

## **General Aspects of Energy Management and Energy Audit**

This book is a part of the course by Jaipur National University, Jaipur.

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## Abbreviations

AFBC	-	Atmospheric (Bubbling) Fluidised Bed Combustion System
CFBC	-	Atmospheric Circulating (Fast) Fluidised Bed Combustion System
CHP	-	Combined Heat and Power
CNG	-	Compressed Natural Gas
ESP	-	Electro Static Precipitators
ETI	-	Economic Thickness of Insulation
FBC	-	Fluidised Bed Combustion
FO	-	Furnace Oil
GCV	-	Gross Calorific Value
HFO	-	Heavy Fuel Oils
HPHE	-	Heat Pipe Exchanger
HSD	-	High Speed Diesel
I.C	-	Internal Combustion
IBR	-	Indian Boilers Regulation
ISO	-	International Standard Organisation
LDO	-	Light Diesel Oil
LNG	-	Liquefied Natural Gas
LP	-	Low Pressure
LPG	-	Liquefied Petroleum Gas
LSHS	-	Low Sulphur Heavy Stock
MP	-	Medium Pressure
PC	-	Pulverised Coal
PCE	-	Pyrometric Cone Equivalent
PFBC	-	Pressurised Fluidised Bed Combustion System
PHF	-	Pumping & Heating
PNG	-	Piped Natural Gas
PUF	-	Poly Urethane Form
RFO	-	Residual Fuel Oils
RLNG	-	Re-gasified Liquefied Natural Gas
RUL	-	Refractoriness Under Load
SRB	-	Self-recuperative Burners
TDS	-	Total Dissolved Solids
USDA FDA	-	United States Department of Agriculture-Food and Drug Administration
VSD	-	Variable Speed Drive

# **Chapter I**

## **Energy Scenario**

### **Aim**

The aim of this chapter is to:

- explicate the global energy scenario
- explain different types of energies
- introduce long term energy scenario

### **Objectives**

The objectives of this chapter are to:

- explain the importance of energy conservation and energy efficiency
- define the role of the Bureau of energy efficiency, Central and State Government
- explain the relationship between the use of energy and environment

### **Learning outcome**

At the end of this chapter, you will be able to:

- understand the classification of energy
- identify renewable sources of energy and their significance
- recognise energy conservation and energy efficiency

## 1.1 Introduction

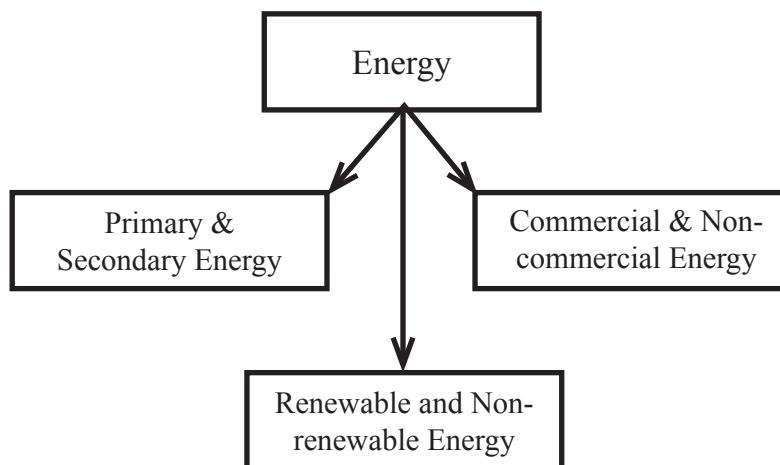
Energy can neither be created nor destroyed. The amount of energy in the universe remains constant; when we use energy, we do not use it, in fact we transform it from one form of energy to another. Energy is involved in each and every action occurring in the universe; including activities performed within and by a human body, physical actions like the shining sun, revolution of planets around the sun, motion of the tides, growth and decay of plants and animals. Energy is one of the most important resources for the economic development of any country.

Energy efficiency means identifying use of wasted energy and taking action to reduce or eliminate the wastage of energy. The objective of energy efficiency initiatives is to reduce energy costs and consequently increase profitability without sacrificing production. Energy efficiency should be given much priority which reflects the overall cost of energy both on an absolute and relative basis compared to other costs incurred by the company. With economic development, the demand for energy in the country will grow phenomenally in every segment of the economy and society. It would be therefore necessary to understand the importance and means to achieve energy efficiency and ensure the cost of energy and its availability do not cause any hindrance to development.

## 1.2 Classification of Energy

Energy is classified into the following types:

- primary and secondary energy
- commercial and non-commercial energy
- renewable and non-renewable energy



**Fig. 1.1 Block diagram to show energy classification**

## 1.3 Primary and Secondary Energy

### 1.3.1 Primary Energy

- primary energy sources are those that are either found or stored in nature, which can be used directly.
- example coal, oil, natural gas, biomass, nuclear energy (from radioactive substances), thermal energy stored in the earth's interior and potential energy due to the earth's gravity.

### 1.3.2 Secondary Energy

- secondary energy sources are those that are produced from primary energy for use.
- example - electricity obtained from water, electricity obtained from coal and petroleum, steam energy used from water and chemicals (fuels).

## **1.4 Commercial and Non-commercial Energy**

The features of commercial and non-commercial energy are discussed below:

### **1.4.1 Commercial Energy**

- The energy sources available in the market for a definite price are known to be the sources of commercial energy.
- The various forms of commercial energy include electricity, coal and refined petroleum products.
- Commercial energy forms the basis for industrial, agricultural, transport and commercial development in the modern world.
- In the industrialised countries, commercialised fuels are not only significant for economic production, but also for many household tasks.

### **1.4.2 Non-commercial Energy**

- Non-commercial energy is classified as the energy sources that are not available in the commercial market for any price.
- Non-commercial energy sources include fuels (such as firewood, cattle dung and agricultural wastes), which are traditionally gathered (and not bought) and are used in rural households and traditional fuels (specifically).
- However, non-commercial energy is often ignored in energy accounting.
- Example - Firewood, agro wastes 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.

## **1.5 Renewable and Non-renewable Energy**

The meaning and use of renewable and non-renewable resources are explained in detail below:

### **1.5.1 Renewable Energy**

- Renewable energy is obtained from sources that are essentially inexhaustible.
- Examples - wind power, solar power, geothermal energy, tidal power and hydroelectric power.
- The most important feature of renewable energy is it does not release any harmful pollutants when harnessed.

### **1.5.2 Non-renewable Energy**

- Non-renewable energy resources are the conventional fossil fuels which are likely to deplete with time.
- Examples include - coal, oil and gas, nuclear and natural gas.

## **1.6 Renewable Energy Resources**

Renewable resources are available in various different forms. The forms are as follows:

### **1.6.1 Bio-mass**

- Bio-mass is a renewable source of energy produced when the sun's radiant energy is transformed into chemical energy by plants in a process called **photosynthesis**.
- Bio-mass energy is the oldest form of energy used by humans, and for thousands of years it is the main source of energy for human activity.
- Bio-mass is the most important source of energy which supports the life processes of humans and other animals.
- Wood, crops, and grasses are all primary sources of bio-mass; secondary sources include forest, agricultural, and food manufacturing wastes as well as garbage.

- Bio-mass is used to generate electricity, fuel vehicles, and produce heat for climate control and manufacturing.
- The fermentation of grains (principally corn) in the United States produces ethanol (a fuel). It is blended with gasoline to be used as a transportation fuel.
- Gasification converts decaying bio-mass in landfills and biogas digesters into methane gas, the main ingredient in natural gas.
- Use of bio-mass energy does not produce a significant net increase of carbon dioxide in the atmosphere.

#### **1.6.1.1 Bagasse as Bio-mass**

Bagasse is used as fuel to generate steam, which in turn, is used to generate power and process steam (co-generation plant). In view of lesser fuel cost (since it is a by product), this proves to be the most economical fuel for cogeneration.

#### **1.6.2 Wind Energy**

Wind energy is one of the viable sources of renewable energy, which can be used effectively for power generation. Power generation from wind energy depends on:

- wind speed
- duration of availability (blowing time of wind)
- feasibility of distribution and usage etc.

##### **1.6.2.1 Wind Turbines**

Power from wind is generated by using wind turbines. While wind turbines are commonly classified by their power rate at a given speed of wind; annual energy output is actually most important measure for evaluating a wind turbine's value at a given site.

##### **Wind turbine capacity factor**

The capacity factor is the wind turbine's actual energy output for the year divided by the energy output if the machine operates at its rated power output for the entire year. A reasonable capacity factor would be 0.25 - 0.30. A very good capacity factor would be 0.40.

##### **Power generation through wind turbines**

Since,

$$\text{Energy} = \text{Power} \times \text{Time}$$

And density is a more convenient way to express the mass of flowing air; the kinetic energy equation can be converted into a flow equation:

Power in the area swept by the wind turbine rotor is given by P (in watts)

$$P = 0.5 \times \rho \times A \times V^3$$

Where,

P = power in watts (746 watts = 1 hp) (1,000 watts = 1 kilowatt)

= air density (=about 1.225 kg/m<sup>3</sup>) at sea level)

A = rotor swept area, exposed to the wind (m<sup>2</sup>)

V = wind speed in meters/sec

#### **1.6.3 Hydro Energy**

- Hydropower is a renewable source of energy.
- Water continuously moves through a global cycle; evaporating from lakes and oceans, forming clouds, precipitating as rain or snow, and flowing back to the oceans. This water cycle is produced by the sun and driven by gravity.
- Hydropower facilities can capture the energy in flowing water by building a dam on a river (impoundment), or channelling a portion of a river through a diversion.

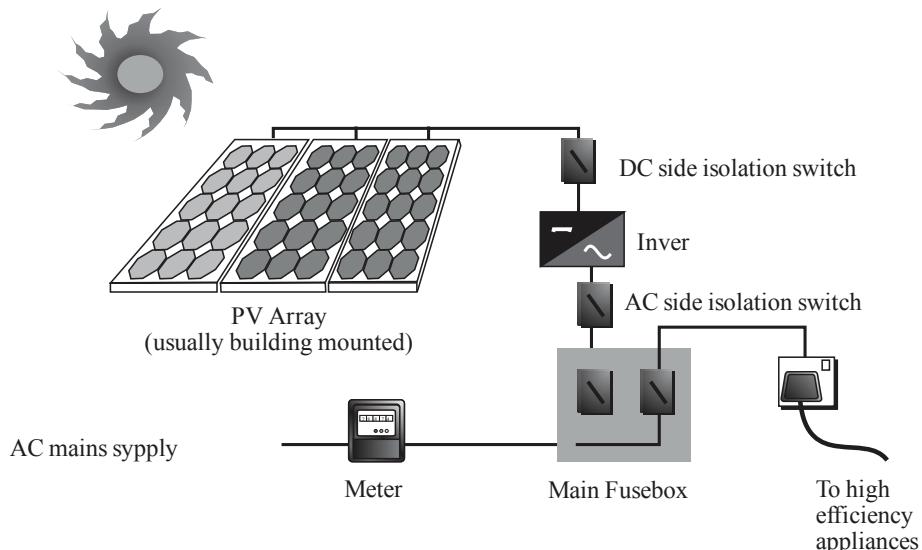
- Hydropower is considered an efficient, cost-effective and clean energy source to generate electricity.
- Hydropower plants return the water to the system unchanged in quantity and quality.

#### 1.6.4 Solar Energy

- Solar energy can be converted directly or indirectly into other forms of energy, example heat and electricity.
- The major drawbacks of solar energy are;
  - the intermittent and variable manner in which it reaches the earth's surface
  - the area required to collect it at a useful rate has to be large in size.
- Electric utilities use photovoltaic devices, wherein solar energy is converted directly to electricity.
- Electricity can be produced indirectly from steam generators using solar thermal collectors to heat a working fluid.

##### 1.6.4.1 Photovoltaic Cells

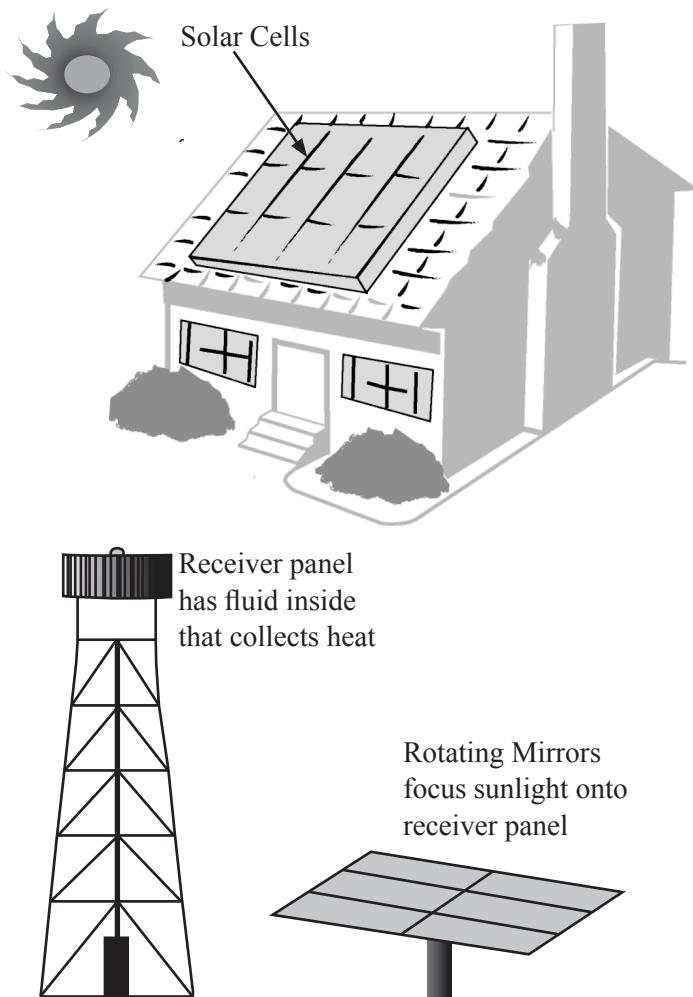
- There are only a handful of materials, especially treated semi-conductors that are known to display the PV effect with reasonable energy conversion efficiency.
- A vast majority of photovoltaic cells are made from silicon. Cells are classified either as crystalline (sliced from ingots or castings or grown ribbons) or thin film (deposited in thin layers on a low cost backing).
- The photovoltaic cell is the basic building block of a PV system.
- Individual cells can vary in size from about 1 cm (1/2 inch) to about 10 cm (4 inches) or more.
- However, one cell only produces 1-2 watts, which isn't enough for most applications. To increase power output, cells are electrically connected into a packaged weather-tight module.
- Modules can be further connected to form an array. The term **array** refers to the entire generating plant, whether it is made up of one or several thousand modules.



**Fig. 1.2 Application of photovoltaic cell**

##### 1.6.4.2 PV System (Solar)

- The lifetime of a PV system is assumed to be 30 years. Many manufacturers now offer 20-year guarantees and PV panels might last 0-50 years in non maritime locations.
- In Port Headland in NW Australia, which is an excellent site by world standards, the average irradiation on the panels is 2, 500 kWh/m<sup>2</sup>/year.



**Fig. 1.3 Solar power tower**

### 1.6.5 Tidal Energy

The worldwide wave power resource potential is huge. Future Energy Solutions highlight that the global power potential has been estimated to be around 8,000-80,000TWh/y (1-10TW), which is the same order of magnitude as world electrical energy consumption. The best wave climates, with annual average power levels between 20-70 kW/m of wave front or higher are found in the temperate zones (30-60degrees latitude), where strong storms occur.

### 1.6.6 Geothermal Energy

- Geothermal energy is considered a renewable source of energy.
- It is heat energy produced within the earth. It is continuously generated by the decay of radioactive elements in the earth's core.
- The most active, high temperature geothermal resources are usually found along major plate boundaries where earthquakes and volcanoes are concentrated.
- Geothermal reservoirs are formed by rainwater seeping through faults in the earth's crust into porous and permeable hot rocks.
- Most geothermal reservoirs contain a mixture of steam and hot water. Once the water has been used, it is injected back into the ground.
- Properly managed geothermal reservoirs can have extensive life spans.

## 1.7 Global Primary Energy Reserves

### 1.7.1 Coal

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

### 1.7.2 Oil

The proven global 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)

### 1.7.3 Gas

The proven global 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

## 1.8 Global Primary Energy Consumption

The global primary energy consumption at the end of 2003 was equivalent to 9741 million tonnes of oil equivalent (Mtoe). Fig. 1.4 shows in what proportions the sources mentioned above contributed to this global figure.

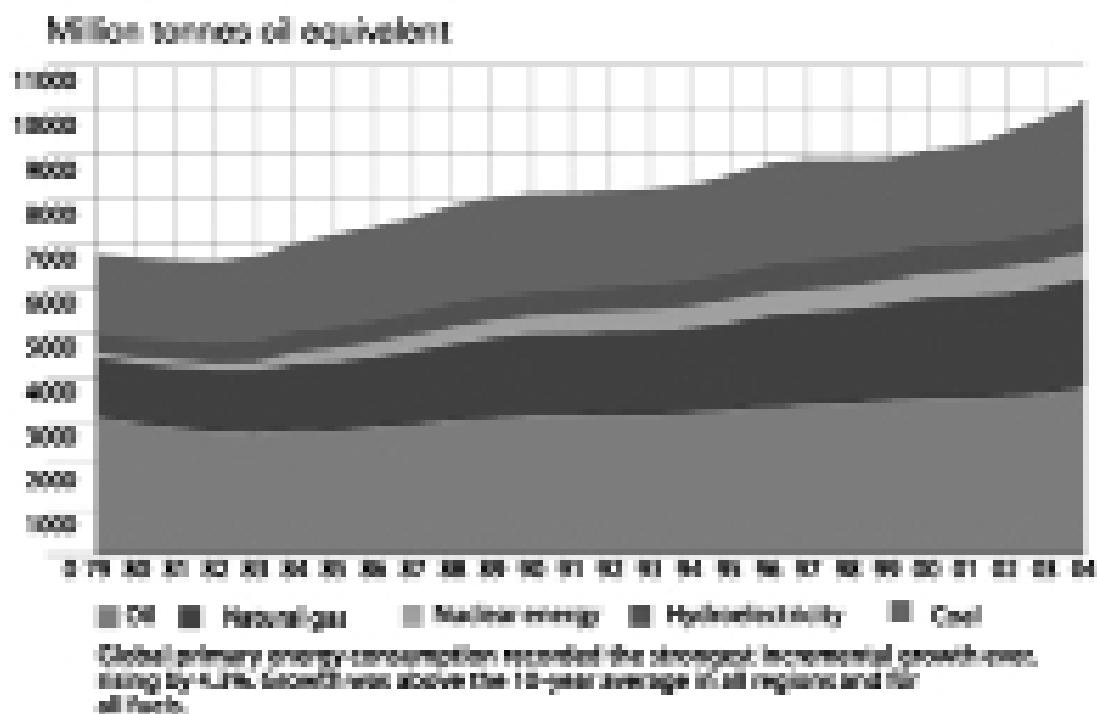


Fig. 1.4 Global primary energy consumption

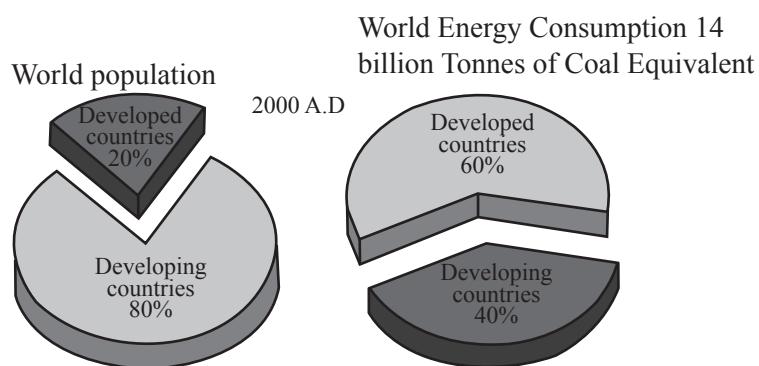
The primary energy consumption for few of the developed and developing countries is shown in Table 1.1. It may be seen that India's absolute primary energy consumption is only 1/29<sup>th</sup> of the world, 1/7<sup>th</sup> of USA, 1/1.6<sup>th</sup> time of Japan but 1.1, 1.3, 1.5 times that of Canada, France and U.K respectively.

<b>In Million tonnes oil equivalent</b>						
<b>Country</b>	<b>Oil</b>	<b>Natural Gas</b>	<b>Coal</b>	<b>Nuclear Energy</b>	<b>Hydro electric</b>	<b>Total</b>
USA	914.3	566.8	573.9	181.9	60.9	<b>2297.8</b>
Canada	96.4	78.7	31.0	16.8	68.6	<b>291.4</b>
France	94.2	39.4	12.4	99.8	14.8	<b>260.6</b>
Russian Federation	124.7	365.2	111.3	34.0	35.6	<b>670.8</b>
United Kingdom	76.8	85.7	39.1	20.1	1.3	<b>223.2</b>
China	275.2	29.5	799.7	9.8	64.0	<b>1178.3</b>
<b>India</b>	<b>113.3</b>	<b>27.1</b>	<b>185.3</b>	<b>4.1</b>	<b>15.6</b>	<b>345.3</b>
Japan	248.7	68.9	112.2	52.2	22.8	<b>504.8</b>
Malaysia	23.9	25.6	3.2	-	1.7	<b>54.4</b>
Pakistan	17.0	19.0	2.7	0.4	5.6	<b>44.8</b>
Singapore	34.1	4.8	-	-	-	<b>38.9</b>
<b>TOTAL World</b>	<b>3636.6</b>	<b>2331.9</b>	<b>2578.4</b>	<b>598.8</b>	<b>595.4</b>	<b>9741.1</b>

**Table 1.1: Primary energy consumption by fuel , 2003****Energy distribution between developed and developing countries**

Although 80 percent of the world's population lies in the developing countries (a four fold population increase in the past 25 years), their energy consumption amounts to only 40 percent of the world's total energy consumption. The high standards of living in the developed countries are attributable to high-energy consumption levels. Also, the rapid population growth in the developing countries has kept the per capita energy consumption low compared with that of highly industrialised developed countries.

The world average energy consumption per person is equivalent to 2.2 tonnes of coal. In industrialised 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.

**Fig. 1.5 Energy distribution between developed and developing countries**

## 1.9 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% - 13% since the year 1994 to 1999. There has been a decline in the share of oil in primary energy production from 20% - 17% during the same period.

### 1.9.1 Energy Supply

Different energy resources are utilised for the purpose of energy supply. These resources are:

#### 1.9.1.1 Coal

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 to the states of Andhra Pradesh, Uttar Pradesh, Bihar, Madhya Pradesh, Maharashtra, Orissa, Jharkhand, and West Bengal.

