard (JIS) GO702 "Method of heat balance for continuous furnaces for steel" is used for the purpose of establishing the heat losses and efficiency of reheating furnaces.

Furnace Efficiency Testing Method

The energy required to increase the temperature of a material is the product of the mass, the change in temperature and the specific heat. i.e. Energy = Mass x Specific Heat x rise in temperature. The specific heat of the material can be obtained from a reference manual and describes the amount of energy required by different materials to raise a unit of weight through one degree of temperature.

If the process requires a change in state, from solid to liquid, or liquid to gas, then an additional quantity of energy is required called the latent heat of fusion or latent heat of evaporation and this quantity of energy needs to be added to the total energy requirement. However in this section melting furnaces are not considered.

The total heat input is provided in the form of fuel or power. The desired output is the heat supplied for heating the material or process. Other heat outputs in the furnaces are undesirable heat losses.

The various losses that occur in the fuel fired furnace (Figure 2.3) are listed below.

1. Heat lost through exhaust gases either as sensible heat or as incomplete combustion
2. Heat loss through furnace walls and hearth
3. Heat loss to the surroundings by radiation and convection from the outer surface of the walls
4. Heat loss through gases leaking through cracks, openings and doors.

Furnace Efficiency

The efficiency of a furnace is the ratio of useful output to heat input. The furnace efficiency can be determined by both direct and indirect method.

2.5.1 Direct Method Testing

The efficiency of the furnace can be computed by measuring the amount of fuel consumed per unit weight of material produced from the furnace.

Figure 2.3 Fuel Fired Furnace

$$\text{Thermal efficiency of the furnace} = \frac{\text{Heat in the stock}}{\textit{Heat in the fuel consumed}}$$

The quantity of heat to be imparted (Q) to the stock can be found from the formula

$$Q = m \, x \, C_p \, x \, (t_2 - t_1)$$

Where

Q	=	Quantity of heat in kCal
m	=	Weight of the material in kg
C_p	=	Mean specific heat, kCal/kg°C
t_2	=	Final temperature desired, °C
t_1	=	Initial temperature of the charge before it enters the furnace, °C

2.5.2 Indirect Method Testing

Similar to the method of evaluating boiler efficiency by indirect method, furnace efficiency can also be calculated by indirect method. Furnace efficiency is calculated after subtracting sensible heat loss in flue gas, loss due to moisture in flue gas, heat loss due to openings in furnace, heat loss through furnace skin and other unaccounted losses from the input to the furnace.

In order to find out furnace efficiency using indirect method, various parameters that are required are hourly furnace oil consumption, material output, excess air quantity, temperature of flue gas, temperature of furnace at various zones, skin temperature and hot combustion air temperature. Efficiency is determined by subtracting all the heat losses from 100.

Measurement Parameters

The following measurements are to be made for doing the energy balance in oil fired reheating furnaces (e.g. Heating Furnace)

i) Weight of stock / Number of billets heated

ii) Temperature of furnace walls, roof etc

iii) Flue gas temperature

iv) Flue gas analysis

v) Fuel Oil consumption

Instruments like infrared thermometer, fuel consumption monitor, surface thermocouple and other measuring devices are required to measure the above parameters. Reference manual should be referred for data like specific heat, humidity etc.

Example: Energy Efficiency by Indirect Method

An oil-fired reheating furnace has an operating temperature of around 1340°C. Average fuel consumption is 400 litres/hour. The flue gas exit temperature after air preheater is 750 °C. Air is preheated from ambient temperature of 40 °C to 190 °C through an air pre-heater. The furnace has 460 mm thick wall (x) on the billet extraction outlet side, which is 1 m high (D) and 1 m wide. The other data are as given below. Find out the efficiency of the furnace by both indirect and direct method.

Flue gas temperature after air preheater	=	750°C
Ambient temperature	=	40°C
Preheated air temperature	=	190°C
Specific gravity of oil	=	0.92
Average fuel oil consumption	=	400 Litres / hr
	=	400 x 0.92 =368 kg/hr
Calorific value of oil	=	10000 kCal/kg
Average O_2 percentage in flue gas	=	12%
Weight of stock	=	6000 kg/hr
Specific heat of Billet	=	0.12 kCal/kg/°C
Surface temperature of roof and side walls	=	122 °C

Surface temperature other than heating and soaking zone = 85 °C

Solution

1. Sensible Heat Loss in Flue Gas:

Excess air $= \frac{O_2\ \%}{21 - O_2\%} x100$

(Where O_2 is the % of oxygen in flue gas = 12%)

	=	12 x 100 / (21 – 12)
	=	133% excess air
Theoretical air required to burn 1 kg of oil	=	14 kg (Typical value for all fuel oil)
Total air supplied	=	Theoretical air x (1 + excess air/100)
Total air supplied	=	14 x 2.33 kg / kg of oil
	=	32.62 kg / kg of oil

Sensible heat loss	=	m x C_p x ΔT
m	=	Weight of flue gas
	=	Actual mass of air supplied / kg of fuel + mass of fuel (1kg)
	=	32.62 + 1.0 = 33.62 kg / kg of oil.
C_p	=	Specific heat of flue gas
	=	0.24 kCal/kg°C
ΔT	=	Temperature difference
Heat loss	=	m x C_p x ΔT
	=	33.62 x 0.24 x (750– 40)
	=	5729 kCal / kg of oil
% Heat loss in flue gas	=	5727 x 100/10000
	=	57.29%

2. Loss Due to Evaporation of Moisture Present in Fuel

$$\% \text{ Loss} = \frac{M\ \{584 + 0.45\ (Tfg\text{-}Tamb)\}}{\text{GCV of Fuel}} x100$$

Where,

M	-	% Moisture of in 1 kg of fuel oil (0.15 kg/kg of fuel oil)
T_{fg}	-	Flue Gas Temperature
T_{amb}	-	Ambient temperature
GCV	-	Gross Calorific Value of Fuel

$$\% \text{ Loss} = \frac{0.15\ \{584 + 0.45\ (750\text{-}40)\}}{10000} \text{ x } 100$$

$$= 1.36\ \%$$

3. Loss Due to Evaporation of Water Formed due to Hydrogen in Fuel

$$\% \text{ Loss} = \frac{9 \text{ x } H_2\ \{584 + 0.45\ (T_{fg}\text{-}T_{amb})\}}{\text{GCV of Fuel}} \text{ x } 100$$

Where, H_2 – % of H_2 in 1 kg of fuel oil (0.1123 kg/kg of fuel oil)

$$= \frac{9 \text{ x } 0.1123\ \{584 + 0.45\ (750\text{-}40)\}}{10000} \text{ x } 100$$

$$= 9.13\ \%$$

Heat Loss due to Openings:

If a furnace body has an opening on it, the heat in the furnace escapes to the outside as radiant heat. Heat loss due to openings can be calculated by computing black body radiation at furnace temperature, and multiplying these values with emissivity (usually 0.8 for furnace brick work), and the factor of radiation through openings. Factor for radiation through openings can be determined with the help of graph as shown in figure 2.4. The black body radiation losses can be directly computed from the curves as given in the figure 2.5 below.

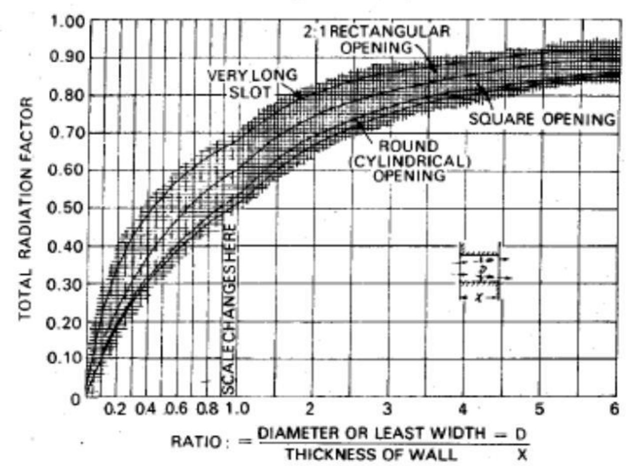


Figure 2.4 Factor for Determining the Equivalent of Heat Release from Openings to the Quality of Heat Release from Perfect Black Body

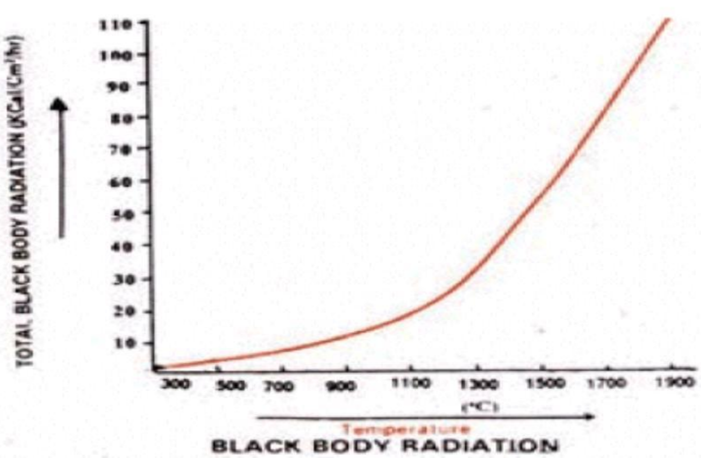


Figure 2.5 Graph for Determining Black Body Radiation at a Particular Temperature

The reheating furnace in example has 460mm thick wall (X) on the billet extraction outlet side, which is 1m high (D) and 1m wide. With furnace temperature of 1340 ^{0}C, the quantity (Q) of radiation heat loss from the opening is calculated as follows:

The shape of the opening is square and D/X	= 1/0.46 = 2.17
The factor of radiation (Refer Figure 2.4)	= 0.71
Black body radiation corresponding to 1340°C (Refer Figure 2.5 On black body radiation)	= 36.00 kCal/cm^2/hr
Area of opening	= 100 cm x 100 cm = 10000 cm^2
Emissivity	= 0.8

Total heat loss = Black body radiation x area of opening x factor of radiation x emissivity

	=36 x 10000 x 0.71 x 0.8 = 204480 kCal/hr
Equivalent Oil loss	= 204480/10,000 = 20.45 kg/hr
% of heat loss	= 20.45 /368 x 100 = 5.56 %

5. Heat Loss through Skin:

Method 1: Radiation Heat Loss from Surface of Furnace

The quantity of heat loss from surface of furnace body is the sum of natural convection and thermal radiation. This quantity can be calculated from surface temperatures of furnace. The temperatures on furnace surface should be measured at as many points as possible, and their average should be used. If the number of measuring points is too small, the error becomes large.

The quantity (Q) of heat release from a reheating furnace is calculated with the following formula:

$$Q = a\ x\ (t_1 - t_2)^{5/4} + 4.88E\left[\left(\frac{t_1 + 273}{100}\right)^4 - \left(\frac{t_2 + 273}{100}\right)^4\right]$$

where

- Q: Quantity of heat release in kCal / W / m^2
- a : factor regarding direction of the surface of natural convection ceiling = 2.8, side walls = 2.2, hearth = 1.5
- t_1 : temperature of external wall surface of the furnace (°C)
- t_2 : temperature of air around the furnace (°C)
- E: emissivity of external wall surface of the furnace

The first term of the formula above represents the quantity of heat release by natural convection, and the second term represents the quantity of heat release by radiation.

Method 2 : Radiation Heat Loss from Surface of Furnace

The following Figure 2.6 shows the relation between the temperature of external wall surface and the quantity of heat release calculated with this formula.

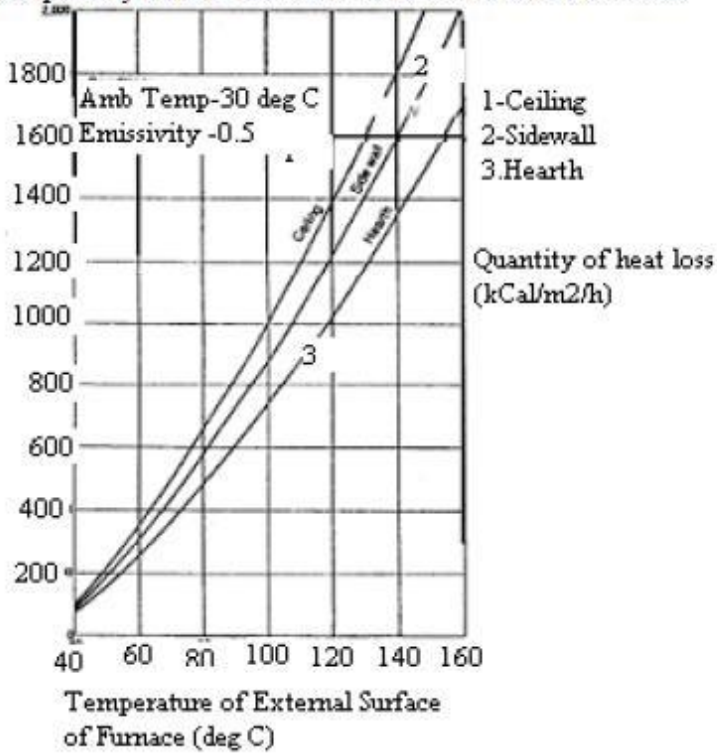


Figure 2.6 Quantity of Heat Release at Various Temperatures

From the Figure 2.6, the quantities of heat release from ceiling, sidewalls and hearth per unit area can be found.

5a). Heat loss through **roof and sidewalls**:

Total average surface temperature	= **122°C**
Heat loss at 122°C	= 1252 kCal / m^2 / hr
Total area of heating + soaking zone	= 70.18 m^2
Heat loss	= 1252 kCal / m^2 / hr x 70.18 m^2
	= 87865 kCal/hr
Equivalent oil loss (a)	= 8.78 kg / hr

5b). Total average surface temperature of

area other than heating and **soaking zone**	= **85°C**
Heat loss at 85°C	= 740 kCal / m^2 / hr
Total area	= 12.6 m^2
Heat loss	= 740 kCal / m^2 / hr x 12.6 m^2
	= 9324 kCal/hr
Equivalent oil loss (b)	= 0.93 kg / hr

Total loss of fuel oil	= a + b = 9.71 kg/hr
Total percentage loss	= 9.71 / 368
	= 2.64%

6. Unaccounted Loss

These losses comprise of heat storage loss, loss of furnace gases around charging door and opening, heat loss by incomplete combustion, loss of heat by conduction through hearth, loss due to formation of scales.

Furnace Efficiency (Direct Method)

Fuel input	= 400 litres / hr
	= 368 kg/hr
Heat Input	= 368 x 10,000 =36,80,000 kCal
Heat output	= m x C_p x ΔT
	= 6000 kg x 0.12 x (1340 – 40)
	= 936000 kCal
Efficiency	= 936000 x 100 / (368 x 10000)
	= 25.43 %
	= 25% (app)
Total Losses	= 75% (app)

Furnace Efficiency (Indirect Method)

1. Sensible heat loss in flue gas	= 57.29%
2. Loss due to evaporation of moisture in fuel	= 1.36 %
3. Loss due to evaporation of water formed from H_2 in fuel	= 9.13 %
4. Heat loss due to openings	= 5.56 %
5. Heat loss through skin	= 2.64%
Total losses	**= 75.98 %**
Furnace Efficiency	= 100 – 75.98
	= 24.02 %
Specific Energy Consumption	= 400 litre /hour (fuel consumption) / 6Tonnes/hour (Wt of stock)

= 66.6 Litre of fuel /tonne of Material (stock)

Factors Affecting Furnace Performance

The important factors, which affect the efficiency, are listed below for critical analysis.

- Under loading due to poor hearth loading and improper production scheduling
- Improper Design
- Use of inefficient burner
- Insufficient draft/chimney
- Absence of Waste heat recovery
- Absence of Instruments/Controls
- Improper operation/Maintenance
- High stack loss
- Improper insulation /Refractories

Data Collection Format for Furnace Performance Assessment

The field-testing format for data collection and parameter measurements are shown below

Stock

Charged amount in furnace	Charging temperature	Discharging temperature	Discharge Material Burning loss temperature
Tons/hr	°C	°C	kg/ton

Fuel Analysis

Fuel type	Consumption	Components of heavy oil						Gross calorific value	Temperature
		C	H_2	O_2	N_2	S	Water content		
	Kg/hr	%	%	%	%	%	%	kCal/kg	°C

Flue gas Analysis

Temperature	Composition of dry exhaust gas		
	CO_2	O_2	CO
°C	%	%	%

Cooling water

Amount of Water	Inlet temperature	Outlet temperature
kg/ton	°C	°C

Temperature of combustion air =
Ambient air temperature =

The Table 2.1 can be used to construct a heat balance for a typical heat treatment furnace

Table 2.1 Heat Balance Table

Heat Input			**Heat output**		
Item	**kCal/t**	**%**	**Item**	**kCal/t**	**%**
Combustion heat of fuel			Quantity of heat in steel		
			Sensible heat in flue gas		
			Moisture and hydrogen loss of fuel		
			Heat loss by Incomplete combustion(CO loss)		
			Heat loss in cooling water		
			Sensible heat of scale		
			Heat Loss Due To Openings		
			Radiation and Other unaccounted heat loss		
Total =		100%	Total =		100%

Theoretical Heat

Example of melting one tonne of steel from an ambient temperature of 20°C . Specific heat of steel = 0.186 Wh/kg/°C, latent heat for melting of steel = 40 Wh/kg/°C. Melting point of steel = 1600 °C.

Theoretical Total heat = Sensible heat + Latent heat

Sensible Heat = 1000 kg x 0.186 Wh /kg °C x (1600-20)°C = 294 kWh/T

Latent heat = 40 Wh/ kg x 1000 kg = 40 kWh/T

Total Heat = 294 + 40 = 334 kWh/T

So the theoretical energy needed to melt one tonne of steel from 20° C = 334 kWh.

Actual Energy used to melt to 1600° C is 700 kWh

$$\text{Efficiency} = \frac{334 \text{ kWh}}{700 \text{ kwh}} \times 100 = 48\%$$

WASTE HEAT RECOVERY

Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved.

Large quantity of hot flue gases is generated from Boilers, Kilns, Ovens and Furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and loss minimized by adopting following measures as outlined in this chapter.

Heat Losses – Quality

Depending upon the type of process, waste heat can be rejected at virtually any temperature from that of chilled cooling water to high temperature waste gases from an industrial furnace or kiln. Usually higher the temperature, higher the quality and more cost effective is the heat recovery. In any study of waste heat recovery, it is absolutely necessary that there should be some use for the recovered heat. Typical examples of use would be preheating of combustion air, space heating, or pre-heating boiler feed water or process water. With high temperature heat recovery, a cascade system of waste heat recovery may be practiced to ensure that the maximum amount of heat is recovered at the highest potential. An example of this technique of waste heat recovery would be where the high temperature stage was used for air pre-heating and the low temperature stage used for process feed water heating or steam raising.

Heat Losses – Quantity

In any heat recovery situation it is essential to know the amount of heat recoverable and also how it can be used. An example of the availability of waste heat is given below:

- **Heat recovery from heat treatment furnace**

In a heat treatment furnace, the exhaust gases are leaving the furnace at 900 °C at the rate of 2100 m^3/hour. The total heat recoverable at 180°C final exhaust can be calculated as

$$Q = V \times \rho \times C_p \times \Delta T$$

Q is the heat content in kCal
V is the flowrate of the substance in m^3/hr

ρ is density of the flue gas in kg/m^3
C_p is the specific heat of the substance in kCal/kg °C
ΔT is the temperature difference in °C
Cp (Specific heat of flue gas) = 0.24 kCal/kg/°C

Heat available (Q) = 2100 × 1.19 × 0.24 × ((900-180) = 4,31,827 kCal/hr

By installing a recuperator, this heat can be recovered to pre-heat the combustion air. The fuel savings would be 33% (@ 1% fuel reduction for every 22 °C reduction in temperature of flue gas.

Classification and Application

In considering the potential for heat recovery, it is useful to note all the possibilities, and grade the waste heat in terms of potential value as shown in the following Table 8.1:

TABLE 8.1 WASTE SOURCE AND QUALITY

S.No.	Source	Quality
1.	Heat in flue gases.	The higher the temperature, the greater the potential value for heat recovery
2.	Heat in vapour streams.	As above but when condensed, latent heat also recoverable.
3.	Convective and radiant heat lost from exterior of equipment	Low grade – if collected may be used for space heating or air preheats.
4.	Heat losses in cooling water.	Low grade – useful gains if heat is exchanged with incoming fresh water
5.	Heat losses in providing chilled water or in the disposal of chilled water	a) High grade if it can be utilized to reduce demand for refrigeration. b) Low grade if refrigeration unit used as a form of heat pump.
6.	Heat stored in products leaving the process	Quality depends upon temperature.
7.	Heat in gaseous and liquid effluents leaving process.	Poor if heavily contaminated and thus requiring alloy heat exchanger.

High Temperature Heat Recovery

The following Table 8.2 gives temperatures of waste gases from industrial process equipment in the high temperature range. All of these results from direct fuel fired processes.

Medium Temperature Heat Recovery

The following Table 8.3 gives the temperatures of waste gases from process equipment in the medium temperature range. Most of the waste heat in this temperature range comes from the exhaust of directly fired process units.

TABLE 8.2 TYPICAL WASTE HEAT TEMPERATURE AT HIGH TEMPERATURE RANGE FROM VARIOUS SOURCES	
Types of Device	**Temperature, °C**
Nickel refining furnace	1370 –1650
Aluminium refining furnace	650–760
Zinc refining furnace	760–1100
Copper refining furnace	760– 815
Steel heating furnaces	925–1050
Copper reverberatory furnace	900–1100
Open hearth furnace	650–700
Cement kiln (Dry process)	620– 730
Glass melting furnace	1000–1550
Hydrogen plants	650–1000
Solid waste incinerators	650–1000
Fume incinerators	650–1450

TABLE 8.3 TYPICAL WASTE HEAT TEMPERATURE AT MEDIUM TEMPERATURE RANGE FROM VARIOUS SOURCES	
Type of Device	**Temperature, °C**
Steam boiler exhausts	230–480
Gas turbine exhausts	370–540
Reciprocating engine exhausts	315–600
Reciprocating engine exhausts (turbo charged)	230–370
Heat treating furnaces	425–650
Drying and baking ovens	230–600
Catalytic crackers	425–650
Annealing furnace cooling systems	425–650

Low Temperature Heat Recovery

The following Table 8.4 lists some heat sources in the low temperature range. In this range it is usually not practical to extract work from the source, though steam production may not be completely excluded if there is a need for low-pressure steam. Low temperature waste heat may be useful in a supplementary way for preheating purposes.

TABLE 8.4 TYPICAL WASTE HEAT TEMPERATURE AT LOW TEMPERATURE RANGE FROM VARIOUS SOURCES	
Source	**Temperature, °C**
Process steam condensate	55–88
Cooling water from:	
Furnace doors	32–55
Bearings	32–88
Welding machines	32–88
Injection molding machines	32–88
Annealing furnaces	66–230
Forming dies	27–88
Air compressors	27–50
Pumps	27–88
Internal combustion engines	66–120
Air conditioning and refrigeration condensers	32–43
Liquid still condensers	32–88
Drying, baking and curing ovens	93–230
Hot processed liquids	32–232
Hot processed solids	93–232

Commercial Waste Heat Recovery Devices

Recuperators

In a recuperator, heat exchange takes place between the flue gases and the air through metallic or ceramic walls. Duct or tubes carry the air for combustion to be pre-heated, the other side contains the waste heat stream. A recuperator for recovering waste heat from flue gases is shown in Figure 8.1.

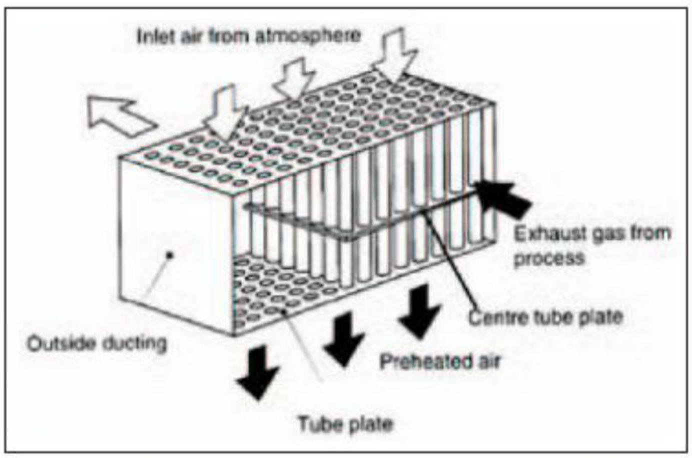


Figure 8.1 Waste Heat Recovery using Recuperator

The simplest configuration for a recuperator is the metallic radiation recuperator, which consists of two concentric lengths of metal tubing as shown in Figure 8.2.

The inner tube carries the hot exhaust gases while the external annulus carries the combustion air from the atmosphere to the air inlets of the furnace burners. The hot gases are cooled by the incoming combustion air which now carries additional energy into the combustion chamber. This is energy which does not have to be supplied by the fuel; consequently, less fuel is burned for a given furnace loading. The saving in fuel also means a decrease in combustion air and therefore

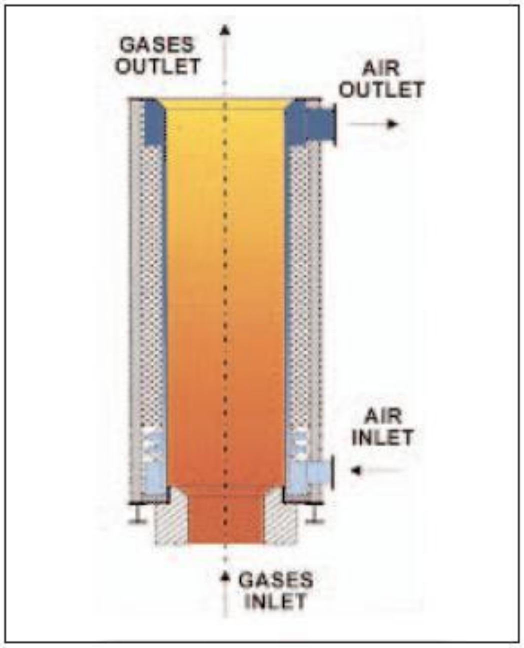


Figure 8.2 Metallic Radiation Recuperator

stack losses are decreased not only by lowering the stack gas temperatures but also by discharging smaller quantities of exhaust gas. The radiation recuperator gets its name from the fact that a substantial portion of the heat transfer from the hot gases to the surface of the inner tube takes place by radiative heat transfer. The cold air in the annuals, however, is almost transparent to infrared radiation so that only convection heat transfer takes place to the incoming air. As shown in the diagram, the two gas flows are usually parallel, although the configuration would be simpler and the heat transfer more efficient if the flows were opposed in direction (or counterflow). The reason for the use of parallel flow is that recuperators frequently serve the additional function of cooling the duct carrying away the exhaust gases and consequently extending its service life.

A second common configuration for recuperators is called the tube type or convective recuperator. As seen in the figure 8.3, the hot gases are carried through a number of parallel small diameter tubes, while the incoming air to be heated enters a shell surrounding the tubes and passes over the hot tubes one or more times in a direction normal to their axes.

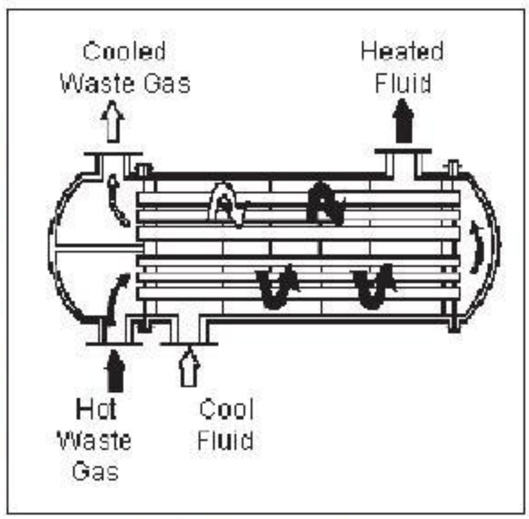


Figure 8.3 Convective Recuperator

If the tubes are baffled to allow the gas to pass over them twice, the heat exchanger is termed a two-pass recuperator; if two baffles are used, a three-pass recuperator, etc. Although baffling increases both the cost of the exchanger and the pressure drop in the combustion air path, it increases the effectiveness of heat exchange. Shell and tube type recuperators are generally more compact and have a higher effectiveness than radiation recuperators, because of the larger heat transfer area made possible through the use of multiple tubes and multiple passes of the gases.