#### 1.9.1.2 Oil

Oil accounts for about 36 % of India's total energy consumption, making India counted among the top ten oil-guzzling nations in the world. India will soon overtake Korea, 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 tonnes as against the current peak demand of about 110 million tonnes. In the current scenario, India's oil consumption by the end of 2007 is expected to reach 136 million tonnes (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, and 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 Raising Import Bill		
Year	Quantity	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
*(Source: Ministry of Petroleum and Natural Gas)		

**Table 1.2 The ever raising import bill**

### 1.9.1.3 Natural Gas

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

### 1.9.1.4 Electrical Energy

The all India installed capacity of electric power generating stations under utilities was 1,12,581 MW as on 31<sup>st</sup> May 2004, consisting of 28,860 MW- hydro, 77,931 MW - thermal and 2,720 MW- nuclear and 1,869 MW- wind (\*Source - Ministry of Power).

The gross generation of power in the year 2002-2003 stood at 531 billion units (kWh).

### 1.9.1.5 Nuclear Power

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

<b>Nuclear Power in India</b>		<b>% of Total installed</b>
As of 2004	2720 MW	2.8
Planned till 2012	9380MW	8.1
Total	12100 MW	5.6

**Table 1.3 Nuclear power in india**

### 1.9.1.6 Hydro Power

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

## 1.10 Final Energy Consumption

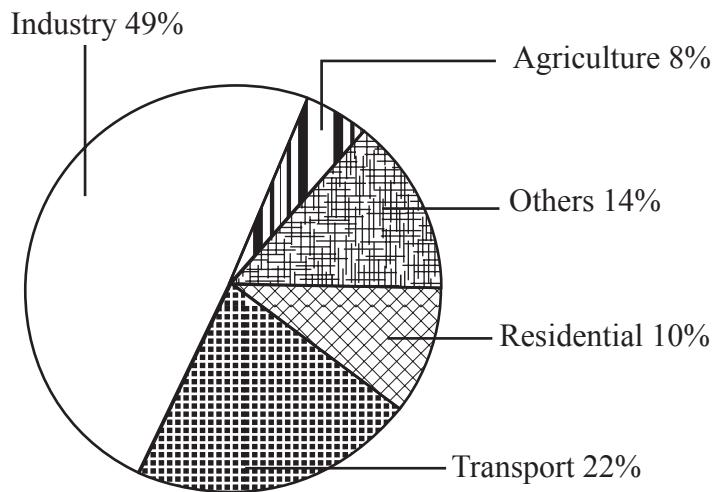
Final energy consumption is the actual energy demand at the user end. This is the difference between primary energy consumption and the losses that takes place in transport, transmission & distribution and refinement. The actual final energy consumption (past and projected) is given in Table 1.4.

<b>Source</b>	<b>Units</b>	<b>1994-95</b>	<b>2001-02</b>	<b>2006-07</b>	<b>2011-12</b>
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 <b>BAU: Business As Usual</b>					

**Table 1.4 Demands for commercial energy for final consumption (bau scenario)**

## 1.11 Sector wise Energy Consumption in India

The major commercial energy consuming sectors in the country are classified as shown in the Figure 1.6. 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)



**Fig. 1.6 Sector wise energy consumption (1999-2000)**

## 1.12 Energy Needs of Growing Economy

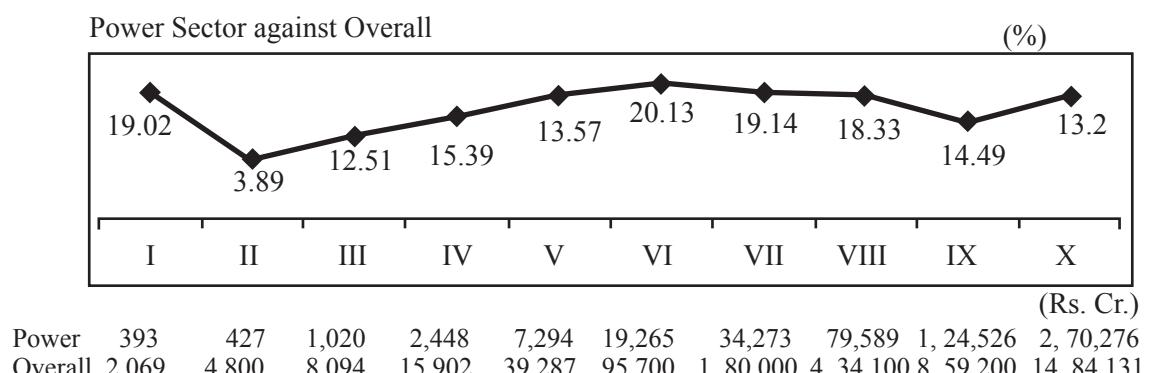
Economic growth is desirable for developing countries, and energy is essential for economic growth. However, the relationship between economic growth and increased energy demand is not always a straightforward linear one. Example, under present conditions, 6% increase in India's Gross Domestic Product (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 Fig. 1.7. As seen from the Figure, 18.0% of the total five-year plan outlay is spent on the energy sector.

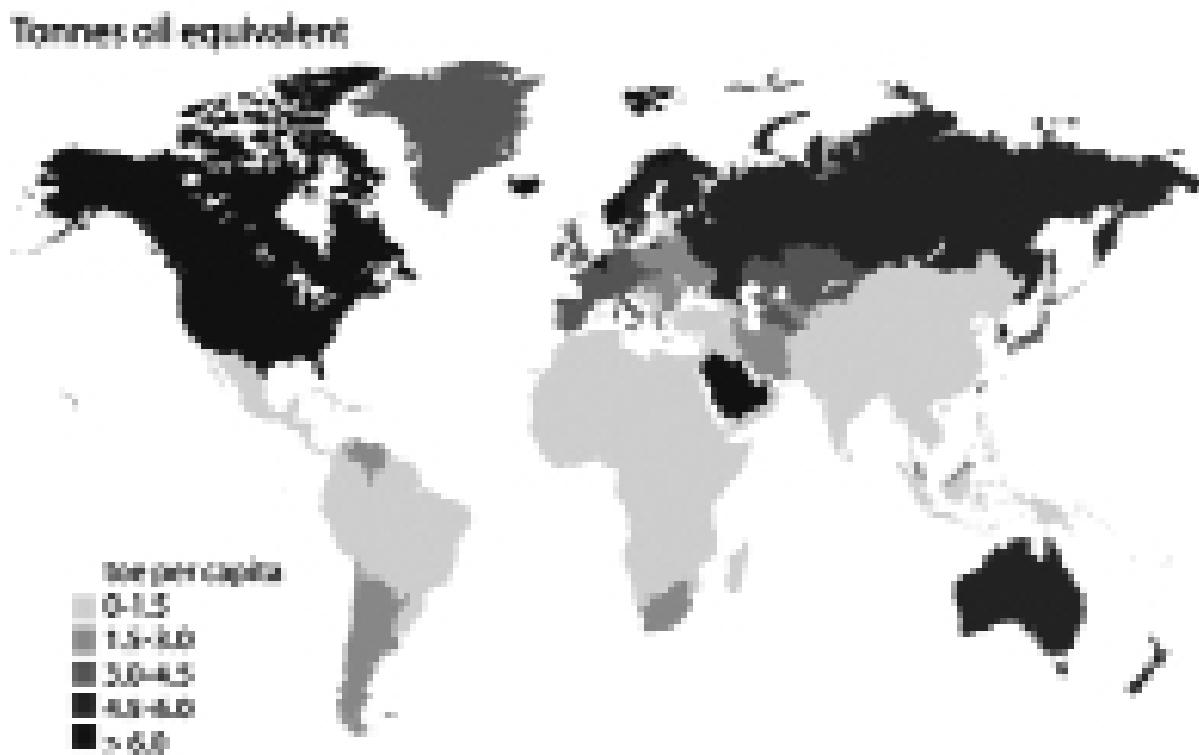
### Plan wise outlay



**Fig. 1.7 Expenditure towards energy sector**

### 1.13 Per Capita Energy Consumption

The per capita energy consumption (see Fig. 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.



**Fig.1.8 Per capita energy consumption**

#### 1.13.1 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.

### 1.14 Long Term Energy Scenario For India

The long term scenario of the energy resources in India has been discussed in the following points.

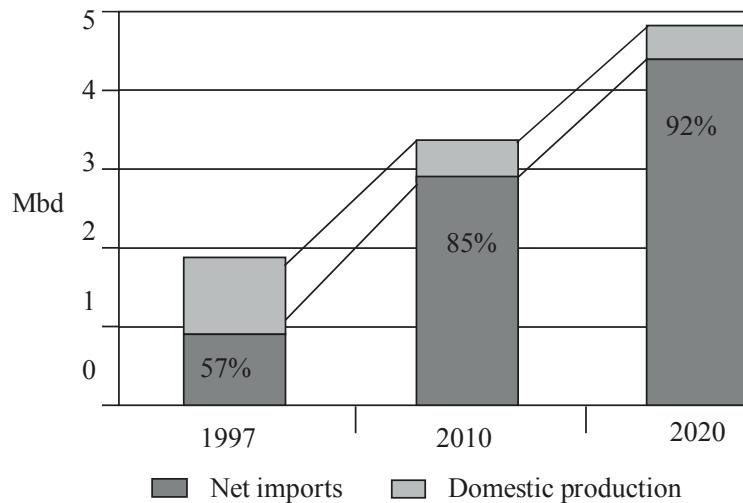
#### 1.14.1 Coal

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 increase in total installed capacity during the last decade, the gap between electricity supply and demand also 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 being improvement of the quality. Coal imports will also need to increase dramatically to satisfy industrial and power generation requirements.

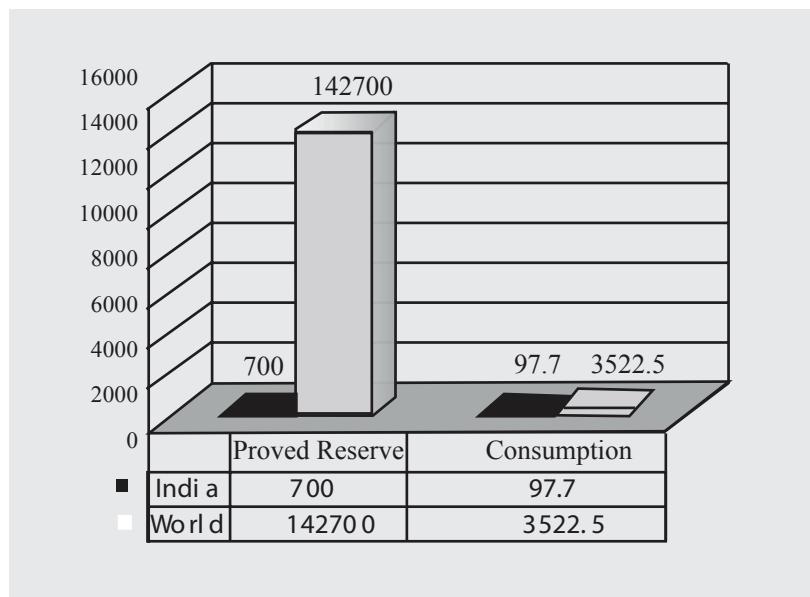
#### 1.14.2 Oil

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 10<sup>th</sup> plan period (2006-07). India's self sufficiency in oil has consistently declined from 60% in the 50s to the current value of 30%. Same is expected to go down to 8% by 2020. As shown in Fig.1.8, around 92% of India's total oil demand by 2020 has to be met by imports.



**Fig. 1.9 India's oil balance**



**Fig.1.10 Proven oil reserve/consumption (in million tones)  
India vs world (end of 2002)**

#### 1.14.3 Natural Gas

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

#### 1.14.4 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 1.5).

	<b>Thermal (Coal) (MW)</b>	<b>Gas / LNG / Diesel (MW)</b>	<b>Nuclear (MW)</b>	<b>Hydro (MW)</b>	<b>Total (MW)</b>
Installed capacity as on		Gas: 10,153			
March 2001	61,157	Diesel: 864	2720	25,116	100,010
Additional capacity (2001-2012)	53,333	20,408	9380	32,673	115,794
Total capacity as on	114,490	31,425	12,100	57,789	215.804
March 2012	(53.0%)	(14.6%)	(5.6%)	(2.6.8%)	

**Table 1.5 India's perspective plan for power for zero deficit power by 2011/12**  
 (Source Tenth And Eleventh Five-Year Plan Projections)

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

## 1.15 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 subsidized by petrol, petroleum products for industrial usage and industrial, and commercial consumers of electricity subsidizing the agricultural and domestic consumers.

### 1.15.1 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.

### 1.15.2 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 subsidized. Subsidies and cross-subsidies have resulted in serious distortions in prices, as they do not reflect economic costs in many cases.

### 1.15.3 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 price varies from Rs 5 to Rs.15 per cubic metre.

### 1.15.4 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. Example, for an industrial consumer the demand charges may vary from Rs. 150-300 per kVA, whereas the energy charges may vary anywhere between Rs. 2-5 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.

## **1.16 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 realised that if substance has to be provided to macroeconomic policy reform, then it should 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.

### **1.16.1 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.

### **1.16.2 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.

### **1.16.3 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 was 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.

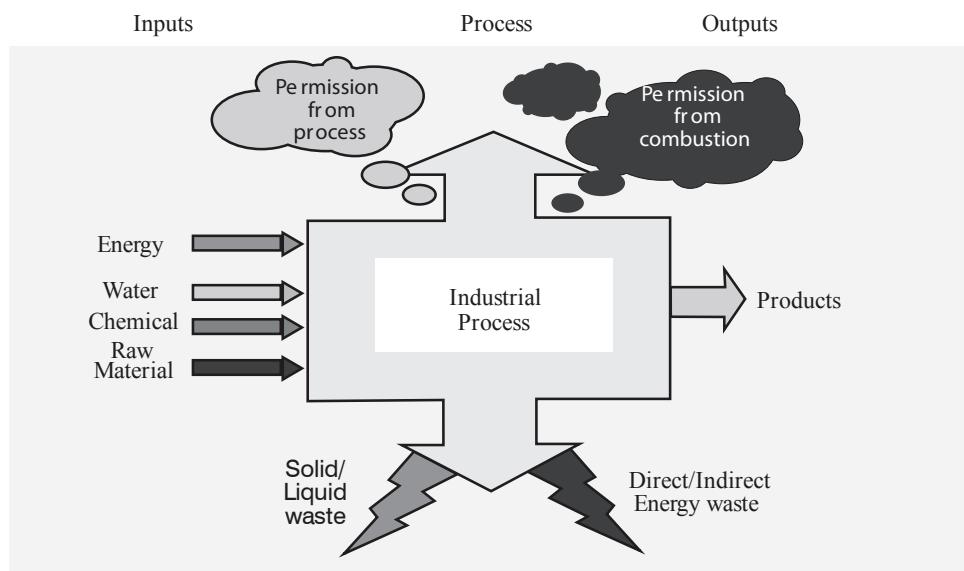
## **1.17 Electricity Act, 2003**

The government has enacted Electricity Act, 2003 which seeks to bring about a qualitative transformation within the electricity sector. The Act seeks to create liberal framework of development for the power sector by distancing Government from regulation. It replaces the three existing legislations, namely, Indian Electricity Act, 1910, the Electricity (Supply) Act, 1948 and the Electricity Regulatory Commissions Act, 1998. The objectives of this Act are “to consolidate the laws relating to generation, transmission, distribution, trading and use of electricity and generally for taking measures conducive to development of electricity industry, promoting competition therein, protecting interest of consumers and supply of electricity to all areas, rationalization of electricity tariff, ensuring transparent policies regarding subsidies, promotion of efficient and environmentally benign policies, constitution of Central Electricity Authority, Regulatory Commissions and establishment of Appellate Tribunal and for matters connected therewith or incidental thereto”.

### The salient features of the Electricity Act, 2003 are;

- The Central Government to prepare a National Electricity Policy in consultation with State Governments. (Section 3)
- Thrust to complete the rural electrification and provide for management of rural distribution by Panchayats, Cooperative Societies, non-Government organisations, franchisees etc. (Sections 4, 5 & 6)
- Provision for license free generation and distribution in the rural areas. (Section 14)
- Generation being de-licensed and captive generation being freely permitted. Hydro projects would, however, need clearance from the Central Electricity Authority. (Sections 7, 8 & 9)
- Transmission Utility at the Central as well as State level, to be a Government company – with responsibility for planned and coordinated development of transmission network. (Sections 38 & 39)
- Provision for private licensees in transmission and entry in distribution through an independent network, (Section 14)
- Open access in transmission from the outset. (Sections 38-40)
- Open access in distribution to be introduced in phases with surcharge for current level of cross subsidy to be gradually phased out along with cross subsidies and obligation to supply. SERCs to frame regulations within one year regarding phasing of open access. (Section 42)
- Distribution licensees would be free to undertake generation and generating companies would be free to take up distribution businesses. (Sections 7, 12)
- The State Electricity Regulatory Commission is a mandatory requirement. (Section 82)
- Provision for payment of subsidy through budget. (Section 65)
- Trading, a distinct activity is being recognised with the safeguard of the Regulatory Commissions being authorised to fix ceilings on trading margins, if necessary. (Sections 12, 79 & 86)
- Provision for reorganisation or continuance of SEBs. (Sections 131 & 172)
- Metering of all electricity supplied made mandatory. (Section 55)
- An Appellate Tribunal to hear appeals against the decision of the CERC and SERCs. (Section 111)
- Provisions relating to theft of electricity made more stringent. (Section 135-150)
- Provisions safeguarding consumer interests. (Sections 57-59, 166) Ombudsman scheme (Section 42) for consumers' grievance redressal

### 1.18 Energy and Environment



**Fig. 1.11 Inputs and outputs of process**

### 1.18.1 Air Pollution

The usage of energy resources in industry leads to environmental damages by polluting the atmosphere. Few examples of air pollution are sulphur dioxide ( $\text{SO}_2$ ), nitrous oxide ( $\text{NO}_x$ ) and carbon monoxide ( $\text{CO}$ ) emissions from boilers and furnaces, chlorofluorocarbons (CFC) emissions from refrigerants use, etc. In chemical and fertilizer 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 Fig.1.10.

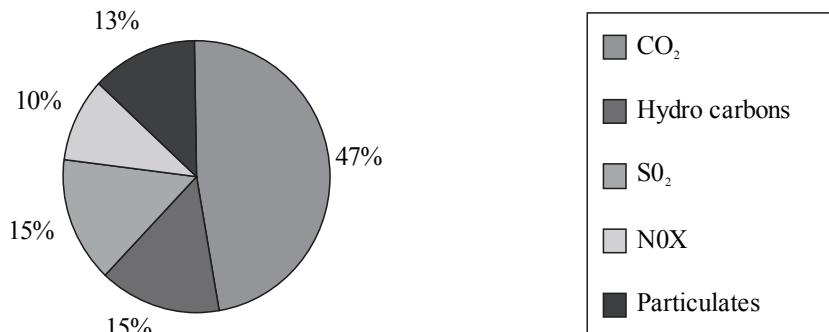


Fig. 1.12 Composition of major air pollutants

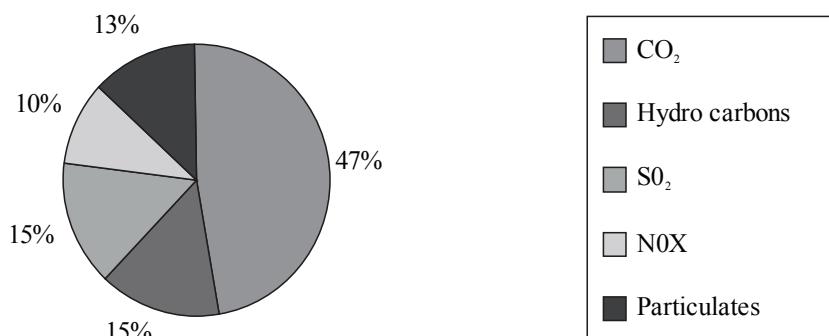
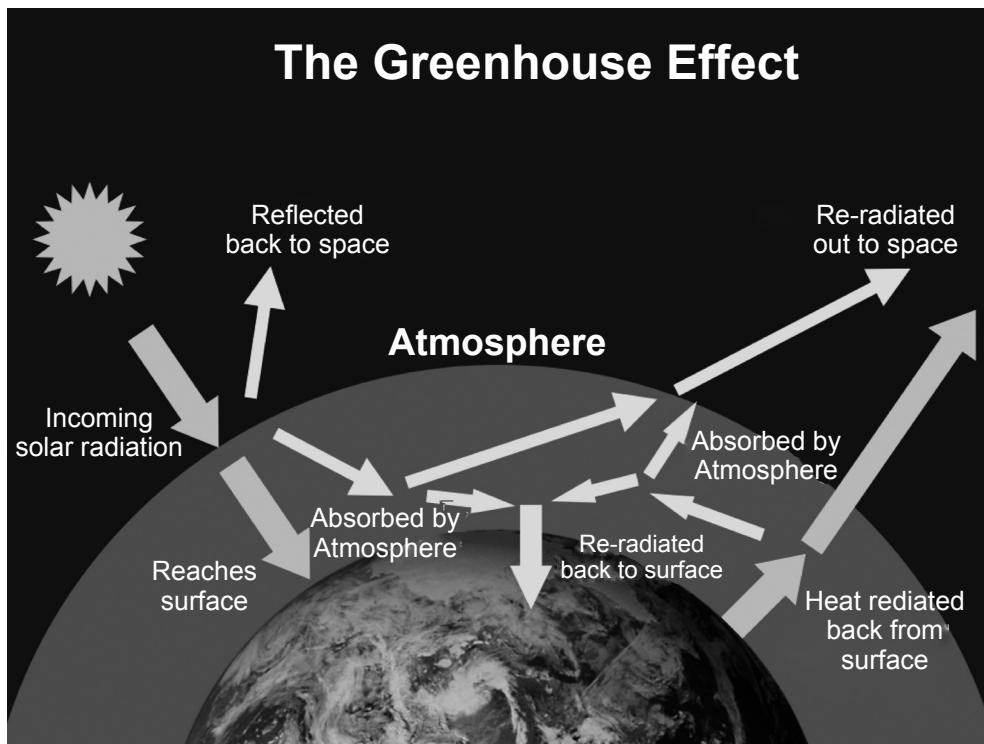


Fig. 1.13 Major pollutants in air-sector wise

### 1.19 Global Warming and Climate Change

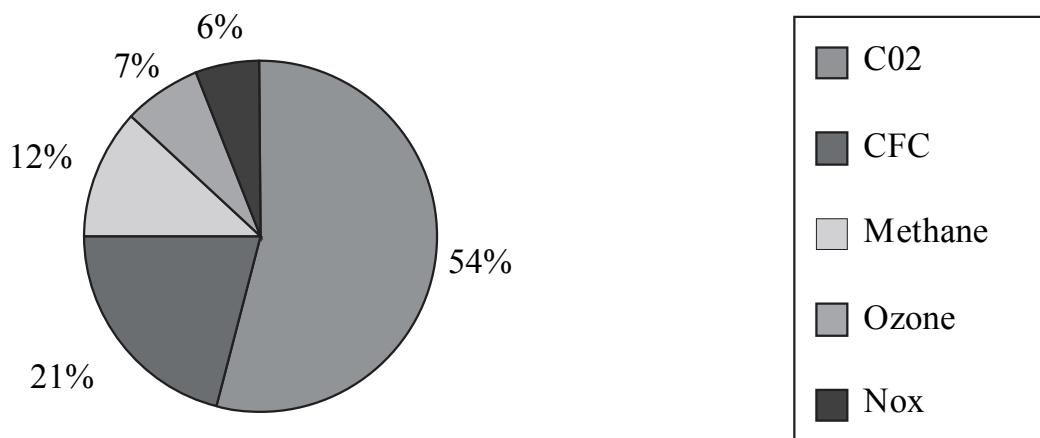
Climate change, also called global warming, refers to long-term fluctuations in temperature, precipitation, wind and other elements of the earth's climate system. Energy use has attracted huge attention in present times due to its associated global climatic impacts. Increasing fossil fuel use has led to increasing carbon dioxide emissions leading to the greenhouse effect and global warming (see Figure. 1.13).