Radiation/Convective Hybrid Recuperator:

For maximum effectiveness of heat transfer, combinations of radiation and convective designs are used, with the high-temperature radiation recuperator being first followed by convection type.

These are more expensive than simple metallic radiation recuperators, but are less bulky. A Convective/radiative Hybrid recuperator is shown in Figure 8.4

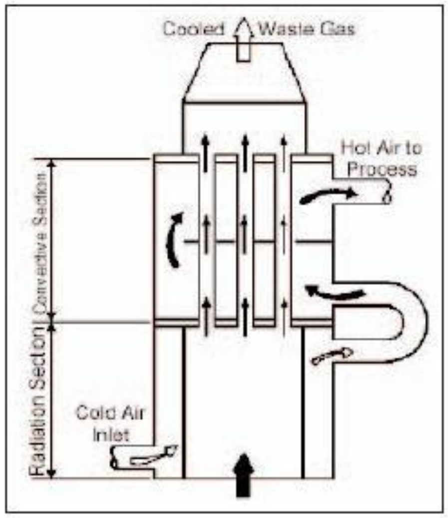


Figure 8.4 Convective Radiative Recuperator

Ceramic Recuperator

The principal limitation on the heat recovery of metal recuperators is the reduced life of the liner at inlet temperatures exceeding 1100°C. In order to overcome the temperature limitations of metal recuperators, ceramic tube recuperators have been developed whose materials allow operation on the gas side to 1550°C and on the preheated air side to 815°C on a more or less practical basis. Early ceramic recuperators were built of tile and joined with furnace cement, and thermal cycling caused cracking of joints and rapid deterioration of the tubes. Later developments introduced various kinds of short silicon carbide tubes which can be joined by flexible seals located in the air headers.

Earlier designs had experienced leakage rates from 8 to 60 percent. The new designs are reported to last two years with air preheat temperatures as high as 700°C, with much lower leakage rates.

Regenerator

The Regeneration which is preferable for large capacities has been very widely used in glass and steel melting furnaces. Important relations exist between the size of the regenerator, time between reversals, thickness of brick, conductivity of brick and heat storage ratio of the brick.

In a regenerator, the time between the reversals is an important aspect. Long periods would mean higher thermal storage and hence higher cost. Also long periods of reversal result in lower average temperature of preheat and consequently reduce fuel economy. (Refer Figure 8.5).

Accumulation of dust and slagging on the surfaces reduce efficiency of the heat transfer as the furnace becomes old.

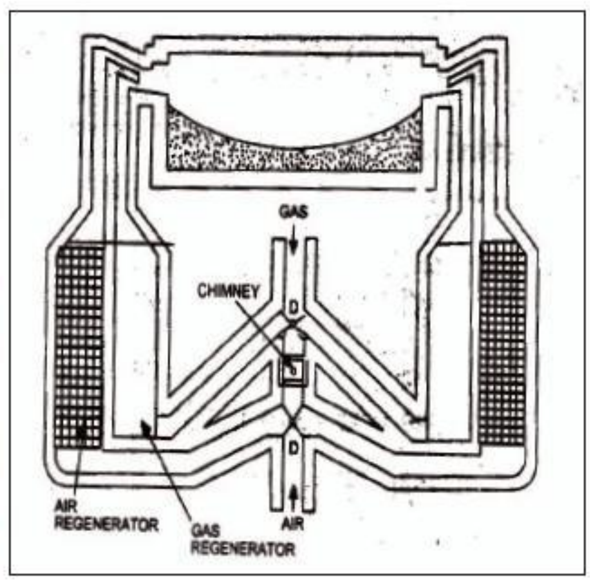


Figure 8.5 Regenerator

Heat losses from the walls of the regenerator and air in leaks during the gas period and out-leaks during air period also reduces the heat transfer.

Heat Wheels

A heat wheel is finding increasing applications in low to medium temperature waste heat recovery systems. Figure 8.6 is a sketch illustrating the application of a heat wheel.

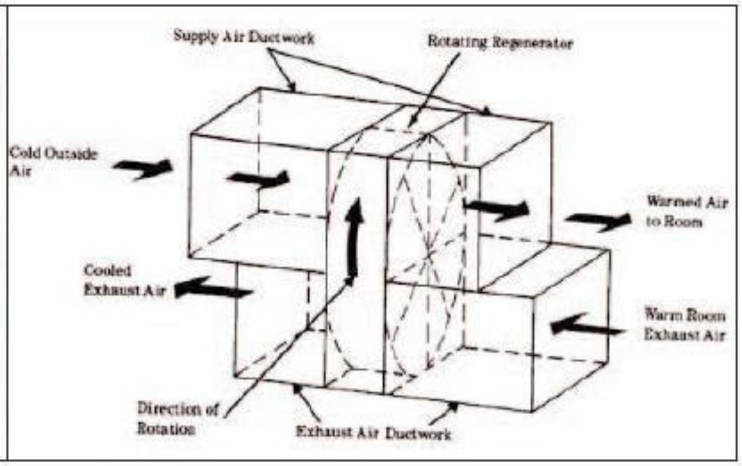


Figure 8.6 Heat Wheel

It is a sizable porous disk, fabricated with material having a fairly high heat capacity, which rotates between two side-by-side ducts: one a cold gas duct, the other a hot gas duct. The axis of the disk is located parallel to, and on the partition between, the two ducts. As the disk slowly rotates, sensible heat (moisture that contains latent heat) is transferred to the disk by the hot air and, as the disk rotates, from the disk to the cold air. The overall efficiency of sensible heat transfer for this kind of regenerator can be as high as 85 percent. Heat wheels have been built as large as 21 metres in diameter with air capacities up to 1130 m^3 / min.

A variation of the Heat Wheel is the rotary regenerator where the matrix is in a cylinder rotating across the waste gas and air streams. The heat or energy recovery wheel is a rotary gas heat regenerator, which can transfer heat from exhaust to incoming gases.

Its main area of application is where heat exchange between large masses of air having small temperature differences is required. Heating and ventilation systems and recovery of heat from dryer exhaust air are typical applications.

Case Example

A rotary heat regenerator was installed on a two colour printing press to recover some of the heat, which had been previously dissipated to the atmosphere, and used for drying stage of the process. The outlet exhaust temperature before heat recovery was often in excess of 100°C. After heat recovery the temperature was 35°C. Percentage heat recovery was 55% and payback on the investment was estimated to be about 18 months. Cross contamination of the fresh air from the solvent in the exhaust gases was at a very acceptable level.

Case Example

A ceramic firm installed a heat wheel on the preheating zone of a tunnel kiln where 7500 m^3/hour of hot gas at 300°C was being rejected to the atmosphere. The result was that the flue gas temperature was reduced to 150°C and the fresh air drawn from the top of the kiln was preheated to 155°C. The burner previously used for providing the preheated air was no longer required. The capital cost of the equipment was recovered in less than 12 months.

Heat Pipe

A heat pipe can transfer up to 100 times more thermal energy than copper, the best known conductor. In other words, heat pipe is a thermal energy absorbing and transferring system and have no moving parts and hence require minimum maintenance.

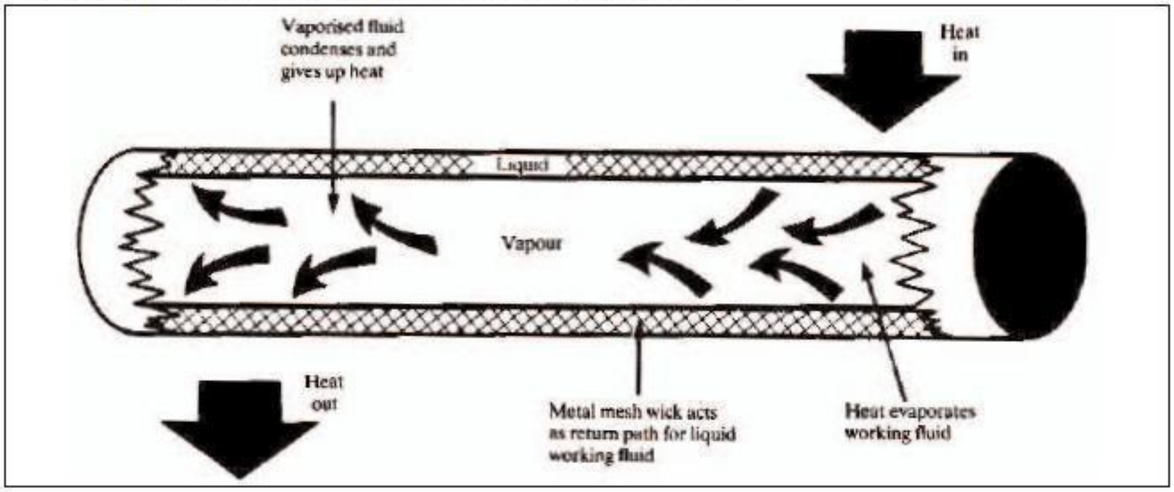


Figure 8.7 Heat Pipe

The Heat Pipe comprises of three elements - a sealed container, a capillary wick structure and a working fluid. The capillary wick structure is integrally fabricated into the interior surface of the container tube and sealed under vacuum. Thermal energy applied to the external surface of the heat pipe is in equilibrium with its own vapour as the container tube is sealed under vacuum. Thermal energy applied to the external surface of the heat pipe causes the working fluid near the surface to evaporate instantaneously. Vapour thus formed absorbs the latent heat of vapourisation and this part of the heat pipe becomes an evaporator region. The vapour then travels to the other end the pipe where the thermal energy is removed causing the vapour to condense into liquid again, thereby giving up the latent heat of the condensation. This part of the heat pipe works as the condenser region. The condensed liquid then flows back to the evaporated region. A figure of Heat pipe is shown in Figure 8.7

Performance and Advantage

The heat pipe exchanger (HPHE) is a lightweight compact heat recovery system. It virtually does not need mechanical maintenance, as there are no moving parts to wear out. It does not need input power for its operation and is free from cooling water and lubrication systems. It also lowers the fan horsepower requirement and increases the overall thermal efficiency of the system. The heat pipe heat recovery systems are capable of operating at 315°C. with 60% to 80% heat recovery capability.

Typical Application

The heat pipes are used in following industrial applications:

a. Process to Space Heating: The heat pipe heat exchanger transfers the thermal energy from process exhaust for building heating. The preheated air can be blended if required The requirement of additional heating equipment to deliver heated make up air is dras tically reduced or eliminated.

b. Process to Process: The heat pipe heat exchangers recover waste thermal energy from the process exhaust and transfer this energy to the incoming process air. The incoming air thus become warm and can be used for the same process/other processes and reduces process energy consumption.

c. HVAC Applications:

Cooling: Heat pipe heat exchangers precools the building make up air in summer and thus reduces the total tons of refrigeration, apart from the operational saving of the cool ing system. Thermal energy is supply recovered from the cool exhaust and transferred to the hot supply make up air.

Heating: The above process is reversed during winter to preheat the make up air.

The other applications in industries are:

- Preheating of boiler combustion air
- Recovery of Waste heat from furnaces
- Reheating of fresh air for hot air driers
- Recovery of waste heat from catalytic deodorizing equipment
- Reuse of Furnace waste heat as heat source for other oven
- Cooling of closed rooms with outside air
- Preheating of boiler feed water with waste heat recovery from flue gases in the heat pipe economizers.
- Drying, curing and baking ovens
- Waste steam reclamation
- Brick kilns (secondary recovery)
- Reverberatory furnaces (secondary recovery)
- Heating, ventilating and air-conditioning systems

Case Example

Savings in Hospital Cooling Systems

Volume	140 m^3/min Exhaust
Recovered heat	28225 kCal/hr
Plant capacity reduction	9.33 Tons of Refrigeration
Electricity cost (operation)	Rs. 268/Million kCal (based on 0.8 kW/TR)
Plant capacity reduction cost (Capital)	Rs.12,000/TR
Capital cost savings	Rs. 1,12,000/-
Payback period	16570 hours

HEAT EXCHANGERS

Economiser

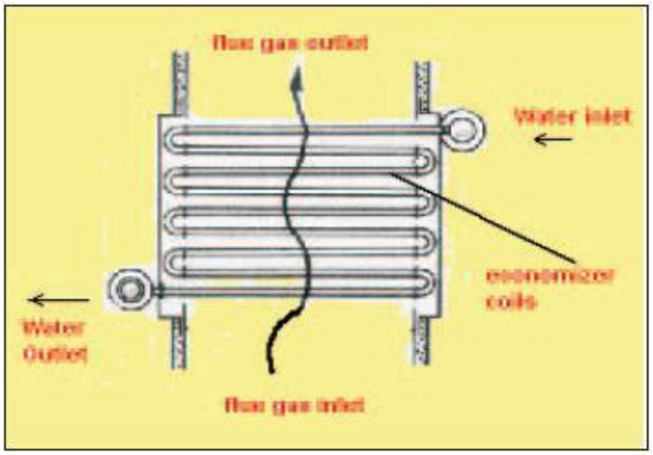


Figure 8.8 Economiser

In case of boiler system, economizer can be provided to utilize the flue gas heat for pre-heating the boiler feed water. On the other hand, in an air pre-heater, the waste heat is used to heat combustion air. In both the cases, there is a corresponding reduction in the fuel requirements of the boiler. An economizer is shown in Figure 8.8.

For every 22°C reduction in flue gas temperature by passing through an economiser or a pre-heater, there is 1% saving of fuel in the boiler. In other words, for every 6°C rise in feed water temperature through an economiser, or 20°C rise in combustion air temperature through an air pre-heater, there is 1% saving of fuel in the boiler.