**Fig. 1.14 The greenhouse effect**

The heating up of the earth's atmosphere due to trapping of long wavelength infrared rays (reflected from the earth's surface) by the carbon dioxide layer in the atmosphere is called the greenhouse effect. The name greenhouse effect comes from the fact that this effect is used usefully in horticulture for growing green plants in an enclosure made of glass or some other transparent material to act as a heat trap. Scientists generally believe that the combustion of fossil fuels and other human activities are the primary reason for the increased concentration of carbon dioxide. Plant respiration and the decomposition of organic matter release more than 10 times the CO<sub>2</sub> released by human activities; but these releases have generally had a favourable balance earlier during the centuries with carbon dioxide being absorbed by terrestrial vegetation and the oceans. The key greenhouse gases driving global warming are shown in Fig.1.14.

Increase in carbon dioxide is largely produced by the burning of fossil fuels, which is considered as the primary global warming gas. CFC's, even though they exist in very small quantities, are significant contributors to global warming. And, (not shown in Fig.1.14), per fluorocarbons (PFC's), sulphur hexafluoride (SF6) and hydro fluorocarbons (HFC's) are other growing contributors.



**Fig. 1.15 Share of greenhouse gases in gw**

There are six gases, which contribute to the greenhouse gas effect. The emission factor of each gas varies and Table 1.5 gives the factors in terms of intensities. Thus, it is seen that carbon dioxide has the lowest emission factor, while SF (what's this?) has the highest. However, the amount of carbon dioxide runs into a billion tonnes and therefore all efforts are on to reduce CO emissions on a priority basis.

Carbon dioxide	1
Methane	21
Nitrous Oxide	310
Hydrofluorocarbons	140-9800
Perfluorocarbons	4800-9200
Sulphur Hexafluoride	23900

**Table 1.6 Emission factors of GHG**

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 contribute to the rapid rise in atmospheric concentrations since pre-industrial times.

## **1.20 What do Humans do that Increases Atmospheric CO<sub>2</sub> (Reconsider the CO<sub>2</sub> or CO)**

Burning of fossil fuels like coal, oil and gas contributes to 80% of CO emission. Whereas, cutting down forests particularly in tropical region contributes to 20% of CO emission. These figures only prove that the land under forest has to be preserved as CO emission increases. The latest ideas are creation of carbon basins which mean plantation of millions of trees which will absorb the additional CO emission and convert it back to carbon. USA is in the forefront in this regard. The condition in India is not very encouraging as the forest cover is going down. Ideally the forest cover should be around 33% of the total land area and the percentage is being drastically reduced. It is therefore absolutely essential to take up a massive programme of a forestation during the coming years.

As far as usage of energy is concerned, the following figures throw light on population verses energy consumption. As India's per capita energy consumption is quite low compared to the USA and other developed nations, the total energy used is quite high due to a high population. It will be seen from Table 1.6 that India has already overtaken developed nations like France and Italy. It uses the energy almost as Germany and is likely to exceed in coming years. These figures are very vital as global energy consumption percentage is growing rapidly.

Because estimates indicate that approximately 80% of all anthropogenic carbon dioxide emissions currently are from fossil fuel combustion, world energy use has emerged as the centre of the climate change debate.

<b>Country</b>	<b>Population in millions</b>	<b>Energy consumption in quadrillion Btu's</b>
China	1295	43.2
India	1050	14.0
United States	288	97.4
Brazil	176	8.6
Pakistan	150	1.8
Russia	144	27.5
Bangladesh	144	0.6
Japan	128	22.0
Nigeria	121	0.9
Mexico	102	6.6
Germany	82	14.3

France	60	11.0
United Kingdom	59	9.6
Italy	57	7.6
South Korea	47	8.4
Canada	31	13.1

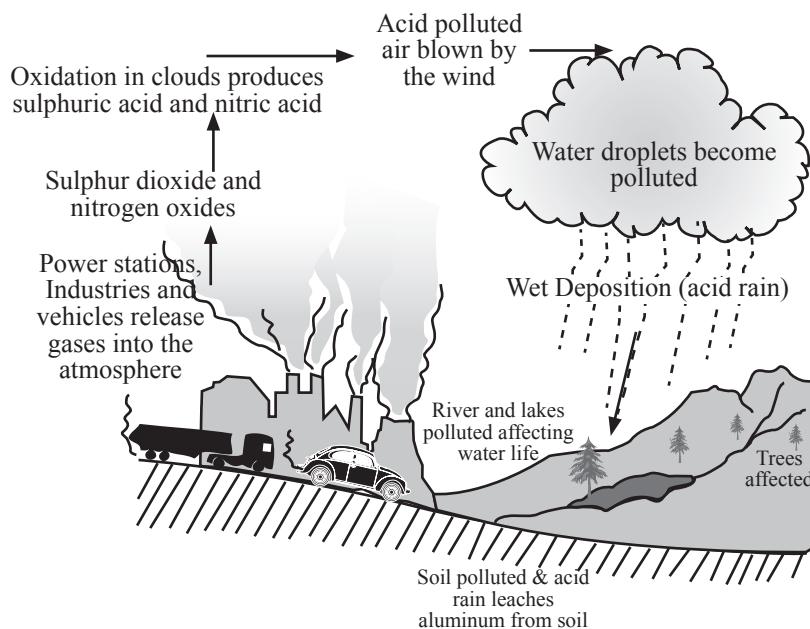
**Table 1.7 Representative countries and energy usage, 2002**

International accords began in Rio de Janeiro in 1992 (Rio Earth Summit), where in developed nations were asked to reduce GHG emissions to 1990 levels by the year 2000. New levels of commitment were taken during the third Conference of Parties (COP) on “The Framework Convention on Climate Change”, held at Kyoto in 1997 (Kyoto Protocol), which made GHG reductions mandatory for 38 developed nations with an average reduction of 5.2% below 1990 levels by 2012. The emergence of the Clean Development Mechanism (CDM) as a framework for the involvement of industrialised countries in the developing world may lead to financing opportunities for energy efficiency projects.

## 1.21 Acid Rain

Acid rain is caused by release of  $\text{SO}_x$  and  $\text{NO}_x$  from combustion of fossil fuels, which then mix with water vapour in atmosphere to form sulphuric acid and nitric acid respectively. (See Fig.1.15). The effects of acid rain are as follows:

- acidification of lakes, streams, and soils
- direct and indirect effects (release of metals, example: aluminium 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)

**Fig 1.16 Acid rain formation**

## **1.22 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 the 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 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 are not 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 are reducing demand through persistent energy conservation efforts.

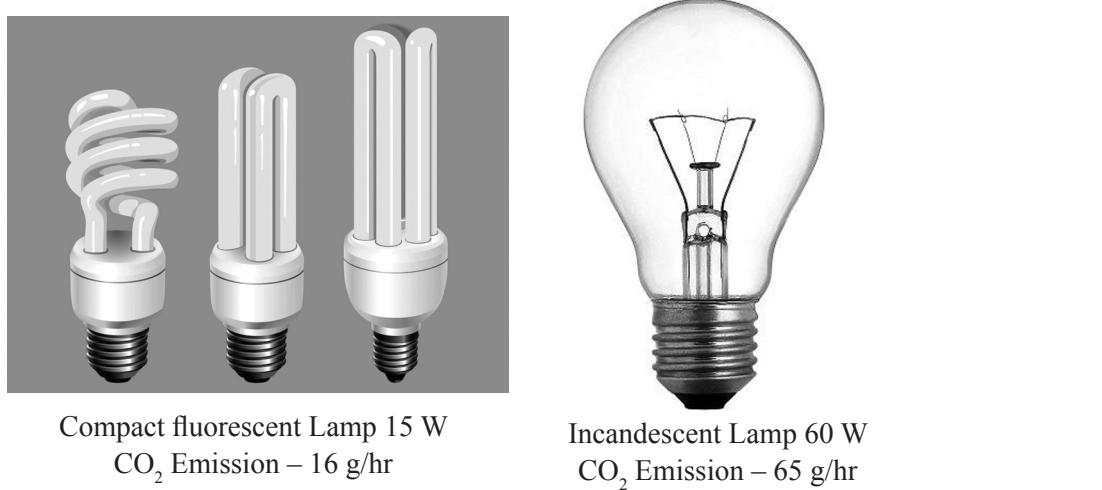
## **1.23 What is Energy Conservation**

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

Energy efficiency is often viewed as a resource option like coal, oil or natural gas. It provides additional economic value by preserving the resource base and reducing pollution. Example, replacing traditional light bulbs with Compact Fluorescent Lamps (CFLs) means you will use only 1/4<sup>th</sup> of the energy to light a room. Pollution levels also get reduced by the same amount.

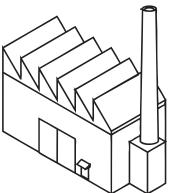
Nature sets some basic limits on how efficiently energy can be used, but in most cases our products and manufacturing processes are still a long way from operating at this theoretical limit. Very simply, energy efficiency means using less energy to perform the same function.

Energy Efficient Equipment uses less energy for same output and reduces CO<sub>2</sub> emissions



**Fig 1.17 Energy efficient equipments**

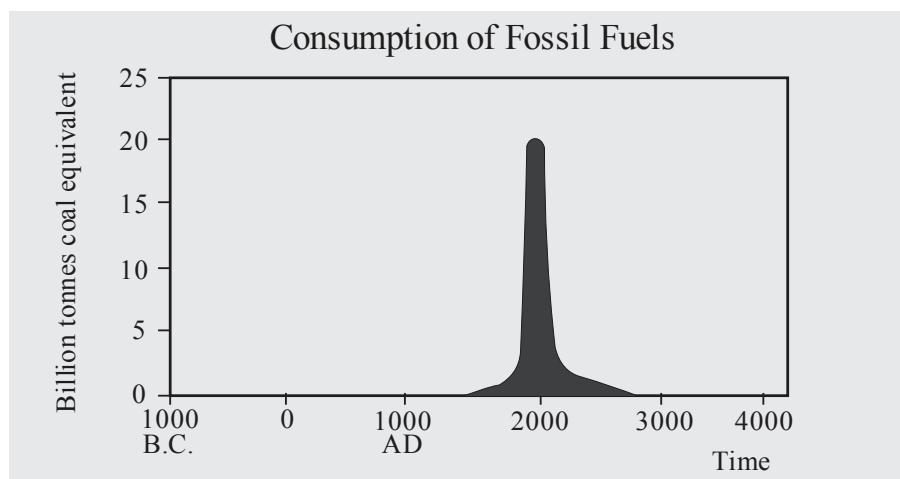
Although, energy efficiency has been in practice ever since the first oil crisis in 1973, it has assumed even more importance today because of being the most cost-effective and reliable means of mitigating the global climatic change. Recognition of that potential has led to high expectations for the control of future CO<sub>2</sub> emissions through even more energy efficiency improvements than have occurred in the past. The industrial sector accounts for some 41% of global primary energy demand and approximately the same share of CO<sub>2</sub> emissions. The benefits of Energy conservation for various players are given in Fig. 1.17.

Energy Efficiency Benefits		
Industry	Nation	Globe
 <ul style="list-style-type: none"> <li>• Reduced energy bills</li> <li>• Increased competitiveness increased productivity</li> <li>• Improved quality</li> <li>• Increases profits</li> </ul>	 <ul style="list-style-type: none"> <li>• Reduced energy imports</li> <li>• Avoided costs can be used for poverty reduction</li> <li>• Conservation of limited resources</li> <li>• Improved energy security</li> </ul>	 <ul style="list-style-type: none"> <li>• Reduced GHG and other emissions</li> <li>• Sustainable environment</li> </ul>

**Fig 1.18 Energy efficiency benefits**

## 1.24 Energy Conservation and its Importance

Coal and other fossil fuels 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 Fig.1.18).



**Fig 1.19 Consumption of fossil fuels**

## 1.25 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 a 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 a 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
  - labelling programmes for products and adoption of energy efficient technologies in large industries
- Deregulation and privatisation 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

## **1.26 The Energy Conservation Act, 2001 and its Features**

The various energy conservation (EC) Acts and their important features are as follows:

### **1.26.1 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.

### **1.26.2 Standards and Labelling**

Standards and Labelling (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 labelling 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 labelling scheme for notified equipment appliances to enable consumers to make informed choices
- disseminate information on the benefits to consumers

### **1.26.3 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
- the 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

#### **1.26.4 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 designs training modules and conduct a National level examination for the certification of energy managers and energy auditors.

#### **1.26.5 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

#### **1.26.6 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.

#### **1.26.7 Bureau of Energy Efficiency (BEE)**

- The mission of Bureau of Energy Efficiency is to institutionalise 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.

### **1.26.8 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.

### **1.27 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.

### **1.28 Enforcement through Self-Regulation**

The 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.

### **1.29 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.

## **Summary**

- Energy is classified into several types based on the following criteria: Primary and Secondary energy; Commercial and Non-commercial energy; and Renewable and Non-Renewable energy.
- Renewable energy resources are bio-mass and bagasses as bio-mass; wind energy, wind turbine capacity factor, power generation, hydro energy, solar energy, photovoltaic cells and PV system
- Indian energy scenario and long term energy scenario are explained in brief. Energy supply like coal, oil, natural gas, electrical, nuclear power hydro power with sector-wise consumption of energy and the energy needs of a growing economy
- Energy and environment go hand in hand. The energy conservation has a direct relation to degradation. The important features of the Energy Conservation Act highlight the need and importance to conserve energy for the future requirement.

## **References**

- Capehart, B.L., Wayne, C.T. and Kennedy, W.J., 2008. *Guide to Energy Management*. The Fairmont Press, Inc.
- Eden, J.R., 1981. *Energy economics*. Cambridge University Press.
- *INDIA'S ENERGY SCENARIO IN 2020* [Pdf] Available at: <[http://www.cesc.co.in/cesc/e-prognya/cms/wp-content/uploads/Energyscenario\\_at\\_india.pdf](http://www.cesc.co.in/cesc/e-prognya/cms/wp-content/uploads/Energyscenario_at_india.pdf)> [Accessed 5 July 2013].
- *World Energy Scenarios to 2050: Issues and Options* [Pdf] Available at: <<http://www.nezhadpmd.com/worldenergyscenarios.pdf>> [Accessed 5 July 2013].
- *The Energy Report - A fully sustainable and renewable global energy system is possible by 2050* [Video online] Available at: <[http://www.youtube.com/watch?v=wG6b\\_amCmHw](http://www.youtube.com/watch?v=wG6b_amCmHw)> [Accessed 5 July 2013].
- *Energy Scenarios 2050* [Video online] Available at: <<http://www.youtube.com/watch?v=A75GRANfvrQ>> [Accessed 5 July 2013].

## **Recommended Reading**

- Wesley, M., 2007. *Energy Security in Asia*. Routledge.
- Beggs, C., 2009. *Energy: Management, Supply and Conservation*. Elsevier Ltd.
- Geller, H., 2003. *Energy Revolution: Policies For a Sustainable Future*. Island Press.

## Self Assessment

1. 1. Energy sources that are available in the market for a definite price are known as \_\_\_\_\_
  - a. primary
  - b. secondary
  - c. commercial
  - d. non-commercial
  
2. \_\_\_\_\_ is energy obtained from sources that are essentially inexhaustible.
  - a. Primary
  - b. Secondary
  - c. Non- commercial
  - d. Renewable
  
3. Which of the following is false?
  - a. Non renewable energy resources are the conventional fossil fuels which are likely to deplete with time.
  - b. Bio-mass energy is the oldest form of energy used by humans, and for thousands of years and is the main source of energy for human activity.
  - c. Gasification converts decaying bio-mass in landfills and biogas digesters into a gas called ethane, the main ingredient in natural gas.
  - d. The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants.
  
4. Which of the following is true?
  - a. Geothermal energy is considered a renewable source of energy.
  - b. Geothermal energy is considered a non- renewable source of energy.
  - c. Geothermal energy is considered a commercial source of energy.
  - d. Geothermal energy is considered a non-commercial source of energy.
  
5. Which fuel is produced by fermentation of grains?
  - a. Ethanol
  - b. Butanol
  - c. Methanol
  - d. Pentanol
  
6. Which of the following energy is available in the market for a definite price?
  - a. Non-commercial
  - b. Commercial
  - c. Renewable
  - d. Non-renewable

7. Match the following

1. Oldest form of energy	a. Photo synthesis
2. Climate change is also called	a. Primary energy
3. Bio Mass is related with	b. Global warming
4. Secondary energy is produced from	c. Bio-mass

a. 1-b, 2-c, 3-d, 4-a

b. 1-b, 2-,a 3-,d 4-c

c. 1-c, 2-d, 3-b, 4-a

d. 1-d, 2-c, 3-a, 4-b

8. Match the following

1. Energy that are converted to steam and electricity	a. Primary Energy
2. Energy that are either found or stored in nature	a. Non-renewable Energy
3. Energy that is obtained from sources those are essentially inexhaustible.	b. Secondary Energy
4. Energy resources which are likely to deplete with time	c. Renewable Energy

a. 1-c, 2-a, 3-d, 4-b

b. 1-b, 2-d, 3-a, 4-c

c. 1-d, 2-c, 3-b, 4-a

d. 1-c, 2-d,3-b, 4-a

9. \_\_\_\_\_ is used as fuel to generate stem.

a. Methane

b. Bagasse

c. Ethane

d. Ethanol

10. Power from wind is generated by \_\_\_\_\_ turbines.

a. hydrogen

b. wind

c. water

d. nitrogen

## Chapter II

# Basics of Energy and its Various Forms

### Aim

The aim of this chapter is to:

- explain the types and forms of energy
- define energy conversion
- introduce electrical energy

### Objectives

The objectives of this chapter are to:

- explain electrical energy basics and its characteristics
- elucidate electrical and thermal energy
- define heat transfer and its modes

### Learning outcome

At the end of this chapter, the students should be able to:

- describe thermal energy basics
- recognize the significance of heat transfer and its various modes
- understand energy units and conversion

## **2.1 Introduction**

Energy is the ability to do work and work is the transfer of energy from one form to another. Energy is what an individual use to manipulate the world around them, whether by exciting their muscles, by using electricity, or by using mechanical devices such as automobiles. Energy comes in different forms - heat (thermal), light (radiant), mechanical, electrical, chemical, and nuclear energy. One form of energy can be transformed to another.

## **2.2 Forms of Energy**

There are two types of energy:

- Stored or potential energy: Potential energy is the form which is acquired while in the state of rest (due to its static storage).
- Working or kinetic energy: kinetic energy is the form acquired due to its state of motion.

### **2.2.1 Potential energy**

Potential energy is the stored energy and is also called the energy of position (gravitational). It exists in various forms:

#### **Chemical Energy**

- Chemical energy is the energy stored in the bonds of atoms and molecules. Examples: biomass, petroleum, natural gas, propane and coal.

#### **Nuclear Energy**

- Nuclear energy is the energy stored in the nucleus of an atom - the energy that holds the nucleus together. Example: The nucleus of a uranium atom.

#### **Stored Mechanical Energy**

- Stored mechanical energy is energy stored in objects by the application of a force. Examples: Compressed springs and stretched rubber bands.

#### **Gravitational Energy**

- Gravitational energy is the energy of place or position. Example: Water in a reservoir behind a hydropower dam. When the water is released to spin the turbines, it becomes motion energy.

### **2.2.2 Kinetic Energy**

Kinetic energy is energy in motion- the motion of waves, electrons, atoms, molecules and substances. It also exists in various forms:

#### **Radiant Energy**

- Radiant energy is the electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Example: Solar energy.

#### **Thermal Energy**

- Thermal energy (or heat) is the internal energy in substances- the vibration and movement of atoms and molecules within substances. Example: Geothermal energy.

#### **Motion**

- The movement of objects or substances from one place to another is motion. Examples: Wind and hydropower.

#### **Sound**

- Sound is the movement of energy through substances in longitudinal (compression/rarefaction) waves.

## Electrical Energy

- Electrical energy is the movement of electrons. Examples: Lightning and electricity.

## 2.3 Energy Conversion

Energy is defined as the “ability to do work.” Examples of work include; moving something, lifting something, warming something, or lighting something. A few examples of energy conversion/transformation are as follows;

- oil burns to generate heat
- heat required to boil water
- water turns to steam
- steam pressure turns a turbine
- turbine turns an electric generator
- generator produces electricity
- electricity powers light bulbs
- light bulbs give off light and heat

It is difficult to imagine spending an entire day without using energy. Energy is used to light homes and cities, to power machinery in factories, cook food, play music and operate television and other electrical appliances.

## 2.4 Grades of Energy

### 2.4.1 High-Grade Energy

- Electrical and chemical energy are considered to be high-grade energy because the energy is concentrated in a small space.
- Even a small amount of electrical and chemical energy can do a great amount of work. The molecules or particles that store these forms of energy are highly ordered and compact and thus classified as high grade energy.
- High-grade energy such as, electricity is better used for high grade applications, like melting of metals, rather than simply heating of water.

### 2.4.2 Low-grade Energy

- Heat is considered to be low-grade energy.
- Heat can still be used to do work (example of a heater boiling water), but it rapidly dissipates.
- The molecules, in which this kind of energy is stored (air and water molecules), are more randomly distributed than the molecules of carbon in a coal. This disordered state of the molecules and the dissipated energy are classified as low-grade energy.

## 2.5 Electrical Energy Basics

Electric current is divided into two types:

- Directional Current (DC)
- Alternating Current (AC)

Characteristics	Direct Current	Alternating Current
Electric current	<ul style="list-style-type: none"> <li>• non-varying</li> <li>• unidirectional</li> </ul>	<ul style="list-style-type: none"> <li>• reverses regularly in recurring intervals of time and which has alternately positive and negative values,</li> <li>• occurring at a specified number of times per second</li> </ul>

Direction of current (positive charges)	<ul style="list-style-type: none"> <li>constant over time</li> <li>reverses periodically with time</li> </ul>
Voltage (tension) between two points of the circuit	<ul style="list-style-type: none"> <li>does not change polarity with time</li> <li>changes polarity with time</li> </ul>
Examples	<ul style="list-style-type: none"> <li>Current produced by batteries</li> <li>household electricity produced by generators, electricity supplied by utilities</li> </ul>

**Table 2.1 Difference between direct current and alternating current**

Note - In 50 cycles AC, current reverses direction 100 times a second (two times during one cycle).

### Ampere (A)

- The ampere is the basic unit of electric current. Current is the rate of flow of charge.
- An Ampere is the current that produces a specified force between two parallel wires, which are 1 metre apart in a vacuum.

### Voltage (V)

- The volt is the International System of Units (SI) measure of electric potential or electromotive force.
- A potential of one volt appears across a resistance of one ohm when a current of one ampere flows through that resistance.

$$1000 \text{ V} = 1 \text{ kiloVolts (kV)}$$

### Resistance

$$\text{Resistance} = \frac{\text{Voltage}}{\text{Current}}$$

The unit of resistance is ohm ( $\Omega$ ).

### Ohm's Law

According to the Ohm's law, the current through a conductor is directly proportional to the potential difference across it, provided the temperature and other external conditions remain constant.

### Frequency

The supply frequency tells us the cycles at which alternating current changes. The unit of frequency is hertz (**Hz**: no. of cycles per second).

### Kilovolt Ampere (kVA)

It is the product of kilovolts and amperes. This measures the electrical load on a circuit or system and is also called the **apparent power**.

$$\text{For a single phase electrical circuit} = \frac{\text{Voltage} \times \text{Amperes}}{1000}$$

$$\text{For a single phase electrical circuit} = \frac{\overline{\text{Voltage}} \times \text{Amperes}}{1000}$$

### kVAr (Reactive Power)

- kVAr is the reactive power, which is the portion of apparent power that does no work. This type of power must be supplied to all types of magnetic equipment.
- Examples: motors, transformers etc.
- Larger the magnetizing requirement, larger the kVAr.

### Kilowatt (kW) (Active Power)

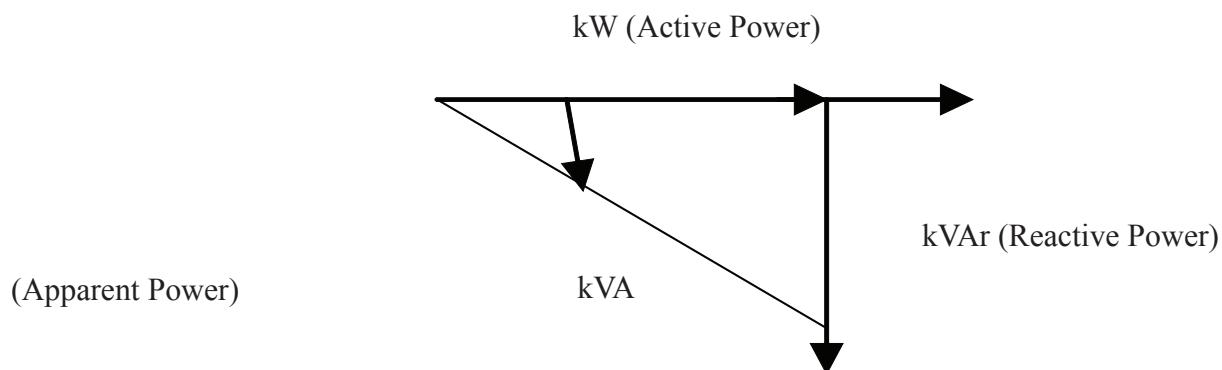
$$\text{Single Phase} = \frac{\text{Voltage}}{1000} \times \text{Amperes} \times \text{Power Factor}$$

$$\text{Three Phase} = 1.732 \times \frac{\text{Voltage}}{1000} \times \text{Amperes} \times \text{Power Factor}$$

$$1.732 \times \frac{\text{Voltage}}{1000} \times \text{Amperes} \times \text{Power Factor}$$

### Relation between kVA, kW and kVAr

$$\text{kVA} = \sqrt{(\text{kW})^2 + (\text{kVAr})^2}$$



**Fig. 2.1 Direction of reactive power**

#### 2.5.1 Power Factor

Power Factor (PF) is the ratio between the active power (kW) and apparent power (kVA).

$$\text{Power Factor (Cos } \theta) = \frac{\text{Active Power (kW)}}{\text{Apparent Power (kVA)}}$$

$$= \frac{\text{kW}}{\sqrt{(\text{kW})^2 + (\text{kVAr})^2}}$$

$$= 1.0 \text{ (when kVAr=0)}$$

- **Lagging power factor:** When current lags the voltage like in inductive loads, it is called lagging power factor.
- **Leading power factor:** When current leads the voltage like in capacitive loads, it is called leading power factor.

Inductive loads such as induction motors, transformers, discharge lamp, etc. absorb comparatively more lagging reactive power (kVAr) and hence, their power factor is poor. Lower the power factor; electrical network is loaded with more current. It would be advisable to have highest power factor (close to 1) so that network carries only active power which does real work. PF improvement is done by installing capacitors near the load centres, which improve power factor from the point of installation back to the generating station.

## 2.5.2 Kilowatt-hour (kWh)

- Kilowatt-hour is the energy consumed by 1000 Watts in one hour.
- If 1kW (1000 watts) of an electrical equipment is operated for 1 hour, it would consume 1 kWh of energy (1 unit of electricity).
- For a company, it is the amount of electrical units in kWh recorded in the plant over a month for billing purpose. The company is charged or billed based on kWh consumption.

## 2.6 Electricity Tariff

### Billing Demand

Billing demand is the highest average kVA recorded during any one demand interval within the month. The demand interval is normally 30 minutes, but may vary from utility to utility from 15 - 60 minutes. Demand is measured using a tri-vector meter/digital energy meter.

### Calculation of electric bill for a company

Electrical utility or power supplying companies charge industrial customers not only based on the amount of energy used (kWh) but also on the peak demand (kVA) for each month.

### Contract Demand

Contract demand is the amount of electric power that a customer demands from utility in a specified interval. Unit used is kVA or kW. It is the amount of electric power that the consumer agreed upon with the utility. This would mean that utility has to plan for the specified capacity.

### Maximum demand

Maximum demand is the highest average kVA recorded during any one-demand interval within the month. The demand interval is normally 30 minutes, but may vary from utility to utility from 15 - 60 minutes. The demand is measured using a tri-vector meter / digital energy meter.

### Prediction of Load

While considering the methods of load prediction, some of the terms used in connection with power supply must be appreciated.

- Connected Load - is the nameplate rating (in kW or kVA) of the apparatus installed on a consumer's premises.
- Demand Factor - is the ratio of maximum demand to the connected load.
- Load Factor - The ratio of average load to maximum load.

$$\text{Load Factor} = \frac{\text{Average Load}}{\text{Maximum Load}}$$

The load factor can also be defined as the ratio of the energy consumed during a given period to the energy, which would have been used if the maximum load had been maintained throughout that period. For example, load factor for a day (24 hours) will be given by

$$\text{Load Factor} = \frac{\text{Energy Consumed during 24 Hours}}{\text{Maximum Load recorded} \times 24 \text{ Hours}}$$

## 2.7 PF Measurement

A power analyser can measure PF directly, or alternately kWh, kVAh or kVArh readings are recorded from the billing meter installed at the incoming point of supply. The relation kWh / kVAh gives the power factor.

### 2.7.1 Time Of Day (TOD) Tariff

Many electrical utilities like to have flat demand curve to achieve high plant efficiency. They encourage user to draw more power during off-peak hours (say during night time) and less power during peak hours. As per their plan, they offer TOD Tariff, which may be incentives or disincentives. Energy meter will record peak and non-peak consumption separately by timer control. TOD tariff gives opportunity for the user to reduce their billing, as off peak hour tariff charged are quite low in comparison to peak hour tariff.

The table below illustrate the mechanism of TOD

A ZONE	2200-600 HRS
B ZONE	600-900 HRS + 1200-1800 HRS
C ZONE	900-1200 HRS
D ZONE	1800-2200 HRS

Table.2.2 TOD divided in 4 zones

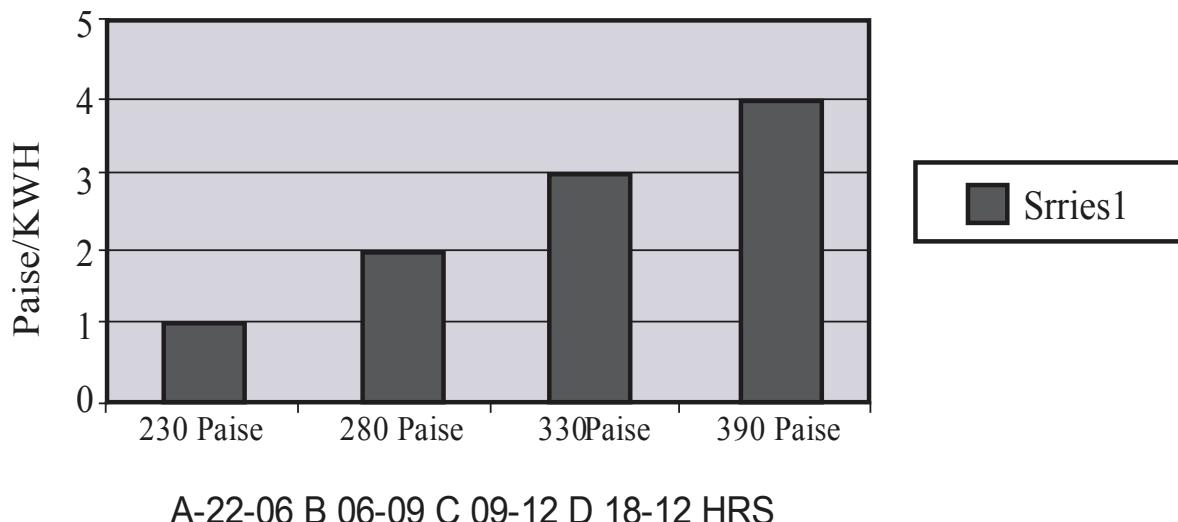


Fig. 2.2 Time of the day tariff

### 2.7.2 Three phase AC power measurement

Most of the motive drives such as pumps, compressors, machines etc. operate with 3 phase AC Induction motor. Power consumption can be determined by using the relation.

$$\text{Power} = \sqrt{3} \times V \times I \times \cos \theta$$

Portable power analysers /instruments are available for measuring all electrical parameters.

#### Example

A 3-phase AC induction motor (20 kW capacity) is used for pumping operation. Electrical parameters such as current, volt and power factor were measured with power analyser. Find energy consumption of motor in one hour? (line volts. = 440 V, line current = 25 amps and PF = 0.90).

$$\text{Energy consumption} = \sqrt{3} \times 0.440 (\text{kV}) \times 25(\text{A}) \times 0.90(\text{PF}) \times 1(\text{hour}) = 17.15 \text{ kWh}$$

### 2.7.3 Motor Loading Calculation

The nameplate details of motor, kW or HP indicate the output parameters of the motor at full load. The voltage, amps and PF refer to the rated input parameters at full load.

### **Example**

A three phase, 10 kW motor has the name plate details as 415 V, 18.2 amps and 0.9 PF. Actual input measurement shows 415 V, 12 amps and 0.7 PF which was measured with power analyser during motor running.

Rated output at full load = 10 kW

Rated input at full load =  $1.732 \times 0.415 \times 18.2 \times 0.9 = 11.8 \text{ kW}$

The rated efficiency of motor at full load =  $(10 \times 100) / 11.8 = 85\%$

Measured (Actual) input power =  $1.732 \times 0.415 \times 12 \times 0.7 = 6.0 \text{ kW}$

$$\text{Motor Loading \%} = \frac{\text{Measured kW}}{\text{Rated kW}} \times 100 = \frac{6.0}{11.8} \times 100 = 5102\%$$

### **Which applications use single-phase power in an industry?**

Single-phase power is mostly used for lighting, fractional HP motors and electric heater applications.

### **Example**

A 400 Watt mercury vapour lamp was switched on for 10 hours per day. The supply volt is 230 V. Find the power consumption per day?

(Volt = 230 V, Current = 2 amps, PF = 0.8)

$$\begin{aligned}\text{Electricity consumption (kWh)} &= V \times I \times \cos \theta \times \text{No of Hours} \\ &= 0.230 \times 2 \times 0.8 \times 10 = 3.7 \text{ kWh or Units}\end{aligned}$$

### **Example**

An electric heater of 230 V, 5 kW rating is used for hot water generation in an industry. Find the electricity consumption per hour

- a. at the rated voltage
- b. at 200 V

- a. Electricity consumption (kWh) at rated voltage  
 $= 5 \text{ kW} \times 1 \text{ hour} = 5 \text{ kWh.}$
- b. Electricity consumption at 200 V (kWh)  
 $= (200 / 230)^2 \times 5 \text{ kW} \times 1 \text{ hour} = 3.78 \text{ kWh}$

## **2.8 Thermal Energy Basics**

### **Temperature and Pressure**

Temperature and pressure are measures of the physical state of a substance. They are closely related to the energy contained in the substance. As a result, measurements of temperature and pressure provide a means of determining energy content.

### **Temperature**

It is the degree of hotness or coldness measured on a definite scale. Heat is a form of energy; temperature is a measure of its thermal effects. In other words, temperature is a means of determining sensible heat content of the substance

In the Celsius scale the freezing point of water is 0°C and the boiling point of water is 100°C at atmospheric pressure.

To change temperature given in Fahrenheit (°F) to Celsius (°C)

Start with (°F); subtract 32; multiply by 5; divide by 9; the answer is (°C)

To change temperature given in Celsius (°C) to Fahrenheit (°F)

Start with (°C); multiply by 9; divide by 5; add on 32; the answer is (°F)

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 5/9$$

### **Pressure**

It is the force per unit area applied to outside of a body. When we heat a gas in a confined space, we create more force; a pressure increase.

For example, heating the air inside a balloon will cause the balloon to stretch as the pressure increases. Pressure, therefore, is also indicative of stored energy. Steam at high pressures contains much more energy than at low pressures.

### **Heat**

Heat is a form of energy, a distinct and measurable property of all matter. The quantity of heat depends on the quantity and type of substance involved.

### **Unit of Heat**

Calorie is the unit for measuring the quantity of heat. It is the quantity of heat, which can raise the temperature of 1 g of water by 1°C.

Calorie is too small a unit for many purposes. Therefore, a bigger unit Kilocalorie (1 Kilocalorie = 1000 calories) is used to measure heat. 1 kilocalorie can raise the temperature of 1000g (i.e. 1kg) of water by 1°C.

However, nowadays generally joule as the unit of heat energy is used. It is the internationally accepted unit. Its relationship with calorie is as follows:

$$1 \text{ Calorie} = 4.187 \text{ J}$$

### **Specific Heat**

If the same amount of heat energy is supplied to equal quantities of water and milk, their temperature goes up by different amounts. This property is called the specific heat of a substance and is defined as the quantity of heat required to raise the temperature of 1kg of a substance through 1°C.

The specific heat of water is very high as compared to other common substances; it takes a lot of heat to raise the temperature of water. Also, when water is cooled, it gives out a large quantity of heat.

Substance	Specific Heat (Joules / kg °C)
Lead	130
Mercury	140
Brass	380
Copper	390
Iron	470
Glass	670
Aluminium	910
Rubber	1890
Ice	2100
Alcohol	2400
Water	4200

**Table 2.3 Specific heat of some common substances**

### **Heat Capacity**

Sometimes, we may need to know how much heat energy is required to raise the temperature of an object by 1°C. We define the heat capacity of an object as the quantity of heat required to raise the temperature of the object by 1°C. The heat capacity of two iron blocks, one small and the other big will be different even though they are made of the same substance.

### **Sensible heat**

It is that heat which when added or subtracted results in a change of temperature.

### **Quantity of Heat**

The quantity of heat, Q, supplied to a substance to increase its temperature by 0°C depends on

- mass of the substance (m)
- increase in temperature ( $\Delta t$ )

- specific heat of the substance ( $C_p$ )

The quantity of heat is given by:

$Q = \text{mass} \times \text{specific heat} \times \text{increase in temperature}$

$$Q = m \times C_p \times \Delta t$$

### Phase Change

- The change of state from the solid state to a liquid state is called **fusion**.
- The fixed temperature at which a solid changes into a liquid is called its **melting point**.
- The change of a state from a liquid state to a gas is called **vaporisation**.

### Latent heat of fusion

The latent heat of fusion of a substance is the quantity of heat required to convert 1kg solid to liquid state without change of temperature. It is represented by the symbol L.

Its unit is Joule per kilogram (J/Kg)

Thus, L (ice) = 336000 J/kg

### Latent Heat of Vaporization

The latent heat of vaporization of a substance is the quantity of heat required to change 1kg of the substance from liquid to vapour state without change of temperature.

It is also denoted by the symbol L and its unit is also J/kg.

The latent heat of vaporization of water is 22, 60,000 J/kg.

When 1 kg of steam at 100°C condenses to form water at 100°C, it gives out 2260 kJ (540 kCals) of heat. Steam gives out more heat than an equal amount of boiling water because of its latent heat.

### Latent heat

It is the change in heat content of a substance, when its physical state is changed without a change in temperature.

### Super Heat

Heating of vapour particularly saturated steam to a temperature much higher than the boiling point at the existing pressure. This is done in power plants to improve efficiency and to avoid condensation in the turbine.

## 2.9 Humidity

Humidity is referred to be the moisture content of air as and may be expressed in two ways

- specific humidity
- relative humidity

### Specific Humidity

It is the actual weight of water vapour mixed in a kg of dry air.

### Humidity Factor

Humidity factor = kg of water per kg of dry air (kg/kg).

### Relative Humidity (RH)

The ratio percentage of the amount of water in the air at a give temperature to the maximum amount it could hold at that temperature is called relative humidity.

$$\text{RH} = \text{Percentage (\%)} \text{ at temperature } (\text{°C})$$

### Dew Point

The temperature at which condensation of water vapour from the air begins as the temperature of the air-water vapour mixture falls is known as dew point.

### Dry bulb Temperature

It is an indication of the sensible heat content of air-water vapour mixtures.

### Wet bulb Temperature

It is a measure of total heat content or enthalpy.

It is the temperature approached by the dry bulb and the dew point as saturation occurs.

### Dew Point Temperature

It is a measure of the latent heat content of air-water vapour mixtures and since latent heat is a function of moisture content, the dew point temperature is determined by the moisture content.

## 2.10 Fuel Density

Density is the ratio of the mass of the fuel to the volume of the fuel at a stated temperature.

### Specific gravity of fuel

- The density of fuel, relative to water, is called specific gravity. The specific gravity of water is defined as 1.
- As it is a ratio there are no units.
- Higher the specific gravity, higher will be the heating values.

## 2.11 Viscosity

Viscosity means resistance of a liquid to shear forces (and hence to flow). The viscosity of a fluid is a measure of its internal resistance to flow. All liquid fuels decrease in viscosity with increasing temperature

### Dynamic (absolute) Viscosity

- It is the tangential force per unit area required to move one horizontal plane with respect to the other at unit velocity when maintained a unit distance apart by the fluid.
- It is expressed as N.sec/m<sup>2</sup>

### Kinematic Viscosity

It is the ratio of absolute or dynamic viscosity to density - a quantity in which no force is involved.

Kinematic viscosity can be obtained by dividing the absolute viscosity of a fluid with its mass density.

It is equal to dynamic viscosity / density and expressed as m<sup>2</sup>/ sec

## 2.12 Dimensionless Numbers

It plays a vital role in heat transfer. There are several dimensionless numbers, however only two simple and important numbers are mentioned

- Reynolds Number: this is expressed as  
Velocity  $\times$  Diameter / viscosity (Kinematic) in strokes / centistokes
- Prandtl numbers: this is expressed as  
Specific heat  $\times$  viscosity / Thermal conductivity  
D Sp Heat- kcal/kg/C  
Viscosity-Centipoises kg/hr/m/C

It is proven that heat transfer co-efficient is related to these two numbers (Not in linear proportion).

## 2.13 Calorific Value

Energy content in an organic matter (**Calorific Value**) can be measured by burning it and measuring the heat released. This is done by placing a sample of known mass in a bomb calorimeter, a device that is completely sealed and insulated to prevent heat loss. A thermometer is placed inside (but it can be read from the outside) and the increase in temperature after the sample is burnt completely is measured. From this data, energy content in the organic matter can be found out.

- The heating value of fuel is the measure of the heat released during the complete combustion of unit weight of fuel.
- It is expressed as Gross Calorific Value (GCV) or Net Calorific Value (NCV).
- The difference between GCV and NCV is the heat of vaporization of the moisture and atomic hydrogen (conversion to water vapour) in the fuel.
- Typical GCV and NCV for heavy fuel oil are 10,500 kcal/kg and 9,800 kcal/kg.

## 2.14 Heat Transfer

Heat will always be transferred from higher temperature to lower temperature independent of the mode. The energy transferred is measured in Joules (kcal or Btu). The rate of energy transfer, more commonly called heat transfer, is measured in Joules/second (kcal/hr or Btu/hr).

### Heat is transferred by three primary modes

- Conduction (Energy transfer in a solid)
- Convection (Energy transfer in a fluid)
- Radiation (Does not need a material to travel through)

#### Conduction

The conduction of heat takes place, when two bodies are in contact with one another. If one body is at a higher temperature than the other, the motion of the molecules in the hotter body will vibrate the molecules at the point of contact in the cooler body and consequently result in increase in temperature.

The amount of heat transferred by conduction depends upon the temperature difference, the properties of the material involved, and the thickness of the material, the surface contact area, and the duration of the transfer.

- Good conductors of heat are typically substances that are dense as they have molecules close together. Metals are good conductors of heat
- Poor conductors of heat are usually called insulators. Gaseous substance, having low densities or widely spaced molecules, are poor conductors of heat.

The measure of the ability of a substance to insulate is its thermal resistance. This is commonly referred to as the R-value (RSI in metric). The R-value is generally the inverse of the thermal conductivity, the ability to conduct heat.

Typical units of measure for conductive heat transfer are:

Per unit area (for a given thickness)

Metric (SI): Watt per square meter ( $\text{W/m}^2$ )

#### Convection

The transfer of heat through a fluid (liquid or gas) caused by molecular motion.

There are two types of convective processes which are:

- Natural
- Forced

#### Natural Convection

The fluid in contact with or adjacent to a high temperature body is heated by conduction. As it is heated, it expands, becomes less dense and consequently rises. This begins a fluid motion process in which a circulating current of fluid moves past the heated body, continuously transferring heat away from it.

### Forced Convection

The movement of the fluid is forced by a fan, pump or other external means. A centralized hot air heating system is a good example of forced convection.

Convection depends on the thermal properties of the fluid as well as surface conditions at the body and other factors that affect the ability of the fluid to flow. With a low conductivity fluid such as air, a rough surface can trap air against the surface reducing the conductive heat transfer and consequently reducing the convective currents.

Units of measure for rate of convective heat transfer are

Metric (SI): Watt (W) or kilowatts (kW)

### Thermal Radiation

Thermal radiation is a process in which energy is transferred by electromagnetic waves similar to light waves. The waves may be both visible (light) and invisible. Example of thermal radiation is a heating element on a heater. When the heater element is first switched on, the radiation is invisible, but you can feel the warmth it radiates. As the element heats, it will glow orange and some of the radiation is now visible. The hotter the element, the brighter it glows and the more radiant energy it emits.