Shell and Tube Heat Exchanger:

When the medium containing waste heat is a liquid or a vapor which heats another liquid, then the shell and tube heat exchanger must be used since both paths must be sealed to contain the pressures of their respective fluids. The shell contains the tube bundle, and usually internal baffles, to direct the fluid in the shell over the tubes in multiple passes. The shell is inherently weaker than the tubes so that the higher-pressure fluid is circulated in the tubes while the lower pressure fluid flows through the shell. When a vapor contains the waste heat, it usually condenses, giving up its latent heat to the liquid being heated. In this application, the vapor is almost invariably contained within the shell. If the reverse is attempted, the condensation of vapors within small diameter parallel tubes causes flow instabilities. Tube and shell heat exchangers are available in a wide range of standard sizes with many combinations of materials for the tubes and shells. A shell and tube heat exchanger is illustrated in Figure 8.9.

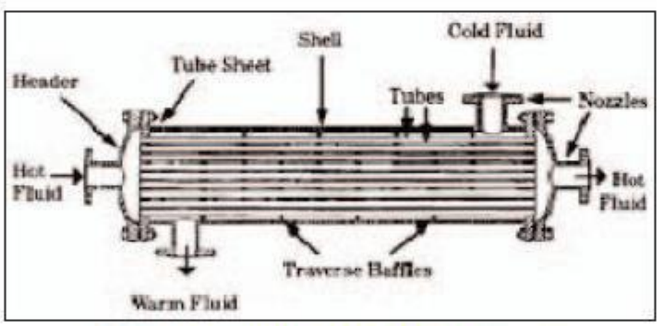


Figure 8.9 Shell & Tube Heat Exchanger

Typical applications of shell and tube heat exchangers include heating liquids with the heat contained by condensates from refrigeration and air-conditioning systems; condensate from process steam; coolants from furnace doors, grates, and pipe supports; coolants from engines, air compressors, bearings, and lubricants; and the condensates from distillation processes.

Plate heat exchanger

The cost of heat exchange surfaces is a major cost factor when the temperature differences are not large. One way of meeting this problem is the plate type heat exchanger, which consists of a series of separate parallel plates forming thin flow pass. Each plate is separated from the next by gaskets and the hot stream passes in parallel through alternative plates whilst the liquid to be heated passes in parallel between the hot plates. To improve heat transfer the plates are corrugated.

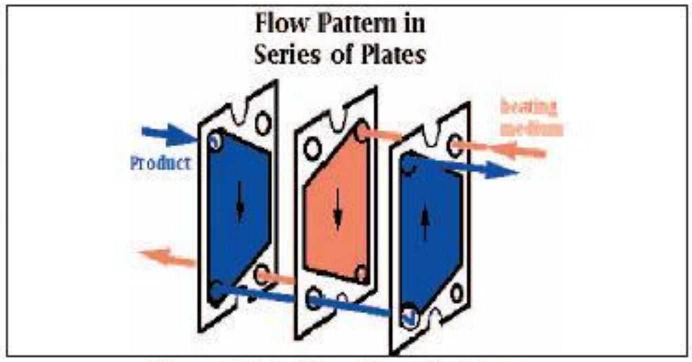


Figure 8.10 Plate Heat Exchanger

Hot liquid passing through a bottom port in the head is permitted to pass upwards between every second plate while cold liquid at the top of the head is permitted to pass downwards between the odd plates. When the directions of hot & cold fluids are opposite, the arrangement is described as counter current. A plate heat exchanger is shown in Figure 8.10.

Typical industrial applications are:

- Pasteurisation section in milk packaging plant.
- Evaporation plants in food industry.

Run Around Coil Exchanger

It is quite similar in principle to the heat pipe exchanger. The heat from hot fluid is transferred to the colder fluid via an intermediate fluid known as the Heat Transfer Fluid. One coil of this closed loop is installed in the hot stream while the other is in the cold stream. Circulation of this fluid is maintained by means of circulating pump.

It is more useful when the hot land cold fluids are located far away from each other and are not easily accessible.

Typical industrial applications are heat recovery from ventilation, air conditioning and low temperature heat recovery.

Direct Contact Heat Exchanger :

Low pressure steam may also be used to preheat the feed water or some other fluid where miscibility is acceptable. This principle is used in Direct Contact Heat Exchanger and finds wide use in a steam generating station. They essentially consists of a number of trays mounted one over the other or packed beds. Steam is supplied below the packing while the cold water is sprayed at the top. The steam is completely condensed in the incoming water thereby heating it. A figure of direct contact heat exchanger is shown in Figure 8.14. Typical application is in the deaerator of a steam generation station.

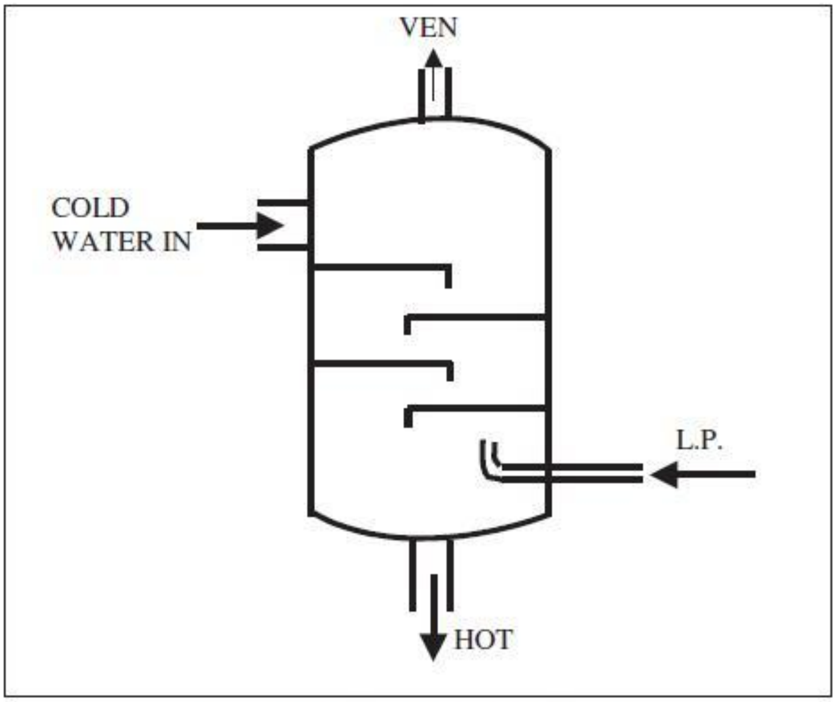


Figure 8.14 Direct Contact Condenser

HEAT PUMPS

In the various commercial options previously discussed, we find waste heat being transferred from a hot fluid to a fluid at a lower temperature. Heat must flow spontaneously "downhill", that is from a system at high temperature to one at a lower temperature. When energy is repeatedly transferred or transformed, it becomes less and less available for use. Eventually that energy has such low intensity (resides in a medium at such low temperature) that it is no longer available at all to perform a useful function. It has been taken as a general rule of thumb in industrial operations that fluids with temperatures less than 120°C (or, better, 150°C to provide a safe margin), as limit for waste heat recovery because of the risk of condensation of corrosive liquids. However, as fuel costs continue to rise, even such waste heat can be used economically for space heating and other low temperature applications. It is possible to reverse the direction of spontaneous energy flow by the use of a thermodynamic system known as a heat pump.

The majority of heat pumps work on the principle of the vapour compression cycle. In this cycle, the circulating substance is physically separated from the source (waste heat, with a temperature of T_{in}) and user (heat to be used in the process, T_{out}) streams, and is re-used in a cyclical fashion, therefore called 'closed cycle'. In the heat pump, the following processes take place:

1. In the evaporator the heat is extracted from the heat source to boil the circulating substance;
2. The circulating substance is compressed by the compressor, raising its pressure and temperature; The low temperature vapor is compressed by a compressor, which requires external work. The work done on the vapor raises its pressure and temperature to a level where its energy becomes available for use
3. The heat is delivered to the condenser;
4. The pressure of the circulating substance (working fluid) is reduced back to the evaporator condition in the throttling valve, where the cycle repeats.

The heat pump was developed as a space heating system where low temperature energy from the ambient air, water, or earth is raised to heating system temperatures by doing compression work with an electric motor-driven compressor. The arrangement of a heat pump is shown in figure 8.12.

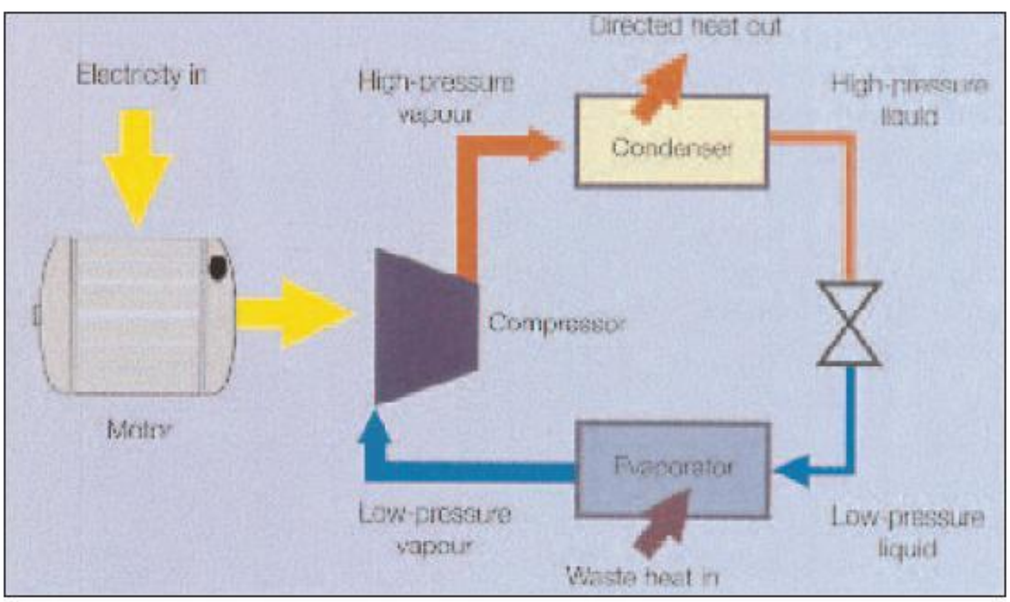


Figure 8.12 Heat Pump Arrangement

The heat pumps have the ability to upgrade heat to a value more than twice that of the energy consumed by the device. The potential for application of heat pump is growing and number of industries have been benefited by recovering low grade waste heat by upgrading it and using it in the main process stream.

Heat pump applications are most promising when both the heating and cooling capabilities can be used in combination. One such example of this is a plastics factory where chilled water from a heat is used to cool injection-moulding machines whilst the heat output from the heat pump is used to provide factory or office heating. Other examples of heat pump installation include product drying, maintaining dry atmosphere for storage and drying compressed air.

QUESTIONS	
1.	What do you understand by the term waste heat?
2.	The heat recovery equipment will be the cheapest when the temperature of flue gases are (a) 200°C (b) 400°C (c) 600°C (d) 800°C
3. **4.**	Give two examples of waste heat recovery. What are the direct and indirect benefits of waste heat recovery?
5.	How will you go about developing a waste heat recovery system?
6.	Explain the various types of recuperators.
7.	The ceramic recuperators can withstand temperatures upto (a) 400°C (b) 1700°C (c) 1300°C (d) 1400°C
8.	Explain the operating principle of a regenerator.
9.	What are heat wheels? Explain with sketch.
10.	Explain the principle of operation of a heat pipe.
11.	What are the typical applications of a heat pipe in heat exchangers ?
12.	Explain the operation of an economizer.
13.	How does a shell and tube heat exchanger work? Give typical examples.
14.	How does a plate heat exchanger work? Give typical examples.
15.	Explain the operating principle of a run around coil exchanger
16.	Explain the operating principle of a waste heat recovery boiler with examples.
17.	Explain the operating principle of a heat pump with examples.

UNIT-IV
ENERGY MANAGEMENT

Principles of energy management

If energy productivity is an important opportunity for the nation as a whole, it is a necessity for the individual company. It represents a real chance for creative management to reduce that component of product cost.

Four main principles underlie in the basis of a well-organized program for energy management: The first of these is to control the costs of the energy function or service provided, but not the MWh of energy.

In addition to energy costs, it is useful to measure the depreciation, maintenance, labor, and other operating costs involved in providing the conversion equipment necessary to deliver required services. These costs add as much as 50% to the fuel cost.

For example - if we can lower the temperature level of a thermal process, along with reducing heat loss will eventually be possible using other sources of heat, and from there to other parts energy conversion elements. In turn, they may require less maintenance and repair. Thus, by managing the quality of the heat achieves a multiplier effect.

The second principle of energy management is to control energy functions as a product cost, not as a part of manufacturing or general overheadIt is surprising how many companies still lump all energy costs into one general or manufacturing overhead account without identifying those products with the highest energy function cost. In most cases, energy functions must become part of the standard cost system so that each function can be assessed as to its specific impact on the product cost. The minimum theoretical energy expenditure to produce a given product can usually be determined en route to establishing a standard energy cost for that product. As in all production cost functions, the minimum standard is often difficult to meet, but it can serve as an indicator of the size of the opportunity.

In comparing actual values with minimum values, four possible approaches can be taken to reduce the variance, usually in this order:

1. An hourly or daily control system can be installed to keep the function cost at the desired level.
2. Fuel requirements can be switched to a cheaper and more available form.
3. A change can be made to the process methodology to reduce the need for the function.
4. New equipment can be installed to reduce the cost of the function.

The starting point for reducing costs should be in achieving the minimum cost possible with the present equipment and processes. Installing management control systems can indicate what the lowest possible energy use is in a well-controlled situation. It is only at that point when a change in process or equipment configuration should be considered. An equipment change prior to actually minimizing the expenditure under the present system may lead to oversizing new equipment or replacing equipment for unnecessary functions.

The third principle is to control and meter only the main energy functions - the roughly 20% that make up 80% of the costs (so called Pareto's Principle). It is important to focus controls on those that represent the meaningful costs and aggregate the remaining items in a general category. Many manufacturing plants in the United States have only one meter, that leading from the gas main or electric main into the plant from the outside source. Regardless of the reasonableness of the standard cost established, the inability to measure actual consumption against that standard will render such a system useless. Sub metering the main functions can provide the information not only to measure but to control costs in a short time interval. The cost of metering and sub metering is usually incidental to the potential for realizing significant cost improvements in the main energy functions of a production system.