Processes in the interaction of a substance with thermal radiation

Absorption: The process by which radiation enters a body and becomes heat

Transmission: The process by which radiation passes through a body

Reflection: The process by which radiation is neither absorbed nor transmitted through the body; rather it bounces off Thermal radiation is received by the objects when they are struck by electromagnetic waves, thus agitating the molecules and atoms. More agitation means more energy and a higher temperature.

Energy is transferred to one body from another without contact or transporting medium such as air or water. Indeed, thermal radiation heat transfer is the only form of heat transfer possible in a vacuum. Bodies emit a certain amount of radiation which depends upon the body's temperature and the nature of its surface. Some bodies emit a small amount of radiant energy for their temperature, generally called 'low emissivity' materials or low-E. Low-E is used to control the heat radiation in and out of the building. Windows can be designed to reflect, absorb and transmit different parts of the sun's radiant energy.

The condition of a body's surface will determine the amount of thermal radiation that is absorbed, reflected or re-emitted. Surfaces that are black and rough, such as black iron, will absorb and re-emit almost all the energy that strikes them. Polished and smooth surfaces will not absorb, but reflect, a large part of the incoming radiant energy.

Units of measure for rate of radiant heat transfer

Metric (SI) Watt per square meter ( $\text{W/m}^2$ )

### 2.15 Evaporation

The change by which any substance is converted from a liquid state and carried off as vapour is called evaporation. In short, evaporation is a cooling process.

### 2.16 Condensation

The change by which any substance is converted from a gaseous state to liquid state is called condensation. In simple word, condensation on the other hand is a heating process

### 2.17 Steam

Steam has been a popular mode of conveying energy, since the industrial revolution.

Characteristics of steam

- High specific heat and latent heat
- High heat transfer coefficient

- Easy to control and distribute
- Cheap and inert

Steam is used for generating power and also used in process industries, such as, sugar, paper, fertilizer, refineries, petrochemicals, chemical, food, synthetic fibre and textiles. In the process industries, the high pressure steam produced in the boiler is first expanded in a steam turbine for generating power. The extraction or bleed from the turbine, which are generally at low pressure, are used for the process. The method of producing power, by using the steam generated for process in the boiler, is called ‘Cogeneration’.

### **How to read a Steam Table?**

Select the pressure and temperature of the steam at which you want to find the enthalpy. Read the intersection of pressure and temperature for enthalpy (Heat content in the steam)

## **2.18 First Law of Thermodynamics**

It states that energy may be converted from one form to another, but it is never lost from the system.

## **2.19 Second Law of Thermodynamics**

In any conversion of energy from one form to another, some amount of energy will be dissipated as heat. Thus, no energy conversion is 100 % efficient. This principle is used in energy equipment efficiency calculations.

## **2.20 Law of Conservation of Matter**

In any physical or chemical change, matter is neither created nor destroyed, but it may be changed from one form to another.

For example: If a sample of coal were burnt in an enclosed chamber, carbon in coal would end up as CO<sub>2</sub> in the air inside the chamber; In fact, for every carbon atom there would be one carbon dioxide molecule in the combustion products (each of which has one carbon atom). So the carbon atoms would be conserved, and so would every other atom. Thus, no matter would be lost during this conversion of the coal into heat. This principle is used in energy and material balance calculations

## **2.21 Units and Conversions**

- The energy units are wide and varied.
- The usage of units varies with country, industry sector, systems such as FPS, CGS, MKS and SI, and also with generations of earlier period using FPS and recent generations using MKS.
- Even technology/equipment suppliers adopt units that are different from the one being used by the user of that technology/equipment.
- For Example: Some compressor manufacturers specify output in m<sup>3</sup>/min while some specify in cubic feet/ minute or even in litres/second. All this causes confusion and hence the need for this chapter on units and conversions.

## **2.22 Energy Units**

1 barrel of oil = 42 U.S. gallons (gal) = 0.16 cubic meters (m<sup>3</sup>)

1MW	1, 000kW
1kW	1,000 Watts
1kWh	3,412 Btu
1kWh	1,340 Hp hours
1,000Btu	0.293 kWh
1Therm	100,000 Btu(British Thermal Units)
1Million Btu	293.1 Kilowatt hours
100,000 Btu	1 Therm

1 Watt	3,412 Btu per hour
1Horsepower	746 Watt or 0.746 Kilowatt
1Horsepower hr	2,545 Btu
1kJ	0.239005 Kilocalories
1 Calorie	4.187 Joules
1kcal/Kg	1.8 Btu's/Ib.
1Million Btu	252 Mega calories
1Btu	252 Calories
1Btu	1,055 Joules
1Btu/Ib.	2.3260 kJ/kg
1Btu/Ib.	0.5559 Kilocalories/kg

<b>Power (Energy Rate) Equivalents</b>	
1 kilowatt (kW)	1kilo joule/second (kJ/s)
1 kilowatt (kW)	3413 BTU/hour (Btu/hr)
1horsepower(hp)	746 watts (0.746 kW)
1Ton of refrigeration	12000 Btu/hr

**Table 2.4 (a) & (b) Units of energy**

The capacity of a boiler is often rated in a “boiler horsepower”. 1 boiler horsepower is equal to 9809.6 watts. This should not be confused with the unit of mechanical power also called a **horsepower**.

## 2.23 Pressure

Gauge pressure is defined relative to the prevailing atmospheric pressure (101.325 kPa at sea level), or as absolute pressure

$$\text{Absolute Pressure} = \text{Gauge Pressure} + \text{Prevailing Atmospheric Pressure}$$

### Units of measure of pressure

Metric (SI): kilopascals (kPa)

1 Pascal (Pa) = 1 Newton/m<sup>2</sup> (N/m<sup>2</sup>)

1 physical atmosphere (atm) = 101325 Pa = 760 mm of mercury (mm Hg)

= 14.69 lb-force/in<sup>2</sup> (psi)

1 technical atmosphere (ata) = 1 kilogram-force/cm<sup>2</sup> (kg/cm<sup>2</sup>) = 9.806650×10<sup>4</sup> Pa

## 2.24 Power

$$1 \text{ W} = 1 \text{ J/s} = 0.9478 \times 10^{-3} \text{ Btu/s} = 3.41214 \text{ Btu/hr}$$

### Fuel to kWh (Approximate conversion)

Natural gas	M3 x 10.6	kWh
LPG (propane)	Ft3 x 0.3	kWh
Coal	therms x 29.3	kWh
Coke	m <sup>3</sup> x 25	kWh
Gas oil	kg x 8.05	kWh
Light Fuel oil	kg x 10.0	kWh
Medium fuel oil	litres x 12.5	kWh
Heavy fuel oil (gr I)	litres x 12.9	kWh

Heavy fuel oil (gr II)	litres x 13.1	kWh
Heavy fuel oil (gr III)	litres x 13.3	kWh

**Table 2.5 Conversion of fuel to kWh**

## 2.25 Prefixes for Units in the International System

Prefix	Symbol	Power	Example	USA/Other
exa	E	$10^{18}$		Quintillion
peta	P	$10^{15}$	pentagrams (pg)	quabtrillion/billiard
tera	T	$10^{12}$	terawatt (tw)	trillon/billion
giga	G	$10^9$	gigawatt(gw)	billion/milliard
mega	M	$10^6$	mégawatt (mw)	million
kilo	K	$10^3$	kilograms (kg)	
hector	h	$10^2$	hectolitre (hl)	
deka	da	$10^1$	dekagram (dag)	
deci	d	$10^{-1}$	decimetre (dm)	
centi	c	$10^{-2}$	centimetre (cm)	
milli	m	$10^{-3}$	millimetre (mm)	
micro	m	$10^{-6}$	micrometre (mm)	
namo	n	$10^{-9}$	nanosecond (ns)	
pico	p	$10^{-12}$	picofarad (pf)	
femto	f	$10^{-15}$	femtogram (fg)	
atto	a	$10^{-18}$		

**Table 2.6 Prefixes for units in the international system**

## 2.26 Energy

To from	TJ Multiply by	Geal	Mto	MBtu	GWh
TJ	1	238.8	$20388 \times 10^5$	947.8	0.2778
Gcal	$4.1868 \times 10^{-3}$	1	$10^{-7}$	3.968	$1.163 \times 10^3$
Mtoe	$4.1868 \times 10^4$	$10^7$	1	$3.968 \times 10^7$	11630
MBtu	$1.0551 \times 010^{-3}$	0.252	$2.52 \times 10^{-8}$	1	$2.937 \times 10^{-4}$
GWh	3.6	860	$8.6 \times 10^{-5}$	3412	1

**Table 2.7 Energy expressed in various units**

## 2.27 Mass

To	kg	t	It	st	Ib
From	multiply by	-	-	-	-
kilogram (kg)	1	0.001	$9.84 \times 10^{-4}$	$1.102 \times 10^{-3}$	2.2046
tonne (t)	1000	1	0.984	1.1023	2204.6
long ton (It)	1016	1.016	1	1.120	2240.0
short ton (st)	907.2	0.9072	0.893	1	2000.0
pound (Ib)	0.454	$4.54 \times 10^{-4}$	$4.46 \times 10^{-4}$	$5.0 \times 10^{-4}$	1

**Table 2.8 Mass expressed in various units**

## 2.28 Volume

To	gal U.S.	gal U.K.	bbl	ft <sup>3</sup>	I	m <sup>3</sup>
From	multiply by	-	-	-	-	-
U.S. gallon (gal)	1	0.8327	0.02381	0.1337	3.785	0.0038
U.K. gallon (gal)	1.201	1	0.02859	0.1605	0.1605	0.0045
Barrel (bbl)	42.0	34.97	1	5.615	159.0	0.159
Cubic foot (ft <sup>3</sup> )	7.48	6.229	0.1781	1	28.3	0.0283
Litre (I)	0.2642	0.220.	0.0063	0.0353	1	0.001
Cubic metre (m <sup>3</sup> )	264.2	220.0	6.289.0	35.3147	1000.0	1

**Table 2.9 Volume expressed in various units**

## Summary

- Energy is the ability to do work and work is the transfer of energy from one form to another.
- There are two types of energy: Stored or potential energy and Working or kinetic energy.
- It is difficult to imagine spending an entire day without using energy. Energy is used to light homes and cities, to power machinery in factories, cook food, play music, and operate television.
- High-Grade Energy And Low-Grade Energy are the two grades of energy.
- Electric current is divided into two types: Directional Current (DC) and Alternating Current (AC). A characteristic of Directional Current is that the direction of current (direction of flow for positive charges) is constant with time. Characteristics of Alternating Current is that the direction of the current reverses periodically with time
- Kilowatt-hour is the energy consumed by 1000 Watts in one hour. If 1kW (1000 watts) of an electrical equipment is operated for 1 hour, it would consume 1 kWh of energy (1 unit of electricity).
- The prevailing electricity tariff of the electricity board has been explained with its various features: Billing Demand, Calculation of electric bill for a company, Contract Demand, Maximum Demand etc.
- A power analyser can measure PF directly, or alternately kWh, kVAh or kVArh readings are recorded from the billing meter installed at the incoming point of supply. The relation kWh / kVAh gives the power factor.
- Temperature and pressure are measures of the physical state of a substance. They are closely related to the energy contained in the substance. As a result, measurements of temperature and pressure provide a means of determining energy content.
- The heat capacity of an object as the quantity of heat required to raise the temperature of the object by  $1^{\circ}\text{C}$ .
- The quantity of heat is given by:  $Q = \text{mass} \times \text{specific heat} \times \text{increase in temperature}; Q = m \times C_p \times \Delta t$
- Dynamic viscosity is the tangential force per unit area required to move one horizontal plane with respect to the other at unit velocity when maintained a unit distance apart by the fluid. It is expressed as  $\text{N.sec/m}^2$ .
- Kinematic viscosity is the ratio of absolute or dynamic viscosity to density - a quantity in which no force is involved. It can be obtained by dividing the absolute viscosity of a fluid with its mass density. It is equal to dynamic viscosity / density and expressed as  $\text{m}^2/\text{sec}$ .
- Energy content in an organic matter (Calorific Value) can be measured by burning it and measuring the heat released.
- Heat will always be transferred from higher temperature to lower temperature independent of the mode. The energy transferred is measured in Joules (kcal or Btu).
- Heat is transferred by three primary modes: Conduction (Energy transfer in a solid), Convection (Energy transfer in a fluid) and Radiation (Does not need a material to travel through).
- The energy units are wide and varied. The usage of units varies with country, industry sector, systems such as FPS, CGS, MKS and SI, and also with generations of earlier period using FPS and recent generations using MKS.

## Reference

- *Energy Savings Toolbox- An energy Audit Manual And Tool* [Pdf] Available at: <<http://oee.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/files/pdf/energy-audit-manual-and-tool.pdf>> [Accessed 5 July 2013].
- *Module 2: Basic Principles of Energy* [Pdf] Available at: <[http://www.energy.gov.za/EEE/Projects/Building%20Energy%20Audit%20Training/Training%20Modules/Building%20Energy%20Auditing%20Module%202\\_final.pdf](http://www.energy.gov.za/EEE/Projects/Building%20Energy%20Audit%20Training/Training%20Modules/Building%20Energy%20Auditing%20Module%202_final.pdf)> [Accessed 5 July 2013].
- Andrews, J. and Jolley, N., 2007. *Energy Science Principle, Technologies, and Impacts*. Oxford University Press.
- Beggs, C., 2009. *Energy: Management, Supply and Conservation*. Elsevier Ltd.
- *Basics and energy of the atmosphere 003* [Video online] Available at: <<http://www.youtube.com/watch?v=WMUjNKEKjA>> [Accessed 5 July 2013].
- *Electrical Energy Basics* [Video online] Available at: <<http://www.youtube.com/watch?v=ZRKnVQNpwD4>> [Accessed 5 July 2013].

## Recommended Reading

- Andrews, J. and Jolley, N. A., 2007. *Energy science: Principles, Technologies, and Impacts*. Oxford University Press.
- Ghosh, T.K. and Prelas, M.A., 2009. *Energy Resources and Systems: Fundamentals and non-renewable resources*. Springer.
- Raja, A.K. and Srivastava, A.P., 2007. *Power Plant Engineering*. New Age International

## Self Assessment

1. Match the following

1. It is the stored energy and the energy of position	a. Gravitational Energy
2. It is the energy stored in bonds of atoms and molecules	b. Nuclear Energy
3. It is the energy of place or position	c. Chemical Energy
4. It is the energy stored in the nucleus of an atom	d. Potential energy

a. 1-b, 2-a, 3-d, 4-c

b. 1-c, 2-d, 3-b, 4-a

c. 1-d, 2-c, 3-a, 4-b

d. 1-c, 2-a, 3-d, 4-b

2. Match the following

1. Energy that deals with the movement of electrons	a. Thermal Energy
2. It is the internal energy in substances	b. Kinetic energy
3. It is the electromagnetic energy that travels in transverse waves	c. Electrical Energy
4. It is the energy in motion	Radiant energy

a. 1-b, 2-c, 3-a, 4-d

b. 1-d, 2-c, 3-b, 4-a

c. 1-b, 2-d, 3-a, 4-c

d. 1-c, 2-a, 3-d, 4-b

3. \_\_\_\_\_ is the movement of energy through substances in longitudinal waves.

a. Electrons

b. Photons

c. Sound

d. Solar Energy

4. \_\_\_\_\_ is the rate of flow of charge.

a. Volt

b. Ampere

c. Watt

d. Horse power

5. Which of the following is false?

a. The unit of frequency is Hertz.

b. The unit of resistance is ohm.

c. kVA is the product of kilovolts and amperes.

d. kVAr is the apparent power.

6. Which of the following is true?

a. Relation between kVA, kW and kVAr is  $kVA = \sqrt{(kW)^2 + (kWAr)^2}$

b. Relation between kVA, kW and kVAr is  $KVA = (kW) \sqrt{(kW)^2 + (kWAr)^2}$

c. Relation between kVA, kW and kVAr is  $KVA = kWAr \sqrt{(kW)^2 + (kWAr)^2}$

d. Relation between kVA, kW and kVAr is  $kWAr = KVA \sqrt{(kW)^2 + (kWAr)^2}$

7. Which is the ratio between the active power(kW) and apparent power (kVA)
  - a. Single phase
  - b. Power factor
  - c. Electrical Tariff
  - d. Kilowatt-hour
8. Which is a measure of the latent heat content of air-water vapour mixtures?
  - a. Dew Point
  - b. Dry bulb temperature
  - c. Wet bulb temperature
  - d. Dew point temperature
9. The energy transferred is measured in \_\_\_\_\_.
  - a. joules
  - b. calorific value
  - c. kilowatt
  - d. watt
10. \_\_\_\_\_ is the process by which radiation passes through a body.
  - a. Absorption
  - b. Evaporation
  - c. Condensation
  - d. Transmission

# **Chapter III**

## **Energy Management and Audit**

### **Aim**

The aim of this chapter is to :

- define the objectives of energy management
- elucidate the method of conducting energy audit
- explain the significance of benchmarking

### **Objectives**

The objectives of this chapter are to:

- define the methods to write an energy audit report
- analyse energy performance
- explain the key instruments for energy audit

### **Learning outcome**

At the end of this chapter students should be able to:

- understand the basic principles and objectives of energy management
- identify electrical utilities and their operation
- recognise the key instruments for energy audit

### 3.1 Introduction

Energy is a variable operating cost that can be controlled by cutting down on wasteful energy consumption. Many cost savings can be delivered through low and no-cost initiatives. Further savings can be made by investing in equipment that uses less energy simply because it meets energy efficiency performance criteria. It is estimated that most companies could reduce their energy consumption by around 20% every year, delivering lower costs, immediate bottom-line improvement and competitiveness. Emissions trading are being developed, internationally. It is a central part of the Kyoto Protocol. This protocol is ratified by many nations. Organisations benefit by reducing emissions. Carbon trading is now a practice in developed countries.

Lets see the cost of energy in the Indian Industry (Source – Business Standard Feb 2005 Figures for Year 2003-2004 A/C year).

Sector	Company	Net Sales in Rs. Crs	Energy Cost as %
Cement	Birla Cement	1034	28.41
Petroleum	Indian Oil	117088	0.38
Steel	TATA Steel	10702	6.77
Sugar	Balrampur	738	1.5
Pharmaceuticals	Cipla	1842	1.55
Pumps and Compressors	Ingresol	456	0.81
Fertilisers	National Fer	3387	24.02
Automobiles	Hero Honda	5832	0.51

**Table 3.1 Cost of energy in india**

### 3.2 Definition and Objectives of Energy Management

- The phrase ‘energy management’ can be different to different people.
- Energy management is defined as the efficient and effective use of energy to maximize profits or maximise costs and enhance competitive positions.
- “The judicious and effective use of energy to maximise profits (minimise costs) and enhance competitive positions.” “The strategy of adjusting and optimising energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems”*

\*Source: (Cape Hart, Turner and Kennedy, (1997) Guide to Energy Management Fairmont Press Inc).

#### Objectives of Energy Management

The primary objective of energy management is to produce goods and provide services with the least cost and energy and the least effecting the environment.

The objective of energy management is also to achieve and maintain optimum energy procurement and utilisation throughout the organisation and the following:

- to minimise energy costs / waste without affecting production & quality
- to minimise environmental effects

### 3.3 Principles of Energy Management

The principles of energy management are as follows:

- Procure all the energy needed at the lowest possible price: Example: Buy from original sources, review the purchase terms.
- Manage energy use at the highest energy efficiency: Example: Improving energy use efficiency at every stage of energy transport, distribution and use.

- Reusing and recycling energy by cascading: Example: Waste heat recovery.
- Use the most appropriate technology: select low investment technology to meet the present requirement and environment condition
- Reduce the avoidable losses: Make use of wastes generated within the plant as sources of energy and reduce the component of purchased fuels and bills.

### 3.4 Energy Management Skills

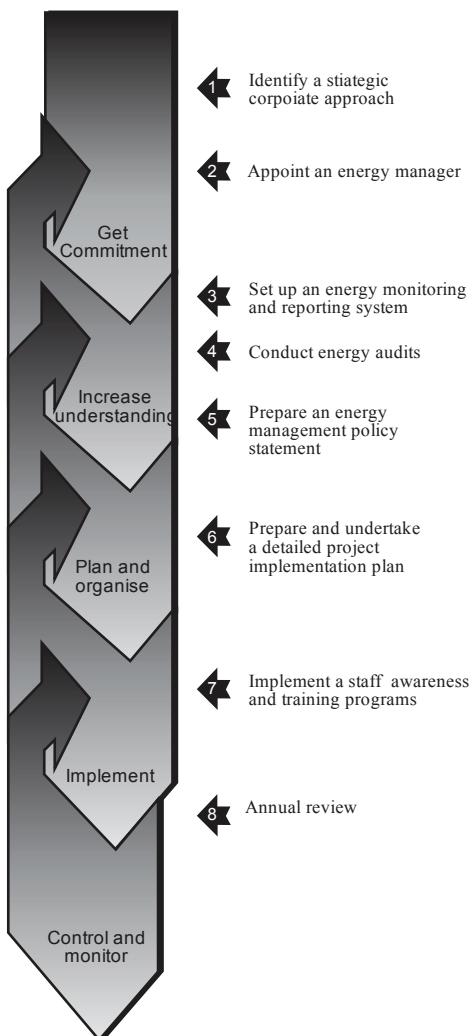
Energy management involve a combination of both managerial and technical knowledge/skills.

- Managerial skills: These include, bringing about awareness, motivating people at all levels, changing structure and procedure, monitoring energy consumption, norms, target setting, etc. Both organisational and people changes are required.
- Technical skills: These include, pre-requisite in improving the energy efficiency of a process or equipment such as boilers, furnaces etc.

The energy manager should be technically well versed with the manufacturing process, energy utilisation technologies, in addition to awareness of statistical techniques of data processing, applied economics and cost accountancy.

### 3.5 Energy Management Strategy

Energy management should be seen as a continuous process. Strategies should be reviewed annually and revised as necessary. The key activities (see Fig. 3.1) are outlined below



**Fig. 3.1 Energy management steps**

### **Identify a Strategic Corporate Approach**

- The starting point in energy management is to identify a strategic corporate approach to energy management.
- Clear accountability for energy management needs to be established, appropriate financial and staffing resources must be allocated, and reporting procedures initiated.
- An energy management programme requires commitment from the whole organisation in order to be successful.

### **Appoint energy manager**

- The energy manager, who should be a senior staff member, will be responsible for the overall co-ordination of the programme and will report directly to the top management.
- Energy managers need to have a technical background, need to be familiar with the organisation's activities and have appropriate technical support.

### **Set up an energy monitoring and reporting system**

Successful energy management requires the establishment of a system to collect analyse and report on the organisation's energy costs and consumption. This will enable an overview of energy use and its related costs, as well as facilitate the identification of savings that might otherwise not be detected. The system needs to record both historical and ongoing energy use, as well as cost information from billing data, and be capable of producing summary reports on a regular basis. This information will provide the means by which trends can be analysed and tariffs reviewed.

### **Conduct energy audit**

An energy audit establishes both where and how energy is being used and the potential for energy savings. It includes a walk-through survey, a review of energy using systems, analysis of energy use and the preparation of an energy budget, and provides a baseline from which energy consumption can be compared over time. An audit can be conducted by an employee of the organisation who has appropriate expertise, or by a specialist energy-auditing firm. An energy audit report also includes recommendations for actions, which will result in energy and cost savings. It should also indicate the costs and savings for each recommended action, and apriority order for implementation.

### **Formalise an energy management policy statement**

A written energy management policy will guide efforts to improve energy efficiency, and represent a commitment to saving energy. It will also help to ensure that the success of the programme is not dependent on particular individuals in the organisation. An energy management policy statement includes a declaration of commitment from senior management, as well as general aims and specific targets relating to:

- energy consumption reduction (electricity, fuel oil, gas, petrol etc.)
- energy cost reduction (by lowering consumption and negotiating lower unit rates)
- time tables
- budgetary limits
- energy cost centres
- organisation of management resources

### **Prepare and undertake a detailed project implementation plan**

A project implementation plan should be developed as part of the energy audit and be endorsed by the management. The plan should include an implementation time-table and state any funding and budgetary requirements. Projects may range from establishing or changing operational procedures to ensure that plant and equipment use minimum energy, renegotiating electricity supply arrangements etc. to adopt asset acquisition programmes that will reduce energy consumption. An overall strategy could introduce energy management projects, which will achieve maximum financial benefits at the least cost to the organisation. A key ingredient to the success of an energy management programme is maintaining a high level of awareness among staff. This can be achieved in a number of ways, including formal training, newsletters, posters and publications, and by incorporating energy management into

existing training programmes. It is important to communicate programme plans and case studies that demonstrate savings, and to report results at least at 12-month intervals. Staff may need training from specialists on energy saving practices and equipment.

#### **Annual review**

An energy management programme will be more effective if its results are reviewed annually. Review of energy management policy and strategies will form the basis for developing an implementation plan for the next 12months. The annual review has normally to be under the chairmanship of either a senior level top manager or CEO if possible. As the policies are signed by the CEO, it is expected that the review is carried out under his guidance so that the implementation becomes more effective.

The following are the samples of the energy management policy, as declared by a few progressive companies, are given below:

### **3.6 Energy Policy Example**

The various examples related to energy policy are:

#### **Glaxo SmithKline**

##### **Energy conservation policy and set up and commitment:**

Glaxo SmithKline Pharmaceuticals Limited, India, is committed to high standards of Energy Management as an integral part of business activities, in line with corporate values and continuous improvements. Glaxo SmithKline Pharmaceuticals Ltd., India's guiding principle is that "Energy saved is energy generated".

#### **Policy**

It is the policy of Glaxo Smith Kline Pharmaceuticals Limited, Nasik to:

- Efficiently utilise the energy supplied by an external authority for carrying out manufacturing activities throughout the factory.
- Operate our business in an energy efficient, environmental friendly and socially responsible manner.
- Commit to continuous improvement in energy conservation performance.
- Comply with legal requirements and global GSK Standards.
- Make energy conservation integral to all GSK Pharmaceuticals business processes, planning and decision making.
- Establish business practices and energy conservation strategies that optimally utilise resources and prevent pollution to ensure the long-term sustainability of GSK Pharmaceuticals Ltd, India and the global environment.
- Ensure that all employees work with due regard to energy management conservation approach.
- Their attitude to energy conservation will be a factor in determining their career advancement.
- GSK Pharmaceuticals Limited, India will use effective systems, metrics and goals in the management of all of Energy Management activities.

S. A. Phadke Issued on: January, 2003.

Sr. Engineering Manager, Nasik Factory

### **3.7 Energy Audit: Types and Methodology**

- 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 a comprehensive energy management programme.

As per the Energy Conservation Act, 2001, energy audit is defined as “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”.

### **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 the 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.

Energy audit would give a positive orientation to 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 energy costs, availability and reliability of the supply of energy, decide on an 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 organisational considerations within a specified time-frame.

The main objective of an 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 organisation and also provides the basis for planning a more effective use of energy throughout the organisation.

### **Types of Energy Audit**

Types of energy audit to be performed depends on:

- function and type of industry
- depth to which the final audit is needed, and
- potential and magnitude of cost reduction desired

Thus, energy audit can be classified into the following two types:

- preliminary audit
- detailed audit

### **Preliminary energy audit methodology**

- The Preliminary energy audit is a relatively quick exercise to:
  - establish energy consumption in the organisation
  - estimate the scope for savings
  - identify the most likely (and the easiest areas for attention)
  - identify immediate improvements / savings
  - set a ‘reference point’
  - identify areas for more detailed study/measurement
  - the 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 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

#### **A guide for conducting energy audit at a glance**

Industry-to-industry, the methodology of Energy Audits needs to be flexible. A comprehensive ten-step methodology for conduct of energy audit at field level is given. The energy manager and energy auditor may follow these steps to start with and add/change as per their needs and industry types.

#### **Ten steps methodology for detailed energy audit**

Step No.	Plan of Action	Purpose/ Result
Step:1	Phase I: Pre Audit Phase 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.) Familiarisation 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
Step:3	Phase II –Audit Phase 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
Step:6	Analysis of energy use	Energy and Material balance & energy loss/waste analysis
Step:7	Identification and development of Energy Conservation (ENCON) opportunities Use brainstorming and value analysis techniques	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
Step:9	Reporting & Presentation to the Top Management	Documentation, Report Presentation to the top Management.
Step:10	Phase III –Post Audit phase Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance Action plan, Schedule for implementation Follow-up and periodic review

**Table 3.2 Ten steps methodology for a detailed energy audit****Phase I –pre audit phase activities**

A structured methodology to carry out an energy audit is necessary for efficient working. An initial study of the site should always be carried out, as the planning of the procedures necessary for an audit is most important.

**Initial site visit and preparation required for detailed auditing**

An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit. During the initial site visit the Energy Auditor/Engineer should carry out the following actions:

- Discuss with the site's senior management the aims of the energy audit.
- Discuss economic guidelines associated with the recommendations of the audit.
- Analyse the major energy consumption data with the relevant personnel.
- Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distribution etc.
- Tour the site accompanied by engineering/production

The main aims of this visit are:

- To finalise Energy Audit team
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify any existing instrumentation/ additional metering required.
- To decide whether any meters will have to be installed prior to the audit example kWh, steam, oil or gas meters.
- To identify the instrumentation required for carrying out the audit.
- To plan with time frame

To collect macro data on plant energy resources, major energy consuming centres

To create awareness through meetings/programme

### **Phase II- detailed energy audit activities**

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

The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process. Means of improving these efficiencies will be listed, and at least a preliminary assessment of the cost of the improvements will be made to indicate the expected payback on any capital investment needed. The audit report should conclude with specific recommendations for detailed engineering studies and feasibility analyses, which must then be performed to justify the implementation of those conservation measures that require investments.

The information to be collected during the detailed audit includes:

- Energy consumption by type of energy, by department, by major items of process equipment, by end-use
- 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.)
- Energy cost and tariff data
- Process and material flow diagrams
- Generation and distribution of site services (example. compressed air, steam).
- Sources of energy supply (e.g. electricity from the grid or self-generation)
- Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and power generation).
- 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

### Data collection hints

It is important to plan additional data gathering carefully. Here are some basic tips to avoid wasting time and effort:

- measurement systems should be easy to use and provide the information to the accuracy that is needed, not the accuracy that is technically possible
- measurement equipment can be inexpensive (flow rates using a bucket and stopwatch)
- The quality of the data must be such that the correct conclusions are drawn (what grade of product is on, is the production normal etc.)
- define how frequent data collection should be to account for process variations.
- measurement exercises over abnormal workload periods (such as start up and shutdowns)
- design values can be taken where measurements are difficult (cooling water through heat exchanger)

**DO NOT ESTIMATE WHEN YOU CAN CALCULATE  
DO NOT CALCULATE WHEN YOU CAN MEASURE**

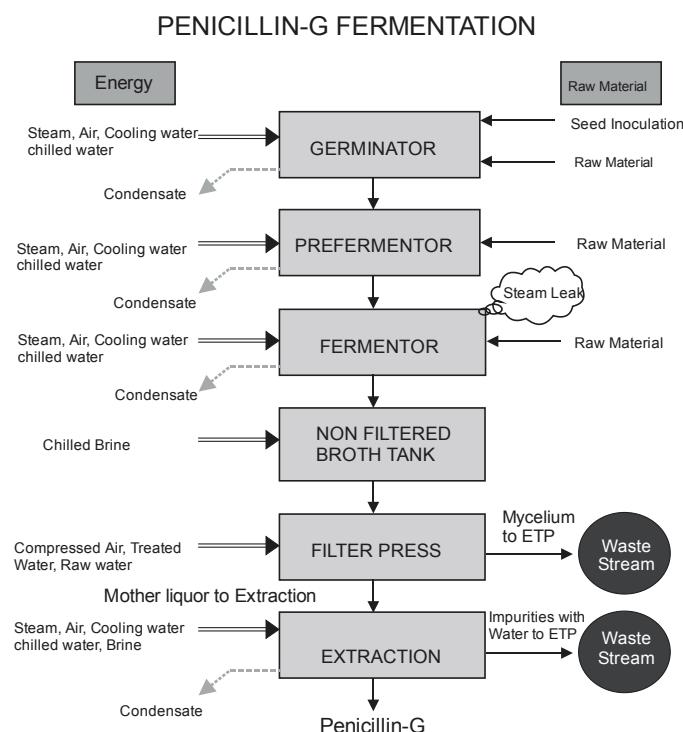
### 3.8 Detailed Process Flow Steps In Energy Management

An overview of unit operations, important process steps, areas of material and energy use and sources of waste generation should be gathered and should be represented in a flowchart as shown in the figure below.

Existing drawings, records and shop floor walk through will help in making this flow chart. Simultaneously the team should identify the various inputs & output streams at each process step.

**Example:** A flowchart of Penicillin-G manufacturing is given in the fig.3.2 below.

**Note:** That waste stream (Mycelium) and obvious energy wastes such as condensate drained and steam leakages have been identified in this flow chart



**Fig. 3.2 Penicillin-G fermentation**

The audit focus area depends on several issues like consumption of input resources, energy efficiency potential, impact of process step on entire process or intensity of waste generation / energy consumption. In the above process, the unit operations such as germinator, pre-fermentor, fermentor, and extraction are the major conservation potential areas identified.

### **3.9 Identification of Energy Conservation Opportunities**

#### **Fuel substitution**

Identifying the appropriate fuel for efficient energy conversion.

#### **Energy generation**

Identifying Efficiency opportunities in energy conversion equipment/utility such as captive power generation, steam generation in boilers, thermic fluid heating, optimal loading of DG sets, minimum excess air combustion with boilers/ thermic fluid heating, optimising existing efficiencies, efficient energy conversion equipment, biomass gasifiers, Cogeneration, high efficiency DG sets, etc.

#### **Energy distribution**

Identifying Efficiency opportunities network such as transformers, cables, switchgears and power factor improvement in electrical systems and chilled water, cooling water, hot water, compressed air, etc.

#### **Energy usage by processes**

This is where the major opportunity for improvement and many of them are hidden. Process analysis is useful tool for process integration measures.

#### **Technical and Economic feasibility**

The technical feasibility should address the following issues

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

The Economic viability often becomes the key parameter for the management acceptance. The economic analysis can be conducted by using a variety of methods. Example: Pay back method, Internal Rate of Return method, Net Present Value method etc. For low investment short duration measures, which have attractive economic viability, simplest of the methods, payback is usually sufficient.

A sample worksheet for assessing economic feasibility is provided below:

#### **Sample worksheet for economic feasibility**

##### **Name of energy efficiency measure**

<b>Investment</b>	<b>Annual operating costs</b>	<b>Annual savings</b>
Equipments	Cost of capital	Thermal Energy
Civil works	Maintenance	Electrical Energy
Instrumentation	Manpower	Raw material
Auxiliaries	Energy	Waste disposal
	Depreciation	

**Table 3.3 Name of energy efficiency measure**

Net Savings /Year (Rs. /year) = (Annual savings-annual operating costs)

Payback period in months = (Investment/net savings/year) x 12

### Classification of energy conservation measures

Based on energy audit and analyses of the plant, a number of potential energy saving projects may be identified. These may be classified into three categories:

- no cost
- low cost – high return
- medium cost – medium return
- high cost – high return

**No cost:** This is basically creating awareness among employees.

For example: switching off the computer and fan + light when leaving a room. These are small steps but they help a lot. In addition the concept of KAIZEN needs to be introduced. This is a Japanese concept where KAI means small and ZEN means improvement. This concept is now widely adopted in many big industries.

This technique is applied to all processes and it can involve almost all the employees. Thus the advantage is that all are participating and total results are far more improved.

### Examples of Small Kaizen

#### Valve position changed

There were many auxiliary valves at a height. The worker had to climb and operate the valves. It was suggested that a main valve be fitted on the wall at a height of one metre and instead of operating many valves only one valve can be operated. This saved efforts and wastage as it is easier to close the valve and timely action can be taken in case of any problem.

#### Light intensity

Light intensity was studied and for the same lumens requirement it was decided to fix special reflectors to tubes. This gave enough light in the working area with a less number of light fittings. Out of 8 tube fittings, three were removed. The saving achieved was Rs. 2500/year.

#### Energy saving by fixing a timer

For the water cooler which runs on/off it was decided to fix a timer after studying the usage pattern. The timer has an adjustable time and one hour switch off for every two hours was tried. This worked well and saving in energy was 2300 Units/annum. Suggestion schemes are extremely good and in some Multinationals it is mandatory to have these practiced. The suggestions are considered every month and on the basis of practicability they are analysed and the best suggestions are rewarded. This brings in a sense of belonging among the employees.

Normally the low cost – high return projects receive priority. Other projects have to be analysed, engineered and budgeted for implementation in a phased manner. Projects relating to energy cascading and process changes almost always involve high costs coupled with high returns, and may require careful scrutiny before funds can be committed. These projects are generally complex and may require long lead times before they can be implemented. Refer Table 3.1 for project priority guidelines.

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

**Table 3.4 Project priority guideline**

### **3.10 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

<b>Report on DETAILED ENERGY AUDIT TABLE OF CONTENTS Table of Contents</b>	
i.	Acknowledgement
ii.	Executive Summary
Energy Audit Options at a glance & Recommendations	
<b>1.0 Introduction about the plant</b>	
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
<b>2.0 Production Process Description</b>	
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
<b>3.0 Energy and Utility System Description</b>	
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

**Fig. 3.3 Energy audit reporting format**

The following Worksheets (refer the tables 3.4 and 3.5 below) can be used as guidance for energy audit assessment and reporting.

Sl.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 3.5 Summary of energy saving recommendations**

	Type of Energy Saving Options	Annual Electricity /Fuel savings kWh/MT (or) kl /MT	Annual Savings (Rs. Lakhs)	Priority
A	No Investment (Immediate) <ul style="list-style-type: none"> <li>• Operational Improvement</li> <li>• Housekeeping</li> </ul>			
B	Low Investment (Short to Medium Term) <ul style="list-style-type: none"> <li>• Controls</li> <li>• Equipment modification</li> <li>• Process change</li> </ul>			
C	High Investment (Long Term) <ul style="list-style-type: none"> <li>• Energy efficient Devices</li> <li>• Product modification</li> <li>• Technology Change</li> </ul>			

**Table 3.6 Types and priority of energy saving measures**

### **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 <sup>3</sup> /hr.
C: Description of Proposed system and its operation	:	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.
D: Energy Saving Calculations	:	The DG Set cooling water flow is only 240 m <sup>3</sup> / 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.
Capacity of main cooling tower	=	5000 m <sup>3</sup> / hr
Temp across cooling tower (design)	=	8 °C
Present capacity	=	3000 m <sup>3</sup> /hr
Temperature across cooling tower(operating)	=	4°C
% loading of main cooling tower	=	(3000 x 4)/(5000 x 8) = 30%
Capacity of DG Set cooling tower	=	240 m <sup>3</sup> /hr
Temp across the tower	=	5°C
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 <sup>3</sup> /h (66.67 l/s) with 6 kg/cm <sup>2</sup>	=	(66.67 x 6) / (102 x 0.55) = 7 kW
Net Energy savings	=	47 – 7 = 40 kW
E: Cost Benefits		
Annual Energy Saving Potential		40kW x 8400hr = 3,36,000 Units/Year
Annual Cost Savings		3,36,000 x Rs.4.00 = Rs.13.4 Lakh per year
Investment (Only cost of piping)		Rs 1.5Lakhs
Simple Pay back Period		Less than 2 months

**Table 3.7 Reporting format for energy conservation recommendations**

Even in cooling tower just making small changes like setting temperatures by 1-2°C is worth experimenting. Many a time good results are achieved. This is also a KAIZEN.

### 3.11 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.

The following can be used for the energy invoices

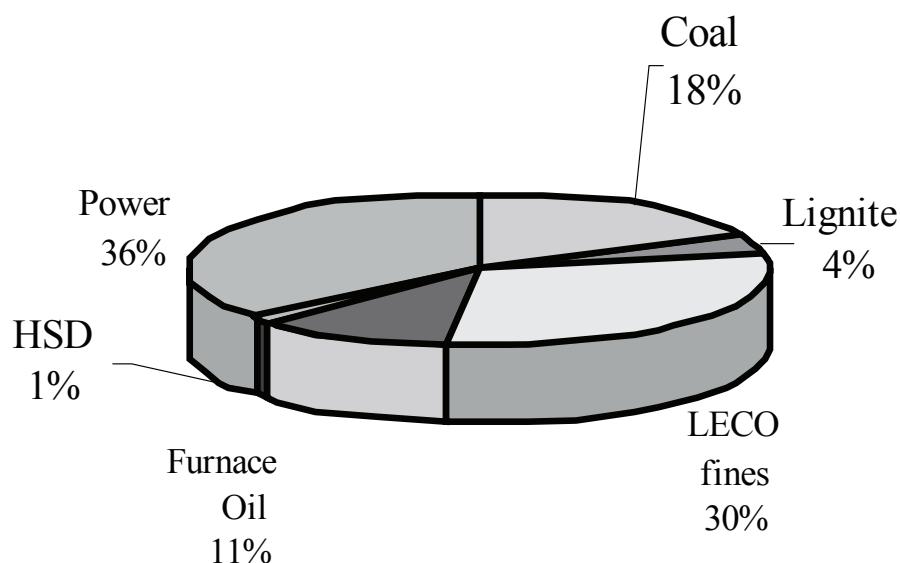
- They provide a record of energy purchased in a given year, which gives a base-line for future reference
- Energy invoices may indicate the potential for savings when related to production requirements or to air conditioning requirements/space heating etc
- When electricity is purchased on the basis 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. Some of them are listed below:

- fuel oil
- low Sulphur Heavy Stock (LSHS)
- light Diesel Oil (LDO)
- liquefied Petroleum Gas (LPG)
- coal
- lignite
- wood etc.



**Fig. 3.4 Annual energy bill with percentages**

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. Coal 18% Lignite4% Furnace Oil 11% HSD1% Power36% LECO fines 30% Total Energy Bill -Rs. 6 Crores/annum Fig. 3.2: Annual energy bill

- Price at source, transport charge, type of transport
- Quality of fuel (contaminations, moisture etc)
- Energy content (calorific value)
- Ease of operation and reduction in environmental pollution

### **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

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	2,000/ ton 20,00, 000	20,00,000
		Total	60,00,000

**Table 3.8 Energy purchase**

Unfortunately the different forms of energy are sold in different units e.g. kWh of electricity, litres 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)

### 3.12 Benchmarking and Energy Performance

Benchmarking of energy consumption internally (historical / trend analysis) and externally (across similar industries) are two powerful tools for performance assessment and logical evolution of avenues for improvement. Historical data well documented helps to bring out energy consumption and cost trends month-wise / day-wise. Trend analysis of energy consumption, cost, relevant production features, specific energy consumption, help to understand effects of capacity utilization on energy use efficiency and costs on a broader scale.

External benchmarking relates to inter-unit comparison across a group of similar units. However, it would be important to determine similarities, as otherwise findings can be grossly misleading. Few comparative factors, which need to be looked into while benchmarking externally are;

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

#### Benchmarking energy performance permits

- Quantification of fixed and variable energy consumption trends vis-à-vis production levels
- Comparison of the industry energy performance with respect to various production levels (capacity utilization)
- Identification of best practices (based on the external benchmarking data)
- Scope and margin available for energy consumption and cost reduction
- Basis for monitoring and target setting exercises.

The benchmark parameters can be

- Gross production related
  - e.g. kWh/MT clinker or cement produced (cement plant)
  - e.g. kWh/kg yarn produced (Textile unit)
  - e.g. kWh/MT, kCal /kg, paper produced (Paper plant)
  - e.g. kCal /kWh Power produced (Heat rate of a power plant)
  - e.g. Million kilocalcs /MT Urea or Ammonia (Fertilizer plant)
  - e.g. kWh/MT of liquid metal output (in a foundry)
- Equipment / utility related
  - e.g. kW/ton of refrigeration (on Air conditioning plant)
  - e.g. % thermal efficiency of a boiler plant
  - e.g. % cooling tower effectiveness in a cooling tower
  - e.g. kWh/NM<sup>3</sup> of compressed air generated
  - e.g. kWh /litre in a diesel power generation plant.

While such benchmarks are referred to, related crucial process parameters need mentioning for meaningful comparison among peers. For instance, in the above case

- For a cement plant: type of cement, blaine number (fineness) i.e. Portland and process used (wet/dry) are to be reported alongside kWh/MT figure.
- For a textile unit: average count, type of yarn i.e. polyester/cotton, is to be reported along side kWh/square meter.
- For a paper plant: paper type, raw material (recycling extent), GSM quality is some important factors to be reported along with kWh/MT, kCal/Kg figures.
- For a power plant / cogeneration plant: plant % loading, condenser vacuum, inlet cooling water temperature, would be important factors to be mentioned alongside heat rate (kCal/kWh).

- For a fertilizer plant: capacity utilisation (%) and on-stream factor are two inputs worth comparing while mentioning specific energy consumption
- For a foundry unit: melt output, furnace type, composition (mild steel, high carbon steel/cast iron etc.) raw material mix, number of power trips could be some useful operating parameters to be reported while mentioning specific energy consumption data.
- For an Air conditioning (A/c) plant: Chilled water temperature level and refrigeration load (TR) are crucial for comparing kW/TR.
- For a boiler plant: fuel quality, type, steam pressure, temperature, flow, are useful comparators alongside thermal efficiency and more importantly, whether thermal efficiency is on gross calorific value basis or net calorific value basis or whether the computation is by direct method or indirect heat loss method, may mean a lot in benchmarking exercise for meaningful comparison.
- Cooling tower effectiveness: ambient air wet/dry bulb temperature, relative humidity, air and circulating water flows are required to be reported to make meaningful sense.
- Compressed air specific power consumption: is to be compared at similar inlet air temperature and pressure of generation.
- Diesel power plant performance: is to be compared at similar loading %, steady run condition etc.