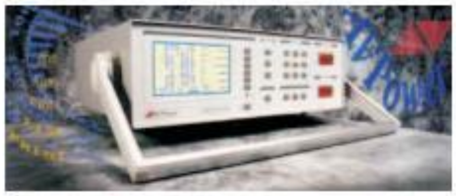
The fourth principle is to put the major effort of an energy management program into installing controls and achieving resultsIt is common to find general knowledge about how large amounts of energy could be saved in a plant. The missing ingredient is the discipline necessary to achieve these potential savings. Each step in saving energy needs to be monitored frequently enough by the manager or first-line supervisor to see noticeable changes. Logging of important fuel usage or behavioral observations are almost always necessary before any particular savings results can be realized. Therefore, it is critical that an energy director or committee have the authority from the chief executive to install controls, not just advise line management. Those energy managers who have achieved the largest cost reductions actually install systems and controls; they do not just provide good advice.

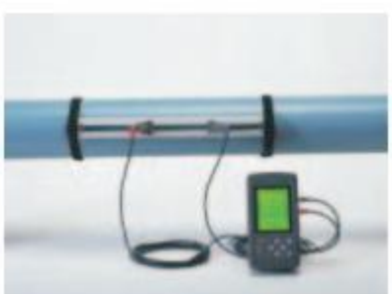
Energy Audit Instruments

The requirement for an energy audit such as identification and quantification of energy necessitates measurements; these measurements require the use of instruments. These instruments must be portable, durable, easy to operate and relatively inexpensive. The parameters generally monitored during energy audit may include the following: Basic Electrical Parameters in AC &DC systems - Voltage (V), Current (I), Power factor, Active power (kW), apparent power (demand) (kVA), Reactive power (kVAr), Energy consumption (kWh), Frequency (Hz), Harmonics, etc. Parameters of importance other than electrical such as temperature & heat flow, radiation, air and gas flow, liquid flow, revolutions per minute (RPM), air velocity, noise and vibration, dust concentration, Total Dissolved Solids (TDS), pH, moisture content, relative humidity, flue gas analysis - CO2, O2, CO, SOx, NOx, combustion efficiency etc. Key instruments for energy audit are listed below.

The operating instructions for all instruments must be understood and staff should familiarize themselves with the instruments and their operation prior to actual audit use.

 Tachometer	 Stroboscope	**Speed Measurements:** In any audit exercise speed measurements are critical as thay may change with frequency, belt slip and loading. 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.
		**Leak Detectors:** Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities.
		**Lux meters:** Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.

 	**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.
	**Combustion analyzer:** This instrument has in-built chemical cells which measure various gases such as O_2, CO, NO_X and SO_X.
	**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.
	**Fyrite:** A hand bellow pump draws the flue gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. A separate fyrite can be used for O_2 and CO_2 measurement.

	**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.
	**Infrared Thermometer:** This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.
	**Pitot Tube and manometer:** Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows.
	**Water flow meter:** This non-contact flow measuring device using Doppler effect / Ultra sonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter.

subject of automatic controls is enormous, covering the control of variables such

As temperature, pressure, flow, level, and speed.The automatic controls can be divided into two parts: The control of Heating, Ventilating and Air Conditioning systems (commonly known as HVAC); and - Process control.

Both are immense subjects, the latter ranging from the control of a simple domestic cooker to a complete production system or process, as may be found in a large petrochemical complex. The Controls Engineer needs to have various skills at his command - knowledge of mechanical engineering, electrical engineering, electronics and pneumatic systems, a working understanding of HVAC design and process applications and, increasingly today, an understanding of computers and digital communications. The intention of this chapter is to provide a basic insight into the practical and theoretical facets of automatic control. It is confined to the control of processes that utilise the following fluids: steam, water, compressed air and hot oils.

Control is generally achieved by varying fluid flow using actuated valves. For the

Fluids mentioned above, the usual requirement is to measure and respond to changes in temperature, pressure, level, humidity and flowrate. Almost always, the response to changes in these physical properties must be within a given time. The combined manipulation of the valve and its actuator with time, and the close control of the measured variable, will be explained later in this Block. The control of fluids is not confined to valves. Some process streams are manipulated by the action of variable speed pumps or fans.

Along with energy conservation, energy management systems (EMS) also have kept this industry active in redesigning and improving their products; energy management systems are computerized control systems implemented mostly by the utility industry, but also by large manufacturers with their own power stations. Automatic controls have been altered and redesigned for energy efficiency to work within these systems and for the HVAC units in the buildings in which they are stored.

Computerized energy management systems,

on a smaller scale, also are being installed in commercial buildings. These systems combine monitoring and controlling of HVAC units with security, lighting, and fire safety systems.

Hotels, department stores, and grocery stores, all large users of energy, began implementing energy management systems in the 1980s. In hotels, for instance, automatic controls on heating and air-conditioning units are regulated by sensors in individual rooms that detect whether the rooms are occupied; the controls also are linked to the hotel's front desk in order to respond to check-ins and check-outs. Similarly, energy management systems have saved energy and money for department and grocery stores. In these cases, computerized systems are monitored for a chain of stores by a centralized network.

The industry entered the 1990s experiencing small growth following the decline in construction of residential and commercial buildings. This modest growth, along with small sales margins, limited research and development in new technologies and investment in new facilities. In addition, as a result of the weak economy at the time, many companies chose to upgrade their existing HVAC systems. Upgrading increased commercial repair and maintenance, but sales of new HVAC systems rebounding by the end of the decade.

In the 2000s, the industry was dominated by large companies that continued to compete in a saturated market by increasing efficiency in their products, such as improving circulation control, compressor design, and network automation. Products became increasingly standardized, causing companies to differentiate themselves by other means, such as expansion into the global market. Deregulation of electricity was expected to be a significant factor in the HVAC industry's future.

The need for automatic controls

There are three major reasons why process plant or buildings require automatic controls:

•Safety

- The plant or process must be safe to operate. The more complex or dangerous the plant or process, the greater is the need for automatic controls and safeguard protocol.

•Stability The plant or processes should work steadily, predictably and repeatably, without fluctuations or unplanned shutdowns.

- This is a primary requirement infactories and buildings to prevent spoilage, increase quality and production rates, and maintain comfort. These are the fundamentals of economic efficiency.

Other desirable benefits such as economy, speed, and reliability are also important, but It is against the three major parameters of safety, stability and accuracy that each control application will be measured.

Elements of automatic control

A controlled condition might be temperature, pressure, humidity, level, or flow. This means that the measuring element could be a temperature sensor, a pressure transducer or transmitter, a level detector, a humidity sensor or a flow sensor. The manipulated variable could be steam, water, air, electricity, oil or gas, whilst the controlled device could be a valve, damper, pump or fan. illustrates the component parts of a basic control system.

The sensor signals to the controller. The controller, which may take signals from more than one sensor, determines whether a change is required in the manipulated variable, based pressures as high as 60 PSI. Advantages of pneumatics: actuators for valve and damper controls are inexpensive, easily maintained, and cost effective. The technology is mature, controls are reliable, and different manufacturer components can be used interchangeably. Disadvantages are: they require clean dry air, calibration of the controls on a regular basis, and customized complex control panels for advanced temperature control systems.

Electric Control Systems

Electric control systems use electricity as the power source of a control device. This system can have two position action in which the controller switches an electric motor, resistance heating element, or solenoid coil directly or through microprocessor based electro-mechanical means. Alternatively, the system can be proportional so that the controlled device is modulated by an electric motor. Advantages are the two-position controls are simple and reliable and use simple low voltage electrical technology. Disadvantages are the controls cannot modulate and actuators can be expensive.

Electronic Control Systems

Electronic control systems use solid state components in electronic circuits to create control signals in response to sensor information. Advantages are that modulated controls are reliable and require less calibration and use electricity. Disadvantages are actuators and controllers are expensive.

Digital Control System

Digital systems controllers utilize electronic technology to detect, amplify, and evaluate sensor information. The evaluation can include sophisticated logical operations and results in a output command signal. It is often necessary to convert this output command signal to an electrical or pneumatic signal capable of operating a controlled device. Advantages are that controls are highly reliable and require minimal maintenance. Disadvantages are initial costs which may be high.

Equipment for automatic controls Sensors

Certain basic field hardware is necessary for a control system to function properly. Sensors provide appropriate information concerningthe HVAC control system. Communications

paths must be available to transmit sensor and control information. Often referred to as inputs, sensed signals convey either analog or binary information. Analog Inputs convey variable signals such as outdoor air temperature. Binary Inputs convey status signals such as fan or pump status, ON or OFF. This network of field hardware must function properly if the building control system is to be effective. It is a distinction of professional building management for the entire network of sensors, controllers and communications to remain functioning and accurate. This necessitates an investment in effective preventive maintenance and continuous fault monitoring and correction, but pays rich dividends in the ability to provide a well controlled, cost effective environment.

Sensors types include:

- Temperature
- Humidity
- Pressure
- Air Quality

Controllers

Controller types include:

- Two Position
- Proportional Action
- Proportional plus Integral (PI)
- Proportional Integral Derivative (PID)

Controllers are devices which create changes, known as system response according to sensor information. Controllers play the critical role of maintaining the desired building conditions. Controllers produce five distinct types of control action to control a buildings environment at desired settings. These types of control action will be presented, beginning with the simplest and progressing through the most sophisticated. Other types of control action are available.

CONTROLLED DEVICES

Controlled Devices include:

- Valves
- Dampers
- Actuators for Valves and Dampers

Just about all HVAC control systems will require some type of controlled device. Water and steam flow controlled devices are called valves while air flow controlled devices are called dampers. The actuator performs the function of receiving the controllers command output signal and produces a force or movement used to move the manipulated device usually the valve or damper.

Advansed technology for effective facility control

Advances in technology brought direct digital control, lighting control, fire management,security monitoring, distributed networks, personal computers, and sophisticated graphics. Electronic chips replaced pneumatic controllers. Personal computers (PC's) replaced minicomputers. Software programs replaced hardwired logic.

Each new advancement in the electronics and communications industries was eagerly snapped up by Facilities Management System (FMS) designers. (Note FMS is also sometime referred to as EMS, but EMS are Energy management systems and FMS tend to be focused on other uses of the data beyond energy conservations such as computerized maintenance management.) Systems are now faster and more capable than ever before. Software programs, electronic components, sensors, actuators, hardware packaging, and communications networks are integrated, share information, and work together.

The overall purpose of a Facilities Management system is to make the job of facilities people easier, to make a facility more efficient, and to keep a facility's occupants comfortable and safe.

The FMS can save money for building owners in several ways:

•By increasing the productivity from
staff by doing mundane tasks for them.

•By reducing energy consumption (energy management programs).

•By identifying equipment needing maintenance, and even rotating the use of some equipment.

•By managing information.

When considering the use of any FMS, you must define the desired functions, make a realistic financial analysis, and determine the amount of time available for building personnel to use and learn to use the system. The following discussion investigates many of the options available throughout the industry, although there may not be any single FMS which includes them all.

ENERGY MANAGEMENT OPPORTUNITIES

•Regular calibrationand maintenance programsare necessary if instruments are to produce reliable data. With the use of electronics today, many instruments are now self-calibrating, saving time and effort and offering continuous accuracy. However, the supporting system must also be taken care of (e.g. ensuring that the compressed air is free of moisture and dirt and that the line filters are maintained regularly).

The management of instrumentation, measuring and testing equipment – which includes applicable test software – is well covered under the broadly used international standards for quality and environmental management systems. Even facilities that have not yet implemented these standards would be well advised to adopt the principles for sound management of their instrumentation, metering and monitoring equipment.

•Records

. Measuring, metering and monitoring equipment is not of much use without good record keeping. Record keeping is particularly important to the process of identifying deviations from normal operation and changes in energy efficiency. Important information should be logged at regular intervals, either manually or automatically. Inexpensive electronic data-loggers with many desirable features and capabilities are now available, and collecting and recording data reliably has never been easier.

•Analysis and follow-up

For the measuring or monitoring activity to make sense, there must be an analysis of the monitored equipment's performance records (conveniently facilitated by many software packages available on the market) and a follow-up on deviations from optimal state. Sometimes, of course, a suitable period must first pass in order to confirm that the deviation is systemic in order to establish a trend and to confirm the need for a corrective or preventive action. At other times, as in a case of simple process inattention, the follow-up must be prompt.

•Acquisition of new measuringand monitoring equipment and instrumentationwith an optimum accuracy. For example, boiler plants and other facilities using combustion processes consume significant quantities of fuel. For these, purchase of an oxygen and combustibles analyser is justifiable because a regularly adjusted boiler combustion system can quickly pay back the equipment cost. Similarly, equipment that detects compressed air leaks is a worthwhile investment. Chances are that it will pay for itself in a short time.

•Correct installation

One should not assume that an existing installation is functioning correctly just because it has been in use for years. Often,measuring inaccuracies result from improper installation that must be corrected. Nonintrusive measurement techniques are now available, with correspondingly easier installation requirements.

•Develop a proper designof instrument-measuring systems.

•Detectors of abnormal conditions(e.g. doors to refrigerated warehouse left ajar; tank overflow level situation).