### 3.13 Plant Energy Performance

Plant energy performance (PEP) is the measure of whether a plant is now using more or less energy to manufacture its products than it did in the past: a measure of how well the energy management programme is doing. It compares the change in energy consumption from one year to the other considering production output. Plant energy performance monitoring compares plant energy use at a reference year with the subsequent years to determine the improvement that has been made.

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

### 3.14 Production factor

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

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

### 3.15 Reference Year Equivalent Energy Use

The reference year's energy use that would have been used to produce the current year's production output may be called the "reference year energy use equivalent" or "reference year equivalent" for short. The reference year equivalent is obtained by multiplying the reference year energy use by the production factor (obtained above)

$$\text{Reference year equivalent} = \text{Reference year energy use} \times \text{Production factor}$$

The improvement or deterioration from the reference year is called "energy performance" and is a measure of the plant's energy management progress. It is the reduction or increase in the current year's energy use over the reference, and is calculated by subtracting the current year's energy use from the reference year's equivalent. The result is divided by the reference year equivalent and multiplied by 100 to obtain a percentage.

$$\text{Plant energy performance} = \frac{(\text{Reference year equivalent Current year's energy})}{\text{Reference year's equivalent}}$$

$$\text{Plant energy performance} = \frac{(\text{Reference year equivalent Current year's energy})}{\text{Reference year's equivalent}} \times 100$$

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

### 3.16 Monthly Energy Performance

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

### 3.17 Matching Energy Usage to Requirement

Mismatch between equipment capacity and user requirement often leads to inefficiencies due to part load operations, wastages etc. Worst case design, is a designer's characteristic, while optimization is the energy manager's mandate and many situations present themselves towards an exercise involving graceful matching of energy equipment capacity to end-use needs.

#### Examples

- Eliminate throttling of a pump by impeller trimming, resizing pump, installing variable speed drives
- Eliminate damper operations in fans by impeller trimming, installing variable speed drives, pulley diameter modification for belt drives, fan resizing for better efficiency.
- Moderation of chilled water temperature for process chilling needs
- Recovery of energy lost in control valve pressure drops by back pressure/turbine adoption
- Adoption of task lighting in place of less effective area lighting

#### Maximising system efficiency

Once the energy usage and sources are matched properly, the next step is to operate the equipment efficiently through best practices in operation and maintenance as well as judicious technology adoption. Some illustrations in this context are:

- Eliminate steam leakages by trap improvements
- Maximise condensate recovery
- Adopt combustion controls for maximizing combustion efficiency
- Replace pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy consuming equipment, wherever significant energy efficiency margins exist.

#### Optimising the input energy requirements

Consequent upon fine-tuning the energy use practices, attention is accorded to considerations for minimizing energy input requirements. The range of measures could include

- Shuffling of compressors to match needs.
- Periodic review of insulation thickness
- Identify potential for heat exchanger networking and process integration.
- Optimisation of transformer operation with respect to load.

### 3.18 Fuel and Energy Substitution

#### Fuel substitution

Substituting existing fossil fuel with more efficient and less cost/less polluting fuel for instance natural gas, biogas and locally available agro-residues. Energy is an important input in the production. There are two ways to reduce energy dependency; energy conservation and substitution. Fuel substitution has taken place in all the major sectors of the Indian economy. Kerosene and Liquefied Petroleum Gas (LPG) have substituted soft coke in residential use.

### Few examples of fuel substitution

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

### Few examples of energy substitution

- Replacement of electric heaters by steam heaters
- Replacement of steam based hot water by solar systems

## 3.19 Energy Efficient Drives

Variable frequency drives are playing a big role in energy conservation and energy efficiency. It is based on the affinity law.

- $Q_1/Q_2 = N_1/N_2$ .
- $P_1/P_2 = (N_1/N_2)^3$
- $HP_1/HP_2 = (N_1/N_2)^3$
- N- SPEED (RPM). Q- VOLUME.
- P-PRESSURE. HP- HORSE POWER

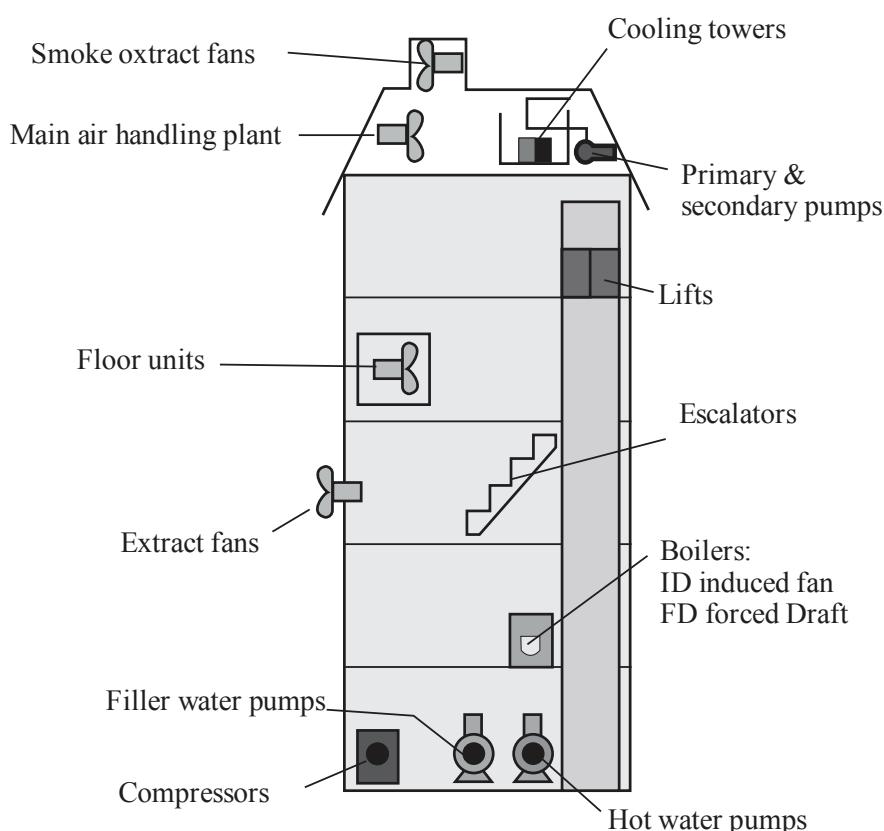


Fig. 3.5 Energy efficient drives group

- Air Extractors and Air Fans
- Cooling Towers
- All types of Pumps
- Compressors

- Mixing Plants
- Agitators and Homogenisers
- Lifts and Escalators

### 3.20 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:

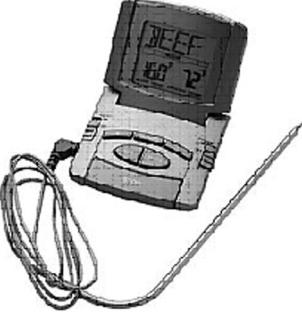
Basic Electrical Parameters in AC &DC systems – Voltage (V), Current (I), Power factor, Active power (kW), apparent power (demand) (kVA), Reactive power (kVAr), Energy consumption (kWh), Frequency (Hz), Harmonics, etc.

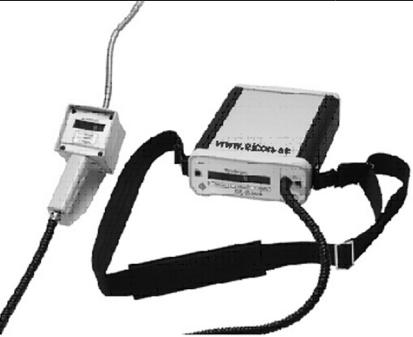
Parameters of importance other than electrical such as temperature & heat flow, radiation, air and gas flow, liquid flow, revolutions per minute (RPM), air velocity, noise and vibration, dust concentration, Total Dissolved Solids (TDS), pH, moisture content, relative humidity, flue gas analysis – CO<sub>2</sub>, O<sub>2</sub>, 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 familiarise themselves with the instruments and their operation prior to actual audit use.

 	<p><b>Electrical Measuring Instruments</b></p> <p>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.</p> <p>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.</p>
	<p><b>Combustion analyser</b></p> <p>This instrument has in-built chemical cells which measure various gases such as O<sub>2</sub>, CO, NOx and SOx.</p>
	<p><b>Fuel Efficiency Monitor</b></p> <p>This measures oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency.</p>

	<p><b>Fyrite</b> 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<sub>2</sub> and CO<sub>2</sub> measurement.</p>
	<p><b>Contact thermometer</b> 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.</p>
	<p><b>Infrared Thermometer</b> 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.</p>
	<p><b>Pitot Tube and manometer</b> Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows.</p>
	<p><b>Water flow meter</b> 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. Bureau of Energy Efficiency 79</p>

 <p><b>Tachometer</b></p>	 <p><b>Stroboscope</b></p>	<p><b>Speed Measurements</b></p> <p>In any audit exercise speed measurements are critical as they may change with frequency, belt slip and loading.</p> <p>A simple tachometer is a contact type instrument which can be used where direct access is possible.</p> <p>More sophisticated and safer ones are non contact instruments such as stroboscopes.</p>
		<p><b>Leak Detectors</b></p> <p>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.</p>
		<p><b>Lux meters</b></p> <p>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.</p>

**Table 3.9 Key instruments for energy audit**

### 3.21 Internal Energy Audit

The Bureau of Energy Efficiency (BEE) has listed certain designated industries where an external energy audit is mandatory. This means all these notified industries will have to get the audit done by accredited energy auditors and the report is to be submitted to the state authority and also to the BEE. As at present only big industries with high energy intensity are covered under the category of designated industries, the need for getting the energy audit done is absolutely essential for all the industries.

It is therefore necessary to have the internal energy auditors to be trained and they can in turn carryout the job with the help of a core team. Here the members from the core team will have to be drawn from different departments. In order to help carry out an internal energy audit, the following tips will be very useful.

#### Internal Energy Audit

Energy consumption registers.

Start from the raw materials arrivals to finished product despatch. Also consider

Energy needs of after sales service.

A.B.C. analysis more than 10% A2--10% Brest C items

#### Duties of the Internal Energy Auditor

- Identify and prioritisation of energy saving measures
- Analysis of technical & financial feasibility of energy saving measures

- Recommend Energy Efficient Technologies and Alternate Energy Sources
- Report writing, presentation and follow-up for implementation

#### **How energy conservation can be done**

- Establish core group
- This group must have multi -functional membership
- Remember it is for every employee
- Carry thorough energy audit
- Follow the guidelines as per following paragraphs

### **3.22 Electrical Energy**

#### **Electrical Substation**

- Study the basic data of distribution transformers
- Record maximum demand at various stages of production
- Study the main cable sizing

#### **Energy Audit**

- Thoroughly analyse items, study the production sequencing operations work out fixed energy needs
- Work out Variable Energy
- Study energy requirements per unit production in the last few years based on old data
- Break up energy needs in to various categories

#### **Fixed Energy Cost**

- Fixed energy cost is based on working pattern and hence it is necessary to study the possibility of changing the working pattern.
- Fixed energy consists of administration and allied buildings yard, lighting, housekeeping requirements, warehousing etc.

#### **Variable Energy Cost**

- Depends directly on production volumes product mix, type of products etc.
- Utilities are electricity, fuel, water, compressed air, inert gas, steam or hot water, chilled water or brine, hot oil, air cooling and conditioning

### **3.23 Electrical Substation**

- Check whether transformers are loaded at least to 80-85%
- When there are many transformers working in parallel there is good scope to switch off some during the lean period
- For essential lighting it is better to have a separate feeder and in large works, a separate transformer
- Normal iron losses are quite low but in case of doubt, it is preferred to carry out iron loss testing
- Capacitor banks at substation will reduce voltage drop
- Maintain pf around unity

### Normal no-load and full load loss of transformers

RATING	LOSS NL	LOSS FL
kVA	kW	kW
100	0.34	2.15
1000	1.75	13.5
10000	14.0	72.0

**Table 3.10 Normal no-load and full load loss of transformers**

### Prime Movers

- All big motors should run to around 85- 90% load if the load is variable then it is better to study idling time load variation etc. by fixing timers and meters.
- A capacitor for large motors is desirable.

### Minimum efficiency of motors

RATING kW	% EFFICIENCY
5	85
10	87
20	88
50	90
100	92
1000	95

**Table 3.11 Minimum efficiency of motors**

### Prime Movers

- If the motor is loaded to only 50% of the capacity, change the connection to star from delta.
- If smaller capacity motor is to be replaced then choose the highest efficiency motor.
- Where motors are idling for more than 50% the time energy saver is a must.
- Energy savers are star delta working base. Vfd are recommended if idling time is low but load is cyclic.

### Electrical Distribution

- Fix meters one very feeder
- Check cable sizing and loading
- Fix capacitors at feeder end
- Record consumption everyday or every shift
- Study the trend for few weeks

### Illumination

- As far as possible all work places should have maximum natural light
- For ac sheet roofing, provide some polycarbonate sheets for sunlight
- Paint walls white
- Use electronic ballasts for fluorescent tubes when total working hours are more than 2500/year.
- Use cfl wherever possible.
- For yard lighting, study the illumination needs and provide hpsl 70 watt lamps.

## Ventilation

- Unless otherwise specified, maximum cross ventilation is best.
- Use big ventilators instead of ceiling fans in work area.
- For ceiling fans in administrative blocks and offices use electronic regulators.

## 3.24 Compressed Air

- C.A. is used in many industries
- This is the area which has maximum conservation potential
- Study the c. a. needs and also the pressure requirements
- Check the c.a. piping design and capacity
- Periodic leakage testing is the right practice

## Kw requirement of compressors

Isothermal	minimum	expo 1.0
Adiabatic	maximum	expo 1.4
Polytropic	normal	expo 1.25

**Table 3.12 Kw requirement of compressors**

$$\text{power} = \frac{n}{n-1} \times q \times p \times (f^{\frac{1}{n}}) \times 100 \text{ kW}$$

Where,

$n = 1.25$   $q = \text{quantity in cum/sec}$ ,

$p = \text{pressure in bars (Normal 0.981)}$

$f = \text{Factor } p/p_1 \text{ to the power of } n - 1/n$

**Example:** 0.25cum/sec at 7 bars.

$$\frac{n}{n-1} = 5 \quad q = 0.25 \quad p = 7 \quad f = 1.4757$$

**Answer** = 58 kW ideal requirement

## How to test compressor capacity

Shut off valve between tank and compressor, start the compressor and let it attain full pressure. A standard orifice nozzle fixed on pipeline should be then opened fully. If the compressor maintains pressure the capacity is alright.

## How to test leaks

- Open the main valve to the tank and let it attain full pressure. Record the time till compressor restarts. Earlier it starts, more the leakage.
- Follow this pattern for other pipelines and tanks.
- Use Teflon tape for threaded joints. Braised or welded lines are better.
- Clean the air tanks thoroughly and observe everyday for oil leaks.
- At the delivery of compressor if oil is found, check piston rings and cylinder.

## 3.25 Oil Heaters and Boilers

- Checking combustion efficiency is by far the most important aspect
- Monitor exhaust gas analysis and also the flue gas temperature
- For better efficiency use recommended additives but check pH of additives
- For partial loads, make use of smaller capacity nozzles. This saves fuel (dual nozzles)
- Carryout oil testing periodically

- Clean coils periodically
- Preheat inlet air for oil heaters
- Choose oil temp 20°-30°C above maximum required temperature

### **Insulation**

- All hot oil lines including even valves should be insulated
- Reactor tops should also be insulated
- Periodic pressure testing is the best practice

### **Instrumentation**

- As far as possible make use of digital meters
- For better control, microprocessors are best suited than on—off controllers
- A fail safe system should be an integral part of the instruments
- Never forget that only instrumentation will not always prevent accidents
- The human factor and control are important aspects and that is why thorough training is necessary

## **3.26 Energy Conservation**

- Cost benefit analysis
- Pay back period working. If more than four years then sensitivity analysis is must
- Sensitivity analysis
- Energy policy should be apart of the ems and qms policy
- Must have full support of top management
- It is a continual programme
- Periodic review and corrective preventive action plan is a must
- Benchmarking must for competitive business
- Suggestion scheme part of EC
- Use of non- conventional energy should be considered

## **3.27 Heat Recovery**

- Boilers DG set; oil heaters are the sources and thorough study to be carried out for possible recovery.
- Use of exhaust heat for absorption refrigeration to be considered.
- Hot water from DG cooling could be utilised if required by some processes.
- Exhaust gas can be used for preheating thick oil like furnace oil and lshs.
- Exhaust gas can be used for combustion air preheating.
- Preheated air can be used as heating source for some processes

## **Summary**

- Energy management is the efficient and effective use of energy to maximize profits or maximise costs and enhance competitive positions.
- The objective of Energy Management is also to achieve and maintain optimum energy procurement and utilisation, throughout the organisation and to minimise energy costs / waste without affecting production & quality and to minimise environmental effects.
- Energy management involve a combination of both managerial and technical skills.
- Energy management should be seen as a continuous process. Strategies should be reviewed annually and revised as necessary.
- Energy audit is the key to a systematic approach for decision-making in the area of energy management. It quantifies energy usage according to its discrete functions.
- Type of energy audit to be performed depends on: Function and type of industry; Depth to which the final audit is needed, and Potential and magnitude of cost reduction desired.
- Energy Audit can be classified into the following two types: Preliminary Audit and Detailed Audit.
- Industry-to-industry, the methodology of Energy Audits needs to be flexible. A comprehensive ten-step methodology for conduct of energy audit at field level are listed.
- The important feature of energy conservation and efficiency is that of energy audit.
- The importance of carrying out an internal energy audit is explained with practical tips for carrying out the energy audit.
- Identifying Efficiency opportunities network such as transformers, cables, switchgears and power factor improvement in electrical systems and chilled water, cooling water, hot water, compressed air, etc.
- Audit energy manager/energy auditor should report to the top management for effective communication and implementation with a typical format for reporting.
- Understanding energy cost is vital factor for awareness creation and saving calculation.
- make out electrical utilities & their basic principle and understand their operation.
- Benchmarking of energy consumption internally (historical / trend analysis) and externally (across similar industries) are two powerful tools for performance assessment and logical evolution of avenues for improvement.
- The benchmark parameters can be gross production related and equipment / utility related.
- Plant energy performance monitoring compares plant energy use at a reference year with the subsequent years to determine the improvement that has been made.
- Production factor is used to determine the energy that would have been required to produce this year's production output if the plant had operated in the same way as it did in the reference year.
- The reference year's energy use that would have been used to produce the current year's production output may be called the "reference year energy use equivalent" or "reference year equivalent" for short.
- Energy is an important input in the production. There are two ways to reduce energy dependency; energy conservation and substitution.
- The operating instructions for all instruments must be understood and staff should familiarise themselves with the instruments and their operation prior to actual audit use.

## **References**

- Energy Conservation, Efficiency& Energy Audit [Pdf] Available at: <<http://www.energymanagertraining.com/Journal/04102006/EnergyConservation,Efficiency&EnergyAudit.pdf>> [Accessed 5 July 2013].
- Capehart, B.L., Wayne, C.T., and Kennedy, W.J., 2008. Guide to Energy Management. The Fairmont Press, Inc.
- Beggs, C., 2009. Energy: Management, Supply and Conservation. Elsevier Ltd.

- Energy Audits - Energy Consultants - Energy Management Consultants - Global Green Consultancy [Video online] Available at: <<http://www.youtube.com/watch?v=sFIL2CRoSAg>> [Accessed 5 July 2013].
- ISO 50000 Energy Management Systems Auditor Training Course [Video online] Available at: <<http://www.youtube.com/watch?v=sDfLBL0l7BQ>> [Accessed 5 July 2013].
- BSR- Energy Management handbook [Pdf] Available at: <<http://www.bsr.org/reports/bsr-energy-management-handbook.pdf>> [Accessed 5 July 2013].
- Capehart, B.L., Wayne, C.T., and Kennedy, W.J., 2008. Guide to Energy Management. The Fairmont Press, Inc.
- Beggs, C., 2009. Energy: Management, Supply and Conservation. Elsevier Ltd.
- Energy Audits - Energy Consultants - Energy Management Consultants - Global Green Consultancy [Video online] Available at: <<http://www.youtube.com/watch?v=sFIL2CRoSAg>> [Accessed 5 July 2013].
- ISO 50000 Energy Management Systems Auditor Training Course [Video online] Available at: <<http://www.youtube.com/watch?v=sDfLBL0l7BQ>> [Accessed 5 July 2013].

## Recommended Readings

- Doty, S. and Turner, W.C., 2009. Energy management handbook. The Fairmont Press, Inc.
- Thumann, A., Younger, W.J. and Niehus, T., 2009. Handbook of Energy Audits. The Fairmount Press, Inc.
- Jayamaha, L., 2006. Energy-efficient building systems: green strategies for operation and maintenance. The McGraw-Hill Companies, Inc.

## Self Assessment

1. \_\_\_\_\_ is the key to a systematic approach for decision-making in the area of energy management.
  - a. Audit Phase
  - b. Energy Audit
  - c. Pre audit phase
  - d. Conduct survey and monitoring
  
2. \_\_\_\_\_ is a Japanese concept which is widely adopted in many big industries.
  - a. TAIKEN
  - b. KAIZEN
  - c. TAWKEI
  - d. KAWKEN
  
3. \_\_\_\_\_ is used to determine the energy that would have been required to produce this year's production output if the plant had operated in the same way as it did in the reference year.
  - a. Plant energy factor
  - b. Power factor
  - c. Production factor
  - d. Reference year energy
  
4. Reference year equivalent = Reference year energy use x \_\_\_\_\_.
  - a. plant energy factor
  - b. power factor
  - c. production factor
  - d. reference year energy
  
5. Which of the following is false?
  - a. There are two ways to reduce energy dependency; energy conservation and substitution.
  - b. Kerosene and Liquefied Petroleum Gas (LPG) have substituted soft coke in residential use.
  - c. The energy performance is the percentage of energy saved at the current rate of use compared to the reference year rate of use. The greater the improvement, the higher the number will be.
  - d. Detailed energy auditing is carried out in two phases.
  
6. Which of the following is false?
  - a. A structured methodology to carry out an energy audit is necessary for efficient working.
  - b. An initial site visit may take one day and gives the Energy Auditor/Engineer an opportunity to meet the personnel concerned, to familiarize him with the site and to assess the procedures necessary to carry out the energy audit.
  - c. The audit report will include a description of energy inputs and product outputs by major department or by major processing function, and will evaluate the efficiency of each step of the manufacturing process.
  - d. Process analysis is not a useful tool for process integration measures.