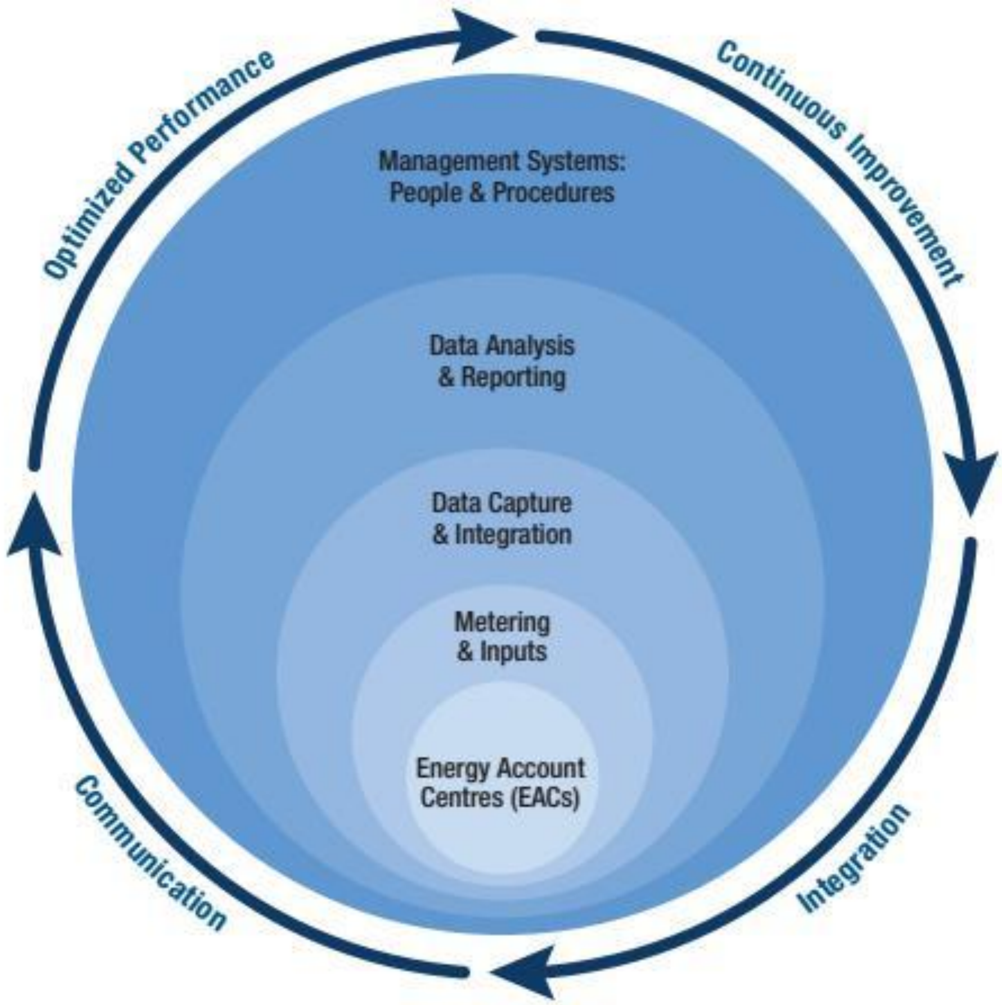
•HVAC monitoring sensors.

•Replacementof pneumatic controls with direct digital controls;

•A specific process equipment or application(e.g. boiler, peak demand regulation);

ENERGY MANAGEMENT INFORMATION SYSTEM (EMIS)

An Energy Management Information System (EMIS) provides relevant information that makes energy performance visible to various levels of an organization, enabling individuals and departments to plan, make decisions and take effective action to manage energy. It can lead to productivity improvements through the continuous monitoring of energy performance, and savings opportunities that, once implemented, are sustained over the long term. The performance information generated by an EMIS enables organizations to take actions that create financial value through the management and control of energy.



What is an EMIS?

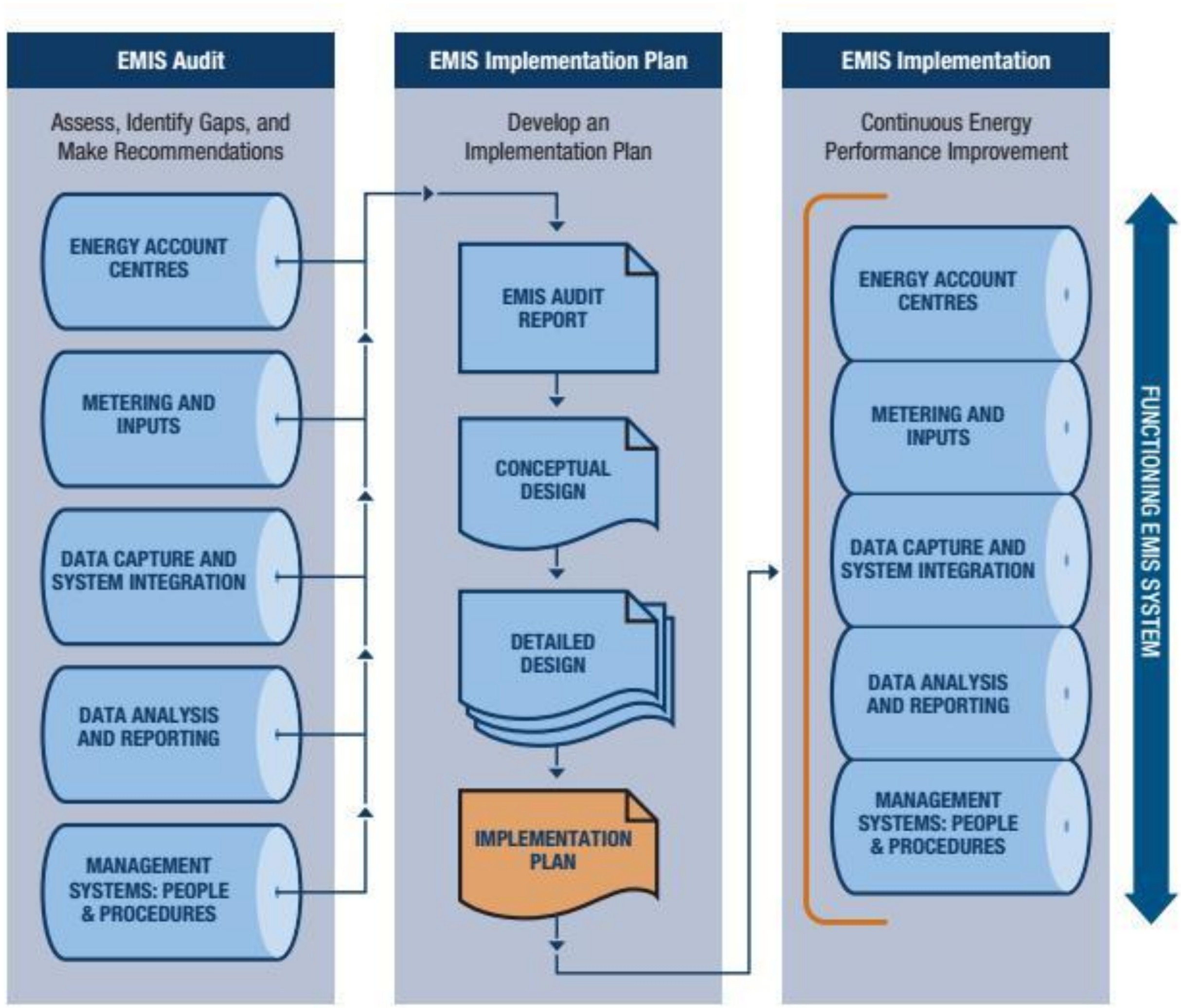
An EMIS provides relevant information that makes energy performance visible so that key individuals and departments within a business can take effective action to create financial value for the organization. In practice, this means that an EMIS should:

ƒ Gather information on energy consumption;

ƒ Gather information on the useful outputs derived from the consumption of energy (e.g., production, heating, lighting);

ƒ Gather information on any other factors that may influence energy consumption (e.g., environmental factors such as ambient temperature and relative humidity, or operational factors

such as building occupancy, packaging sizes);



Phases of EMIS development and Implementation

ƒ Contain analysis routines to allow for a comparison between energy consumption and utility drivers;

ƒ Build and display energy performance reports.

With effective management systems in place, these performance reports can:

ƒ Act as a stimulus for investigation and identification of the root causes of both good and poor

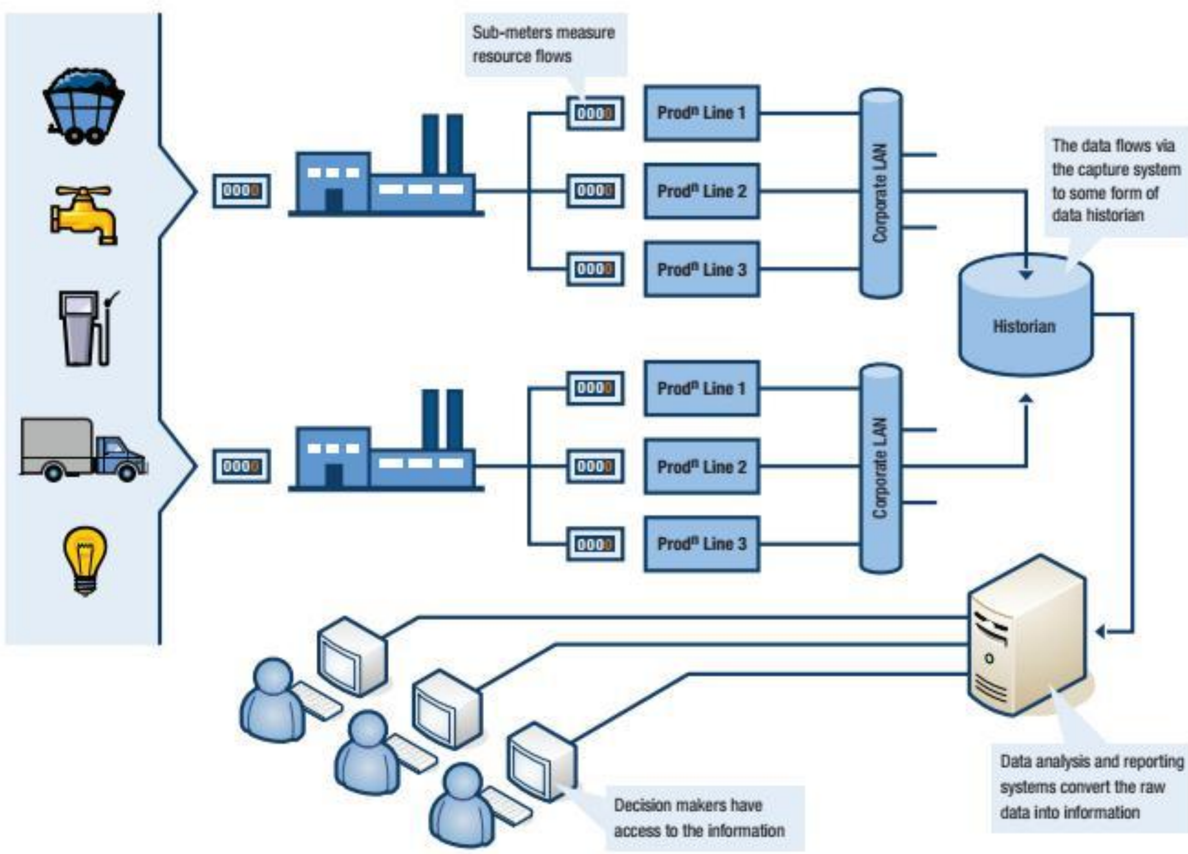
performance;

ƒ Promote operational best practices by eliminating the root causes of poor performance and promoting activities that lead to good performance;ƒ Provide the justification for energy saving projects by making visible the costs of current energy performance and providing a baseline against which savings projects can be compared; and ƒ Demonstrate the success or benefits of projects that have been implemented.an EMIS generally includes the following key components:

ƒ Energy Account centres (EAcs) to manage the energy performance systems (e.g., may be process lines, unit operations such as furnaces or driers, or components such as air compressors or boilers).

ƒ Energy meters and sensors for the key environmental factors that influence energy performance but over which operators have no control (e.g., temperature, relative humidity);ƒ Production meters and sensors for the operational factors;ƒ data capture systems and data historians to store this data; andƒ data analysis and reporting systems.

An EMIS does not exist in isolation but is part of an organization's energy management system (EnMS). Any EMIS should be adequate to the purpose of the organization it serves, i.e., meet the requirements assigned to the EMIS by the organization and be appropriate to the current status and anticipated development of the organization's energy management system. this means that assessors cannot simply restrict themselves to the technical components of the EMIS during the audit, but must also address the interaction between the EMIS and the EnMS.



Technical components of EMIS

What is the Scope of an EMIS?

Although an EMIS usually operates at a site level, in practice it can be implemented at many levels:ƒ Restricted to an area of energy use – this may be a good starting point for those organizations unfamiliar with the technique; ƒ Equipment or process – as an example, EMIS can be used to control air compressors by comparing the compressed air generated with the electricity used in generation with the compressed air generated during

production;ƒ Department level;ƒ Cost centre;ƒ Energy Account Centre;ƒ Site-wide;ƒ Corporate – integrating the performance reporting from multiple sites into a corporate energy or environmental report.

Outcomes and Benefits of an EMIS

The savings potential attributable to the implementation of an EMIS depends on a number of different factors:

ƒ The type of process the site is operating;

ƒ The maturity of the organization in terms of its energy management systems and procedures; The abilities and motivation of the operational staff. There are many types of self-assessment tools available online to help evaluate this capacity. Of the three, the people element is the most important. As a result, it can be difficult to define in advance the savings associated with implementing an EMIS.

It is useful at this stage to clarify how implementing an EMIS may lead to savings. There are a number of recognized outcomes of an EMIS: ƒ Reduced operational variability and embedding of operational best practices. This is determined by an operator's ability to recognize when the process is operating well or poorly. Savings are made by eliminating the root causes of poor performance and promoting activities that lead to good performance.

ƒ An investigation into the causes of poor performance and the identification of energy conservation measures. Ideas for energy conservation measures may be developed as part of the process of understanding the root causes of poor performance.

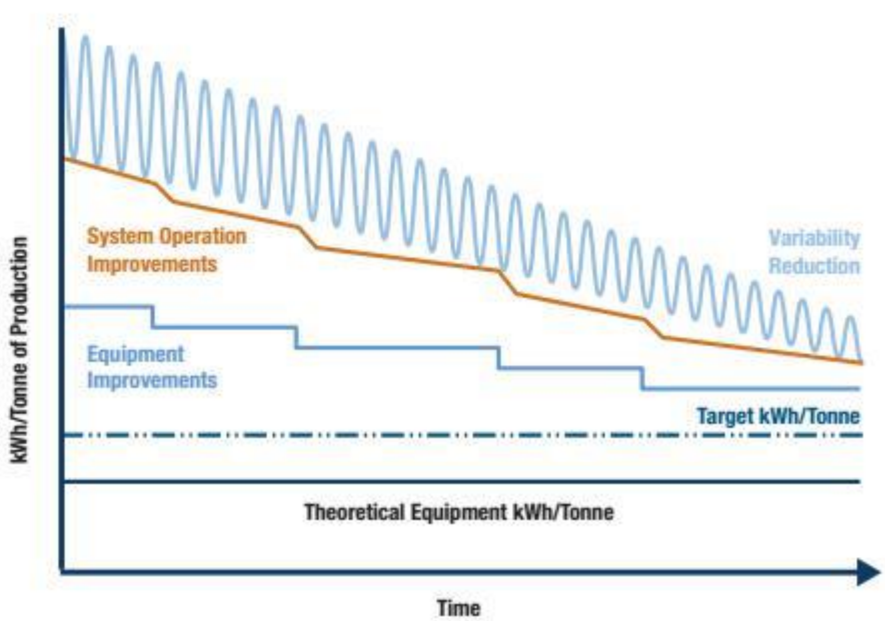
ƒ Benchmarking of similar processes across organizations. Why do the same production processes have different energy performance characteristics at different sites?At a strategic level, implementation of EMIS and energy management may also help to reduce the business risk facing an organization as a result of volatility in energy prices.

By reducing both the amount of operational variability and encouraging investment in energy conservation measures, energy performance becomes more predictable. With predictable energy consumption, the organization is better able to negotiate energy supply agreements and more accurately forecast energy costs.

Energy Management, EMIS and Savings

There is extensive literature on establishing a systematic approach to the management of energy. There is no “one size fits all” approach to the issue. As the purpose of installing an EMIS is to provide information to people that enables energy improvement actions, the organizational context that drives those actions is paramount to EMIS success. In other words, an EMIS alone will not save money. An EMIS must be developed with careful consideration of the broader context of the structured management of energy. The material and tools are aimed at supporting this holistic concept of EMIS.

By placing an EMIS within a context of an energy management program with continuous improvement as one of its objectives, it can also lead to productivity improvements through the progressive elimination of wasted consumption. Using information gained about the behaviors that lead to reduced energy consumption, best practices are quickly identified and less efficient historic ways of working are challenged. Continuous monitoring of performance also means that when savings opportunities are implemented they are sustained in the long term and deviations from best performance can be quickly recognized and corrected



Savings from EMIS

UNIT V
ECONOMICS AND FINANCE

Introduction

In the process of energy management, at some stage, investment would be required for reducing the energy consumption of a process or utility. Investment would be required for modifications/retrofitting and for incorporating new technology. It would be prudent to adopt a systematic approach for merit rating of the different investment options vis-à-vis the anticipated savings. It is essential to identify the benefits of the proposed measure with reference to not only energy savings but also other associated benefits such as increased productivity, improved prod-uct quality etc.

The cost involved in the proposed measure should be captured in totality viz.

- Direct project cost
- Additional operations and maintenance cost
- Training of personnel on new technology etc.

Based on the above, the investment analysis can be carried out by the techniques explained in the later section of the chapter.

Investment Need, Appraisal and Criteria

To persuade your organization to commit itself to a program of investment in energy efficiency, you need to demonstrate:

- The size of the energy problem it currently faces
- The technical and good housekeeping measure available to reduce waste
- The predicted return on any investment
- The real returns achieved on particular measures over time.

The need for investments in energy conservation can arise under following circumstances

- For new equipment, process improvements etc.
- To provide staff training
- To implement or upgrade the energy information system

Criteria

Any investment has to be seen as an addition and not as a substitute for having effective man-agement practices for controlling energy consumption throughout your organization. Spending money on technical improvements for energy management cannot compensate for inadequate attention to gaining control over energy consumption. Therefore, before you make any investments, it is important to ensure that

- You are getting the best performance from existing plant and equipment
- Your energy charges are set at the lowest possible tariffs
- You are consuming the best energy forms - fuels or electricity as efficiently as possible
- Good housekeeping practices are being regularly practiced.

When listing investment opportunities, the following criteria need to be considered:

- The energy consumption per unit of production of a plant or process
- The current state of repair and energy efficiency of the building design, plant and ser-vices, including controls
- The quality of the indoor environment not just room temperatures but indoor air quality and air change rates, drafts, under and overheating including glare, etc.
- The effect of any proposed measure on staff attitudes and behaviour.

Energy Proposals Vs Other Competitive Proposals

One of the most difficult problems which many energy managers face is justifying why their organization should invest money in increasing its energy efficiency, especially when there are other, seemingly more important priorities for the use of its capital.

- Organization typically give priority to investing in what they see as their core or profit-making activities in preference to energy efficiency
- Even when they do invest in saving energy, they tend to demand faster rates of return than they require from other kinds of investment.

Investment Appraisal

Energy manager has to identify how cost savings arising from energy management could be redeployed within his organization to the maximum effect. To do this, he has to work out how benefits of increased energy efficiency can be best sold to top management as,

- Reducing operating /production costs
- Increasing employee comfort and well-being
- Improving cost-effectiveness and/or profits
- Protecting under-funded core activities
- Enhancing the quality of service or customer care delivered
- Protecting the environment

Financial Analysis

In most respects, investment in energy efficiency is no different from any other area of finan-cial management. So when your organization first decides to invest in increasing its energy effi-ciency it should apply exactly the same criteria to reducing its energy consumption as it applies to all its other investments. It should not require a faster or slower rate of return on investment in energy efficiency than it demands elsewhere. The basic criteria for financial investment appraisal include:

- **Simple Payback** - a measure of how long it will be before the investment makes money, and how long the financing term needs to be
- **Return on Investment (ROI) and Internal Rate of Return (IRR)** - measure that allow comparison with other investment options

- **Net Present Value (NPV) and Cash Flow** - measures that allow financial planning of the project and provide the company with all the information needed to incorporate energy efficiency projects into the corporate financial system.

Initially, when you can identify no or low cost investment opportunities, this principle should not be difficult to maintain. However, if your organization decides to fund a rolling pro-gram of such investments, then over time it will become increasingly difficult for you to iden-tify opportunities, which conform to the principle. Before you'll reach this position, you need to renegotiate the basis on which investment decisions are made.

It may require particular thoroughness to ensure that all the costs and benefits arising are taken into account. As an approximate appraisal, simple payback (the total cost of the measure divided by the annual savings arising from it expressed as years required for the original invest-ment to be returned) is a useful tool.

As the process becomes more sophisticated, financial criteria such as Discounted Cash Flow, Internal Rate of Return and Net Present Value may be used. If you do not possess sufficient financial expertise to calculate this yourself, you will need to ensure that you have access, either within your own staff or elsewhere within the organization, to people who can employ them on your behalf.

There are two quite separate grounds for arguing that, at least long after their payback periods. Such measure does not need to be written off using fast discounting rates but can be regard-ed as adding to the long term value of the assets. For this reason, short term payback can be an inadequate yardstick for assessin long after their payback periods. Such measure does not need to be written off using fast discounting rates but can be regarded as adding to the long term value of the assets. For this reason, short term payback can be an inadequate yardstick for assessing longer term benefits. To assess the real gains from investing in saving energy, you should use investment appraisal techniques, which accurately reflect the longevity of the returns on particular types of technical measures.

Protecting Energy Investment

It is essential to keep a careful watch on your organization's maintenance policy and practices in order to protect any investment already made in reducing your organization's energy con-sumption. There is a clear dependence relationship between energy efficiency and maintenance. This operates at two levels:

- Initially, improving energy efficiency is most cost-effectively done in existing facilities through normal maintenance procedures
- Subsequently, unless maintenance is regularly undertaken, savings from installed technical measure, whether in new-build or existing facilities, may not be realized.

Financial Analysis Techniques

In this chapter, investment analysis tools relevant to energy management projects will be discussed.

Simple Pay Back Period:

Simple Payback Period (SPP) represents, as a first approximation; the time (number of years) required to recover the initial investment (First Cost), considering only the Net Annual Saving:

The simple payback period is usually calculated as follows:

Examples

$$\textit{Simple payback period} = \frac{\textit{First}\ \text{cost}}{\textit{Yearly benefits} - \textit{Yearly}\ \text{costs}}$$

Simple payback period for a continuous Deodorizer that costs Rs.60 lakhs to purchase and install, Rs.1.5 lakhs per year on an average to operate and maintain and is expected to save Rs. 20 lakhs by reducing steam consumption (as compared to batch deodorizers), may be calculated as follows:According to the payback criterion, the shorter the payback period, the more desirable the project.

Advantages

A widely used investment criterion, the payback period seems to offer the following advantages:

- It is simple, both in concept and application. Obviously a shorter payback generally indicates a more attractive investment. It does not use tedious calculations.
- It favours projects, which generate substantial cash inflows in earlier years, and discriminates against projects, which bring substantial cash inflows in later years but not in earlier years.

Limitations

- It fails to consider the time value of money. Cash inflows, in the payback calculation, are simply added without suitable discounting. This violates the most basic principle of financial analysis, which stipulates that cash flows occurring at different points of time can be added or subtracted only after suitable compounding/discounting.

- It ignores cash flows beyond the payback period. This leads to discrimination against projects that generate substantial cash inflows in later years.

To illustrate, consider the cash flows of two projects, A and B:

The payback criterion prefers A, which has a payback period of 3 years, in comparison to B,

Investment	Rs. (100,000)	Rs.(100,000)
Savings in Year	**Cash Flow of A**	**Cash flow of B**
1	50,000	20,000
2	30,000	20,000
3	20,000	20,000
4	10,000	40,000
5	10,000	50,000
6	-	60,000

which has a payback period of 4 years, even though B has very substantial cash inflows in years 5 and 6.

- It is a measure of a project's capital recovery, not profitability.
- Despite its limitations, the simple payback period has advantages in that it may be use-ful for evaluating an investment.

Time Value of Money

A project usually entails an investment for the initial cost of installation, called the capital cost, and a series of annual costs and/or cost savings (i.e. operating, energy, maintenance, etc.) throughout the life of the project. To assess project feasibility, all these present and future cash flows must be equated to a common basis. The problem with equating cash flows which occur at different times is that the value of money changes with time. The method by which these var-ious cash flows are related is called **discounting,** or the **present value concept.**

For example, if money can be deposited in the bank at 10% interest, then a Rs.100 deposit will be worth Rs.110 in one year's time. Thus the Rs.110 in one year is a future value equiva-lent to the Rs.100 present value.

In the same manner, Rs.100 received one year from now is only worth Rs.90.91 in today's money (i.e. Rs.90.91 plus 10% interest equals Rs.100). Thus Rs.90.91 represents the present value of Rs.100 cash flow occurring one year in the future. If the interest rate were something different than 10%, then the equivalent present value would also change. The relationship between present and future value is determined as follows:

$$\text{Future Value (FV)} = NPV\,(1 + i)^n \quad \text{or} \quad NPV = FV / (1+i)^n$$

Where

FV = Future value of the cash flow

NPV= Net Present Value of the cash flow

i = Interest or discount rate

n = Number of years in the future

Return on Investment (ROI)

ROI expresses the "annual return" from the project as a percentage of capital cost. The annual return takes into account the cash flows over the project life and the discount rate by converting the total present value of ongoing cash flows to an equivalent annual amount over the life of the project, which can then be compared to the capital cost. ROI does not require similar pro-ject life or capital cost for comparison.

This is a broad indicator of the annual return expected from initial capital investment, expressed as a percentage:

$$ROI = \frac{\text{Annual Net Cash Flow}}{\text{Capital Cost}} \times 100$$

ROI must always be higher than cost of money (interest rate); the greater the return on investment better is the investment.

Limitations

- It does not take into account the time value of money.
- It does not account for the variable nature of annual net cash inflows.

Net Present Value

The net present value (NPV) of a project is equal to the sum of the present values of all the cash flows associated with it. Symbolically,

$$NPV = \frac{CF_0}{(1+\kappa)^0} + \frac{CF_1}{(1+\kappa)^1} + \cdots + \frac{CF_n}{(1+\kappa)^n} = \sum_{t=0}^{n} \frac{CF_t}{(1+\kappa)^t}$$

Where NPV = Net Present Value

CFt = Cash flow occurring at the end of year 't' (t=0,1,….n)

n = life of the project

k = Discount rate

The discount rate (k) employed for evaluating the present value of the expected future cash flows should reflect the risk of the project.

Example

To illustrate the calculation of net present value, consider a project, which has the following cash flow stream:

Investment	Rs. (1,000,000)
Saving in Year	Cash flow
1	200,000
2	200,000
3	300,000
4	300,000
5	350,000

The cost of capital, κ, for the firm is 10 per cent. The net present value of the proposal is:

$$NPV = -\frac{1,000,000}{(1.10)^0} + \frac{200,000}{(1.10)^1} + \frac{200,000}{(1.10)^2}$$

$$+ \frac{300,000}{(1.10)^3} + \frac{300,000}{(1.10)^4} + \frac{350,000}{(1.10)^5} = (5,273)$$

The net present value represents the net benefit over and above the compensation for time and risk.Hence the decision rule associated with the net present value criterion is: "Accept the project if the net present value is positive and rejects the project if the net present value is negative".

Advantages

The net present value criterion has considerable merits.

- It takes into account the time value of money.
- It considers the cash flow stream in its project life.

Internal Rate of Return

This method calculates the rate of return that the investment is expected to yield. The internal rate of return (IRR) method expresses each investment alternative in terms of a rate of return (a compound interest rate). The expected rate of return is the interest rate for which total dis-counted benefits become just equal to total discounted costs (i.e net present benefits or net annu-al benefits are equal to zero, or for which the benefit / cost ratio equals one). The criterion for selection among alternatives is to choose the investment with the highest rate of return.

The rate of return is usually calculated by a process of trial and error, whereby the net cash flow is computed for various discount rates until its value is reduced to zero.

The internal rate of return (IRR) of a project is the discount rate, which makes its net pre-sent value (NPV) equal to zero. It is the discount rate in the equation:

$$0 = \frac{CF_0}{(1+\kappa)^0} + \frac{CF_1}{(1+\kappa)^1} + \ldots\ldots + \frac{CF_n}{(1+\kappa)^n} = \sum_{t=0}^{n} \frac{CF_t}{(1+\kappa)^t} \qquad (7.1)$$

where CFt = cash flow at the end of year "t"

k = discount rate

n = life of the project.

CFt value will be negative if it is expenditure and positive if it is savings.

In the net present value calculation we assume that the discount rate (cost of capital) is known and determine the net present value of the project. In the internal rate of return calculation, we set the net present value equal to zero and determine the discount rate (internal rate of return), which satisfies this condition.

To illustrate the calculation of internal rate of return, consider the cash flows of a project:

Year	0	1	2	3	4
Cash flow	(100,000)	30,000	30,000	40,000	45,000

The internal rate of return is the value of " κ " which satisfies the following equation:

$$100{,}000 = \frac{30{,}000}{(1+\kappa)^1} + \frac{30{,}000}{(1+\kappa)^2} + \frac{40{,}000}{(1+\kappa)^3} + \frac{45{,}000}{(1+\kappa)^4}$$

The calculation of "k" involves a process of trial and error. We try different values of "k" till we find that the right-hand side of the above equation is equal to 100,000. Let us, to begin with, try k = 15 per cent. This makes the right-hand side equal to:

$$+\frac{30{,}000}{(1.15)^2} + \frac{40{,}000}{(1.15)^3} + \frac{45{,}000}{(1.15)^4} = 100,802$$

(1. 1 5)

This value is slightly higher than our target value, 100,000. So we increase the value of k from 15 per cent to 16 per cent. (In general, a higher k lowers and a smaller k increases the right-hand side value). The right-hand side becomes:

$$\frac{30{,}000}{(1.16)} + \frac{30{,}000}{(1.16)^2} + \frac{40{,}000}{(1.16)^3} + \frac{45{,}000}{(1.16)^4} = 98,641$$

Since this value is now less than 100,000, we conclude that the value of k lies between 15 per cent and 16 per cent. For most of the purposes this indication suffices.

Advantages

A popular discounted cash flow method, the internal rate of return criterion has several advan-tages:

- It takes into account the time value of money.
- It considers the cash flow stream in its entirety.
- It makes sense to businessmen who prefer to think in terms of rate of return and find an absolute quantity, like net present value, somewhat difficult to work with.

Limitations

- The internal rate of return figure cannot distinguish between lending and borrowing and hence a high internal rate of return need not necessarily be a desirable feature.

Example

Calculate the internal rate of return for an economizer that will cost Rs.500,000, will last 10 years, and will result in fuel savings of Rs.150,000 each year.

Find the i that will equate the following:

Rs.500,000 = 150,000 x PV (A = 10 years, i = ?)

= Rs.150,000 x 3.571 - Rs.500,000 = Rs.35,650

= Rs.150,000 x 3.092 - Rs. 500,000 = -Rs. 36,200

NPV 25%

NPV 30%

For i = 25 per cent, net present value is positive; i = 30 per cent, net present value is negative. Thus, for some discount rate between 25 and 30 per cent, present value benefits are equated to present value costs. To find the rate more exactly, one can interpolate between the two rates as follows:

i = 0.25 + (0.30-0.25) x 35650 / (35650 + 36200)

= 0.275, or 27.5 percent

Cash Flows

Generally there are two kinds of cash flow; the initial investment as one or more installments, and the savings arising from the investment. This over simplifies the reality of energy manage-ment investment.

There are usually other cash flows related to a project. These include the following:

- Capital costs are the costs associated with the design, planning, installation and com-missioning of the project; these are usually one-time costs unaffected by inflation or dis-count rate factors, although, as in the example, installments paid over a period of time will have time costs associated with them.
- Annual cash flows, such as annual savings accruing from a project, occur each year over the life of the project; these include taxes, insurance, equipment leases, energy costs, ser-vicing, maintenance, operating labour, and so on. Increases in any of these costs repre-sent negative cash flows, whereas decreases in the cost represent positive cash flows.

Factors that need to be considered in calculating annual cash flows are:-

- Taxes, using the marginal tax rate applied to positive (i.e. increasing taxes) or negative (i.e. decreasing taxes) cash flows.
- Asset depreciation, the depreciation of plant assets over their life; depreciation is a "paper expense allocation" rather than a real cash flow, and therefore is not included directly in the life cycle cost. However, depreciation is "real expense" in terms of tax calculations, and therefore does have an impact on the tax calculation noted above. For example, if a Rs.10,00,000 asset is depreciated at 20% and the marginal tax rate is 40%, the depreciation would be Rs.200,000 and the tax cash flow would be Rs.80,000 and it is this later amount that would show up in the costing calculation.
- Intermittent cash flows occur sporadically rather than annually during the life of the pro-ject, relining a boiler once every five years would be an example.

Sensitivity and Risk Analysis

Many of the cash flows in the project are based on assumptions that have an element of uncer-tainty. The present day cash flows, such as capital cost, energy cost savings, maintenance costs, etc can usually be estimated fairly accurately. Even though these costs can be predicted with some certainty, it should always be remembered that they are only estimates. Cash flows in future years normally contain inflation components which are often "guess-timates" at best.

The project life itself is an estimate that can vary significantly.

Sensitivity analysis is an assessment of risk. Because of the uncertainty in assigning values to the analysis, it is recommended that a sensitivity analysis be carried out - particularly on projects where the feasibility is marginal. How sensitive is the project's feasibility to changes in the input parameters? What if one or more of the factors in the analysis is not as favourable as predicted? How much would it have to vary before the project becomes unviable? What is the probability of this happening?

Suppose, for example, that a feasible project is based on an energy cost saving that escalates at 10% per year, but a sensitivity analysis shows the break-even is at 9% (i.e. the project becomes unviable if the inflation of energy cost falls below 9%). There is a high degree of risk associated with this project - much greater than if the break-even value was at 2%.

Many of the computer spreadsheet programs have built-in "what if" functions that make sensitivity analysis easy. If carried out manually, the sensitivity analysis can become laborious reworking the analysis many times with various changes in the parameters.

Sensitivity analysis is undertaken to identify those parameters that are both uncertain and for which the project decision, taken through the NPV or IRR, is sensitive. Switching values showing the change in a variable required for the project decision to change from acceptance to rejection are presented for key variables and can be compared with post evaluation results for similar projects. For large projects and those close to the cut-off rate, a quantitative risk analysis incorporating different ranges for key variables and the likelihood of their occurring simultaneously is recommended. Sensitivity and risk analysis should lead to improved project design, with actions militating against major sources of uncertainty being outlined

The various micro and macro factors that are considered for the sensitivity analysis are listed below.

Micro factors

- Operating expenses (various expenses items)
- Capital structure
- Costs of debt, equity

- Changing of the forms of finance e.g. leasing
- Changing the project duration

Macro factors

Macro economic variables are the variable that affects the operation of the industry of which the firm operates. They cannot be changed by the firm's management. Macro economic variables, which affect projects, include among others:

- Changes in interest rates
- Changes in the tax rates
- Changes in the accounting standards e.g. methods of calculating depreciation
- Changes in depreciation rates
- Extension of various government subsidized projects e.g. rural electrification
- General employment trends e.g. if the government changes the salary scales
- Imposition of regulations on environmental and safety issues in the industry
- Energy Price change
- Technology changes

The sensitivity analysis will bring changes in various items in the analysis of financial statements or the projects, which in turn might lead to different conclusions regarding the implementation of projects.

Financing Options

There are various options for financing in-house energy management

1. From a central budget
2. From a specific departmental or section budget such as engineering
3. By obtaining a bank loan
4. By raising money from stock market
5. By awarding the project to Energy Service Company (ESCO)
6. By retaining a proportion of the savings achieved.

Self-Financing Energy Management

One way to make energy management self-financing is to split savings to provide identifiable returns to each interested party. This has the following benefits:

- Assigning a proportion of energy savings to your energy management budget means you have a direct financial incentive to identify and quantify savings arising from your own activities.
- Separately identified returns will help the constituent parts of your organization under-standing whether they are each getting good value for money through their support for energy management.
- If operated successfully, splitting the savings will improve motivation and commitment to energy management throughout the organization since staff at all levels will see a financial return for their effort or support.
- But the main benefit is on the independence and longevity of the energy management function.

Ensuring Continuity

After implementation of energy savings, your organization ought to be able to make consider-able savings at little cost (except for the funding needed for energy management staff). The important question is what should happen to these savings?

If part of these easily achieved savings is not returned to your budget as energy manager, then your access to self-generated investments funds to support future activities will be lost. And later in the program, it is likely to be much harder for you to make savings.

However, if, an energy manager, has access to a proportion of the revenue savings arising from staff's activities, then these can be reinvested in:

- Further energy efficiency measures
- Activities necessary to create the right climate for successful energy management which do not, of themselves, directly generate savings
- Maintaining or up-grading the management information system.

Energy Performance Contracting and Role of ESCOS

If the project is to be financed externally, one of the attractive options for many organizations is the use of energy performance contracts delivered by energy service companies, or ESCOs.

ESCOs are usually companies that provide a complete energy project service, from assessment to design to construction or installation, along with engineering and project management services, and financing. In one way or another, the contract involves the capitalization of all of the services and goods purchased, and repayment out of the energy savings that result from the project.

In performance contracting, an end user (such as an industry, institution, or utility), seeking to improve its energy efficiency, contracts with ESCO for energy efficiency services and financing.

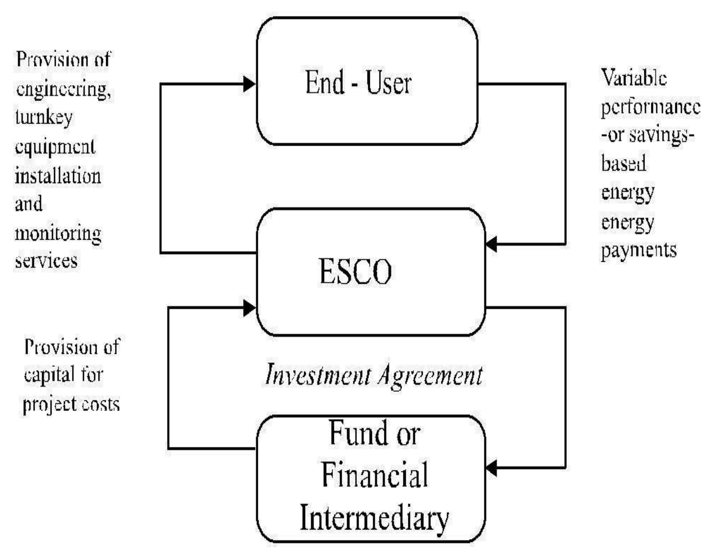
In some contracts, the ESCOs provide a guarantee for the savings that will be realized, and absorbs the cost if real savings fall short of this level. Typically, there will be a risk management cost involved in the contract in these situations. Insurance is sometimes attached, at a cost, to protect the ESCO in the event of a savings shortfall.

Energy efficiency projects generate incremental cost savings as opposed to incremental rev-enues from the sale of outputs. The energycost savings can be turned into incremental cash flows to the lender or ESCO based onthe commitment of the energy user (and in some cases, a utility) to pay for the savings.

What are performance contracts?

Performance contracting represents one of the ways to address several of the most fre-quently mentioned barriers to investment. Performance contracting through an ESCO transfers the technology and management risks away from the end-user to the ESCO.

For energy users reluctant to invest in energy efficiency, a performance contract can be a powerful incentive to implement a project. Performance contracting also mini-mizes or eliminates the up-front cash outlay required by the end-user. Payments are made over time as the energy savings are realized.



Profitability Index (PI) is a **capital budgeting** technique to evaluate the investment projects for their viability or profitability. Discounted cash flow technique is used in arriving at the profitability index. It is also known as a benefit-cost ratio. Calculation of profitability index is possible with a simple formula with inputs as – discount rate, cash inflows and outflows. PI greater than or equal to 1 is interpreted as a good and acceptable criterion.

Profitability Index Definition:

Profitability Index is a ratio of discounted cash inflow to the discounted cash outflow. Discounted cash inflow is our benefit in the project and the initial investment is our cost, which is why we also call it benefit to cost ratio.

Profitability Index Method

The method used for arriving at profitability index of a proposed project is explained stepwise below:

a) Find the expected cash inflows of the project
b) Find the cash outflows of the project (Initial Investment + any other cash outflow)
c) Decide an appropriate discount rate
d) Discount the expected cash inflows using the discount rate
e) Discount the future cash outflows and add to initial investment
f) Divide step (d) by step (e)

How to calculate the Profitability Index?

The calculation of PI is easily possible once we have the cash inflows and outflows with appropriate discount rate are in place.

Profitability Index Formula:

The formula indicates the benefits in the numerator and costs in the denominator. Formula for calculating Profitability Index is as follows:

$$\text{Profitability Index (PI) or Benefit to Cost Ratio} = \frac{\sum_{t=0}^{n} \frac{Benefit_t}{(1 + Discount\ Rate)^t}}{\sum_{t=0}^{n} \frac{Cost_t}{(1 + Discount\ Rate)^t}}$$

Example of Profitability Index (PI):

Let's assume the cash flows of a project as mentioned year wise in the second column of the below table. The negative cash flows are the costs and positive ones are the benefits. In the third column, they are discounted at 10% rate. All the discounted benefits are added to make $ 16,832 and discounted costs to make $15,450.

Year	Cash Flows (CF)	Discounted CF @ 10%	Benefits	Costs
0	-10000	-10,000		10,000
1	5000	4,545	4,545	
2	5000	4,132	4,132	
3	-5000	-3,757		3,757
4	4000	2,732	2,732	
5	4000	2,484	2,484	
6	-3000	-1,693		1,693
7	3000	1,539	1,539	
8	3000	1,400	1,400	
Total		**1,382**	**16,832**	**15,450**
NPV			**16832/15450 = 1.09**	
			Profitability Index	

The benefit to cost ratio or the PI can be found out by dividing benefits by costs (16832/15450 = 1.382)

Acceptance Criteria or Interpretation:

A profitability index of anything equal to or greater than 1 is considered good. It means that the project is worth executing. PI greater than 1 indicates that the project is paying something more than the required rate of return of the investor. In our example, the project should be accepted as it is greater than 1 i.e. 1.09.

Profitability Index (PI) and Net Present Value (NPV)

Profitability Index is closely linked with net present value. Both will present same results as far as acceptance and rejections are concerned. It is because the almost same calculation is followed in both. In PI, we divide our benefits by our costs whereas, in NPV, we deduct our costs from the benefits. PI will give a relative value and contrarily

Profitability Index – Advantages and Disadvantages

The advantage of profitability method is that it considers the **time value of money** and presents a relative profitability of the project. Relative profitability allows comparison of two investments irrespective of their amount of investment. A higher PI would indicate a better IRR and a lower PI would have lower IRR.

The main disadvantage of PI method is also its relative indications. Two projects having the vast difference in investment and dollar return can have the same PI. In such situation, therefore, the NPV method remains the best method.