7. Match the following

1. Plant energy performance is related with	a. Reference year energy
2. Production factor is related with	b. LPG, Kerosene
3. Current years production is related with	c. Reference year's equivalent
4. Example of Fuel substitution is related with	d. Production factor

a. 1-c, 2-a, 3-d, 4-b

b. 1-b, 2-d, 3-a, 4-c

c. 1-d, 2-c, 3-b, 4-a

d. 1-d, 2-a, 3-b, 4-a

8. Which gas can be used for preheating thick oil like furnace oil and lshs?

a. Exhaust

b. Methane

c. Ethane

d. Butane

9. Which is the key to a systematic approach for decision-making in the area of energy management?

a. Audit Phase

b. Energy Audit

c. pre audit phase

d. Conduct survey and monitoring

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

a. Plant energy factor

b. Power factor

c. Production factor

d. Reference year energy

# **Chapter IV**

## **Material and Energy Balance**

### **Aim**

The aim of this chapter is to:

- explicate the need for material and energy balance
- elucidate the basics of flow chart development
- explain various energy system

### **Objectives**

The objectives of this chapter are to:

- explain the fundamental law of mass and energy conservation
- analyse the material balance equation
- enlist the difference between units, values and dimensions

### **Learning outcome**

At the end of this chapter you will be able to:

- understand Sankey diagram and its uses
- recognise the method for preparing a flow chart
- recognise the energy use in closed and open systems

## 4.1 Introduction

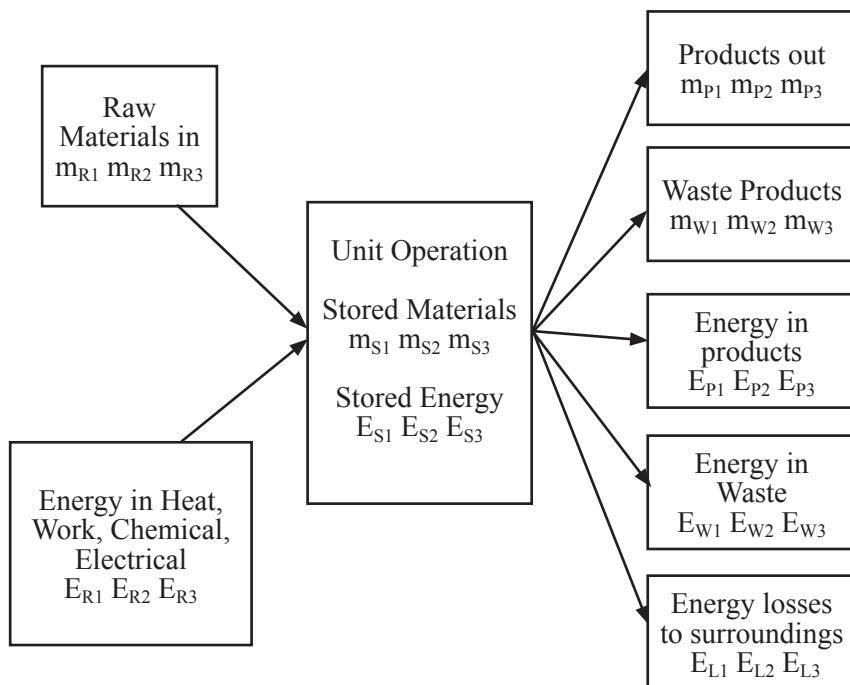
Material quantities, as they pass through processing operations, can be described by material balances. Such balances are statements on the conservation of mass. Similarly, energy quantities can be described by energy balances, which are statements on the conservation of energy. If there is no accumulation, what goes into a process must come out. This is true for batch operation. It is equally true for continuous operation over any chosen time interval. Material and energy balances are very important in an industry. Material balances are fundamental to the control of processing, particularly in the control of yields of the products.

The first material balances are determined in the exploratory stages of a new process, improved during pilot plant experiments when the process is being planned and tested, checked out when the plant is commissioned and then refined and maintained as a control instrument as production continues. When any changes occur in the process, the material balance needs to be determined again. The increasing cost of energy has caused the industries to examine means of reducing energy consumption in processing. Energy balances are used in the examination of the various stages of a process, over the whole process and even extending over the total production system from the raw material to the finished product.

Material and energy balances can be simple, at times they can be very complicated, but the basic approach is general. Experience in working with the simpler systems such as individual unit operations will develop the facility to extend the methods to the more complicated situations, which do arise. The increasing availability of computers has meant that very complex mass and energy balances can be set up and manipulated quite readily and therefore used in everyday process management to maximise product yields and minimise costs.

## 4.2 Basic Principles

If the unit operation, whatever its nature is seen as a whole it may be represented diagrammatically as a box, as shown in Fig. 4. 1. The mass and energy going into the box must balance with the mass and energy coming out.



**Fig. 4.1 Mass and energy balance**

The law of conservation of mass leads to what is called a mass or a material balance.

$$\text{Mass In} = \text{Mass Out} + \text{Mass Stored}$$

$$\text{Raw Materials} = \text{Products} + \text{Wastes} + \text{Stored Materials}$$

$$\Sigma m_R = \Sigma m_p + \Sigma m_w + \Sigma m_s$$

(Where,  $\Sigma$  (sigma) denotes the sum of all terms)

$$\Sigma m_R = \Sigma m_{R1} + \Sigma m_{R2} + \Sigma m_{R3} = \text{Total Raw Materials}$$

$$\Sigma m_p = \Sigma m_{p1} + \Sigma m_{p2} + \Sigma m_{p3} = \text{Total Products}$$

$$\Sigma m_w = \Sigma m_{w1} + \Sigma m_{w2} + \Sigma m_{w3} = \text{Total Waste Products}$$

$$\Sigma m_s = \Sigma m_{s1} + \Sigma m_{s2} + \Sigma m_{s3} = \text{Total Stored Products}$$

If there are no chemical changes occurring in the plant, the law of conservation of mass will apply also to each component, so that for component A:

$$m_A \text{ in entering materials} = m_A \text{ in the exit materials} + m_A \text{ stored in plant.}$$

Example, in a plant that is producing sugar, if the total quantity of sugar going into the plant is not equalled by the total of the purified sugar and the sugar in the waste liquors, then there is something wrong. Sugar is either being burned (chemically changed) or accumulating in the plant or else it is going unnoticed down the drain somewhere.

In this case;

$$M_A = (m_{AP} + m_{AW} + m_{AU})$$

Where,

$m_{AU}$  is the unknown loss and needs to be identified.

So the material balance is now:

$$\text{Raw Materials} = \text{Products} + \text{Waste Products} + \text{Stored Products} + \text{Losses}$$

Where, Losses are the unidentified materials.

Just as mass are conserved, so are energy conserved in food-processing operations. The energy coming into a unit operation can be balanced with the energy coming out and the energy stored.

$$\text{Energy In} = \text{Energy Out} + \text{Energy Stored}$$

$$\Sigma E_R = \Sigma E_p + \Sigma E_w + \Sigma E_L + \Sigma E_s$$

Where,

$$\Sigma E_R = E_{R1} + E_{R2} + E_{R3} + \dots = \text{Total Energy Entering}$$

$$\Sigma E_p = E_{p1} + E_{p2} + E_{p3} + \dots = \text{Total Energy Leaving with Products}$$

$$\Sigma E_w = E_{w1} + E_{w2} + E_{w3} + \dots = \text{Total Energy Leaving with Waste Materials}$$

$$\Sigma E_L = E_{L1} + E_{L2} + E_{L3} + \dots = \text{Total Energy Lost to Surroundings}$$

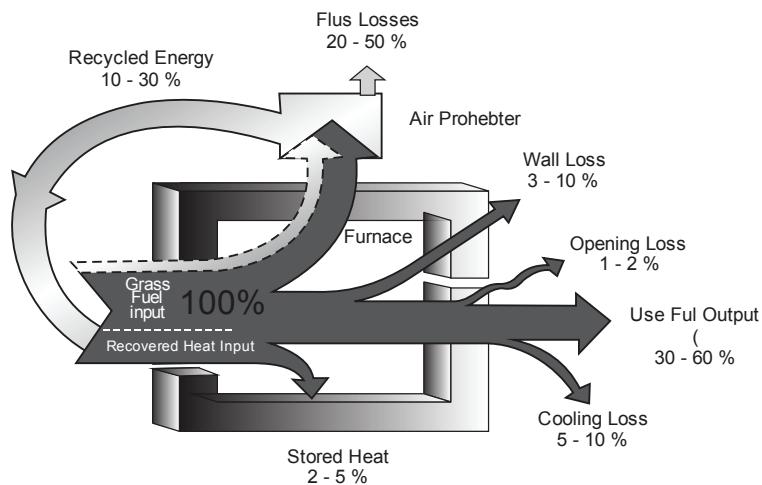
$$\Sigma E_s = E_{s1} + E_{s2} + E_{s3} + \dots = \text{Total Energy Stored}$$

Energy balances are often complicated because forms of energy can be interconverted, for example mechanical energy to heat energy, but overall the quantities must balance.

### 4.3 The Sankey Diagram and its Use

The Sankey diagram is very useful tool to represent an entire input and output energy flow in any energy equipment or system such as boiler generation, fired heaters, furnaces after carrying out energy balance calculation. This diagram represents visually various outputs and losses so that energy managers can focus on finding improvements in a prioritized manner.

The Sankey diagram is quite an old concept and is being used for several years, especially in thermal energy systems. This is the simplest way of expressing various components of input and output.

**Fig. 4.2 Energy balance for a re-heating furnace****Example**

The Fig. 4.2 shows a Sankey diagram for a reheating furnace. From the Fig. 4.2, it is clear that exhaust flue gas losses are a key area for priority attention.

Since the furnaces operate at high temperatures, the exhaust gases leave at high temperatures resulting in poor efficiency. Hence a heat recovery device such as air pre heater has to be necessarily part of the system. The lower the exhaust temperature, higher is the furnace efficiency.

## 4.4 Material Balances

The first step is to look at the three basic categories;

- materials in
- materials out
- materials stored

Then the materials in each category have to be considered whether they are to be treated as a whole, a gross mass balance, or whether various constituents should be treated separately and if so what constituents. To take a simple example, it might be to take dry solids as opposed to total material; this really means separating the two groups of constituents, non-water and water. More complete dissection can separate out chemical types such as minerals, or chemical elements such as carbon. The choice and the detail depend on the reasons for making the balance and on the information that is required. A major factor in industry is, of course, the value of the materials and so expensive raw materials are more likely to be considered than cheaper ones, and products than waste materials.

**Basis and Units**

Having decided which constituents need consideration, the basis for the calculations has to be decided. This might be some mass of raw material entering the process in a batch system, or some mass per hour in a continuous process. It could be: some mass of a particular predominant constituent, for example mass balances in a bakery might be all related to 100 kg of flour entering; or some unchanging constituent, such as in combustion calculations with air where it is helpful to relate everything to the inert nitrogen component; or carbon added in the nutrients in a fermentation system because the essential energy relationships of the growing micro-organisms are related to the combined carbon in the feed; or the essentially inert non-oil constituents of the oilseeds in an oil-extraction process. Sometimes it is unimportant what basis is chosen and in such cases a convenient quantity such as the total raw materials into one batch or passed in per hour to a continuous process is often selected. Having selected the basis, then the units may be chosen such as mass, or concentrations which can be by weight or can be molar if reactions are important.

## Total mass and composition

Material balances can be based on total mass, mass of dry solids, or mass of particular components, for example protein.

### Example: Constituent balance

Skim milk is prepared by the removal of some of the fat from whole milk. This skim milk is found to contain 90.5% water, 3.5% protein, 5.1% carbohydrate, 0.1% fat and 0.8% ash. If the original milk contained 4.5% fat, calculate its composition assuming that fat only was removed to make the skim milk and that there are no losses in processing.

Basis: 100 kg of skim milk.

This contains, therefore, 0.1 kg of fat. Let the fat which was removed from it to make skim milk be  $x$  kg.

$$\text{Total original fat} = (x + 0.1) \text{ kg}$$

$$\text{Total original mass} = (100 + x) \text{ kg}$$

and as it is known that the original fat content was 4.5% so

$$(x + 0.1) / (100 + x) = 0.045$$

Where,

$$= x + 0.1 = 0.045(100 + x)$$

$$x = 4.6 \text{ kg}$$

So the composition of the whole milk is then fat = 4.5%, water =  $90.5/104.6 = 86.5\%$ , protein =  $3.5/104.6 = 3.3\%$ , carbohydrate =  $5.1/104.6 = 4.9\%$  and ash = 0.8%

## Concentrations

Concentrations can be expressed in many ways: weight/ weight (w/w), weight/volume (w/v), molar concentration (M), mole fraction. The weight/weight concentration is the weight of the solute divided by the total weight of the solution and this is the fractional form of the percentage composition by weight. The weight volume concentration is the weight of solute in the total volume of the solution. The molar concentration is the number of molecular weights of the solute expressed in kg in 1 m<sup>3</sup> of the solution. The mole fraction is the ratio of the number of moles of the solute to the total number of moles of all species present in the solution. Notice that in process engineering, it is usual to consider kg moles and in this chapter the term mole means a mass of the material equal to its molecular weight in kilograms. In this chapter percentage signifies percentage by weight (w/w) unless otherwise specified.

### Example of concentrations:

#### Concentrations

A solution of common salt in water is prepared by adding 20 kg of salt to 100 kg of water, to make a liquid of density 1323 kg/m<sup>3</sup>. Calculate the concentration of salt in this solution as a

weight fraction

weight/volume fraction

mole fraction

molal concentration.

#### a. Weight fraction

$$20 / (100 + 20) = 0.167: \% \text{ weight / weight} = 16.7\%$$

#### b. Weight/volume

A density of 1323kg/m<sup>3</sup> means that 1m<sup>3</sup> of solution weighs 1323kg, but 1323kg of salt solution contains  $(20 \times 1323 \text{ kg of salt}) / (100 + 20) = 220.5 \text{ kg salt / m}^3$

1 m<sup>3</sup> solution contains 220.5 kg salt.

$$\text{Weight/volume fraction} = 220.5 / 1000 = 0.2205$$

And so weight / volume = 22.1%

#### c. Moles of water = $100 / 18 = 5.56$

$$\text{Moles of salt} = 20 / 58.5 = 0.34$$

Mole fraction of salt =  $0.34 / (5.56 + 0.34) = 0.058$

The molar concentration (M) is  $220.5 / 58.5 = 3.77$  moles in  $\text{m}^3$

Note that the mole fraction can be approximated by the (moles of salt/moles of water) as the numbers of moles of water are dominant, that is the mole fraction is close to  $0.34 / 5.56 = 0.061$ . As the solution becomes more dilute, this approximation improves and generally for dilute solutions the mole fraction of solute is a close approximation to the moles of solute / moles of solvent.

In solid / liquid mixtures of all these methods can be used but in solid mixtures the concentrations are normally expressed as simple weight fractions.

With gases, concentrations are primarily measured in weight concentrations per unit volume, or as partial pressures. These can be related through the gas laws. Using the gas law in the form:

$$pV = nRT$$

where, p is the pressure, V the volume, n the number of moles, T the absolute temperature, and R the gas constant which is equal to  $0.08206 \text{ m}^3 \text{ atm} / \text{mole K}$ , the molar concentration of a gas is then

$$n / V = p/RT$$

and the weight concentration is then  $n M/V$  where M is the molecular weight of the gas.

The SI unit of pressure is the  $\text{N}/\text{m}^2$  called the Pascal (Pa). As this is of inconvenient size for many purposes, standard atmospheres (atm) are often used as pressure units, the conversion being  $1 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$ , or very nearly  $1 \text{ atm} = 100 \text{ kPa}$ .

### Example of air composition:

#### Air Composition

If air consists of 77% by weight of nitrogen and 23% by weight of oxygen calculate:

- the mean molecular weight of air
- the mole fraction of oxygen
- the concentration of oxygen in  $\text{mole}/\text{m}^3$  and  $\text{kg}/\text{m}^3$  if the total pressure is 1.5 atmospheres and the temperature is  $25^\circ\text{C}$ .

#### a. Taking the basis of 100 kg of air: it contains 77/28 moles of $\text{N}_2$ and 23/32 moles of $\text{O}_2$

Total number of moles =  $2.75 + 0.72 = 3.47$  moles.

So mean molecular weight of air =  $100 / 3.47 = 28.8$

Mean molecular weight of air = 28.8

#### b. The mole fraction of oxygen = $0.72 / (2.75 + 0.72) = 0.72 / 3.47 = 0.21$

Mole fraction of oxygen = 0.21

#### c. In the gas equation, where n is the number of moles present: the value of R is $0.08206 \text{ m}^3 \text{ atm}/\text{mole K}$ and at a temperature of $25^\circ\text{C} = 25 + 273 = 298 \text{ K}$ , and where $V = 1 \text{ m}^3$ $pV = nRT$ and so, $1.5 \times 1 = n \times 0.08206 \times 298$

$n = 0.061 \text{ mole}/\text{m}^3$

weight of air =  $n \times \text{mean molecular weight}$

=  $0.061 \times 28.8 = 1.76 \text{ kg}/\text{m}^3$

and of this 23% is oxygen, so weight of oxygen =  $0.23 \times 1.76 = 0.4 \text{ kg}$  in  $1 \text{ m}^3$

Concentration of oxygen =  $0.4 \text{ kg}/\text{m}^3$

or  $0.4 / 32 = 0.013 \text{ mole}/\text{m}^3$

When a gas is dissolved in a liquid, the mole fraction of the gas in the liquid can be determined by first calculating the number of moles of gas using the gas laws, treating the volume as the volume of the liquid, and then calculating the number of moles of liquid directly.

### Example of gas composition:

#### Gas composition

In the carbonation of a soft drink, the total quantity of carbon dioxide required is the equivalent of 3 volumes of gas to one volume of water at  $0^\circ\text{C}$  and atmospheric pressure. Calculate

- a. the mass fraction and
- b. the mole fraction of the CO<sub>2</sub> in the drink, ignoring all components other than CO<sub>2</sub> and water.

Basis 1 m<sup>3</sup> of water = 1000 kg

Volume of carbon dioxide added = 3 m<sup>3</sup>

From the gas equation, pV = nRT

$$1 \times 3 = n \times 0.08206 \times 273$$

$$n = 0.134 \text{ mole.}$$

Molecular weight of carbon dioxide = 44

And so weight of carbon dioxide added = 0.134 × 44 = 5.9 kg per 1000 kg of water.

$$\text{a. Mass fraction of carbon dioxide in drink} = 5.9 / (1000 + 5.9) = 5.9 \times 10^{-3}$$

$$\text{b. Mole fraction of carbon dioxide in drink} = 0.134 / (1000/18 + 0.134) = 2.41 \times 10^{-3}$$

## 4.5 Types of Process Situations

### Continuous processes

In continuous processes, time also enters into consideration and the balances are related to unit time. Thus in considering a continuous centrifuge separating whole milk into skim milk and cream, if the material holdup in the centrifuge is constant both in mass and in composition, then the quantities of the components entering and leaving in the different streams in unit time are constant and a mass balance can be written on this basis. Such an analysis assumes that the process is in a steady state, that is flows and quantities held up in vessels do not change with time.

### Example

Balance across equipment in continuous centrifuging of milk

If 35,000kg of whole milk containing 4% fat is to be separated in a 6 hour period into skim milk with 0.45% fat and cream with 45% fat, what are the flow rates of the two output streams from a continuous centrifuge which accomplishes this separation?

Basis 1 hour's flow of whole milk

### Mass in

Total mass = 35000/6 = 5833 kg.

Fat = 5833 × 0.04 = 233 kg.

And so Water plus solids-not-fat = 5600 kg.

### Mass out

Let the mass of cream be x kg then its total fat content is 0.45x. The mass of skim milk is (5833 - x) and its total fat content is 0.0045 (5833 - x)

### Material balance on fat

Fat in = Fat out

$$5833 \times 0.04 = 0.0045(5833 - x) + 0.45x. \text{ and so } x = 465 \text{ kg.}$$

So that the flow of cream is 465 kg / hr and skim milk (5833 - 465) = 5368 kg/hr

The time unit has to be considered carefully in continuous processes as normally such processes operate continuously for only part of the total factory time. Usually there are three periods, start up, continuous processing (so-called steady state) and close down, and it is important to decide what material balance is being studied. Also the time interval over which any measurements are taken must be long enough to allow for any slight periodic or chance variation. In some instances a reaction takes place and the material balances have to be adjusted accordingly. Chemical changes can take place during a process, for example bacteria may be destroyed during heat processing, sugars may combine with amino acids, fats may be hydrolysed and these affect details of the material balance. The total mass of the system will remain the same but the constituent parts may change, for example in browning the sugars may reduce but browning compounds will increase.

### Blending

Another class of situations which arise are blending problems in which various ingredients are combined in such proportions as to give a product of some desired composition. Complicated examples, in which an optimum or best

achievable composition must be sought, need quite elaborate calculation methods, such as linear programming, but simple examples can be solved by straightforward mass balances.

### Drying

In setting up a material balance for a process a series of equations can be written for the various individual components and for the process as a whole. In some cases where groups of materials maintain constant ratios, then the equations can include such groups rather than their individual constituents. Example in drying vegetables the carbohydrates, minerals, proteins etc., can be grouped together as ‘dry solids’, and then only dry solids and water need be taken, through the material balance.

#### Example of drying yield:

##### Drying Yield

Potatoes are dried from 14% total solids to 93% total solids. What is the product yield from each 1000 kg of raw potatoes assuming that 8% by weight of the original potatoes is lost in peeling?

Basis 1 000kg potato entering

As 8% of potatoes are lost in peeling, potatoes to drying are 920 kg, solids 129 kg

Mass in (kg)	Mass out (kg)
Potato solids 140 kg	Dried product 92
Water 860 kg	Potato solids 140 <del>XX</del> (92/100)
	=129 kg
	Associated water 10 kg
	Total product 139 kg
	Losses
	Peelings-potato
	Solids 11 kg
	Water 69 kg
	Water evaporated 781 kg
	Total losses 861 kg
	Total 1000 kg
	Product yield = 139/1000 = 14%

Often it is important to be able to follow particular constituents of the raw material through a process. This is just a matter of calculating each constituent

## 4.6 Energy Balances

Energy takes many forms, such as heat, kinetic energy, chemical energy, potential energy but because of inter conversions it is not always easy to isolate separate constituents of energy balances. However, under some circumstances certain aspects predominate. In many heat balances in which other forms of energy are insignificant; in some chemical situations mechanical energy is insignificant and in some mechanical energy situations, as in the flow of fluids in pipes, the frictional losses appear as heat but the details of the heating need not be considered. We are seldom concerned with internal energies.

Therefore practical applications of energy balances tend to focus on particular dominant aspects and so a heat balance, for example, can be a useful description of important cost and quality aspects of process situation. When unfamiliar with the relative magnitudes of the various forms of energy entering into a particular processing situation, it is wise to put them all down. Then after some preliminary calculations, the important ones emerge and other minor ones can be lumped together or even ignored without introducing substantial errors. With experience, the obviously minor ones can perhaps be left out completely though this always raises the possibility of error.

Energy balances can be calculated on the basis of external energy used per kilogram of product, or raw material processed, or on dry solids or some key component. The energy consumed in food production includes direct energy which is fuel and electricity used on the farm, and in transport and in factories, and in storage, selling, etc.; and indirect energy which is used to actually build the machines, to make the packaging, to produce the electricity and the oil and so on. Food itself is a major energy source, and energy balances can be determined for animal or human feeding; food energy input can be balanced against outputs in heat and mechanical energy and chemical synthesis.

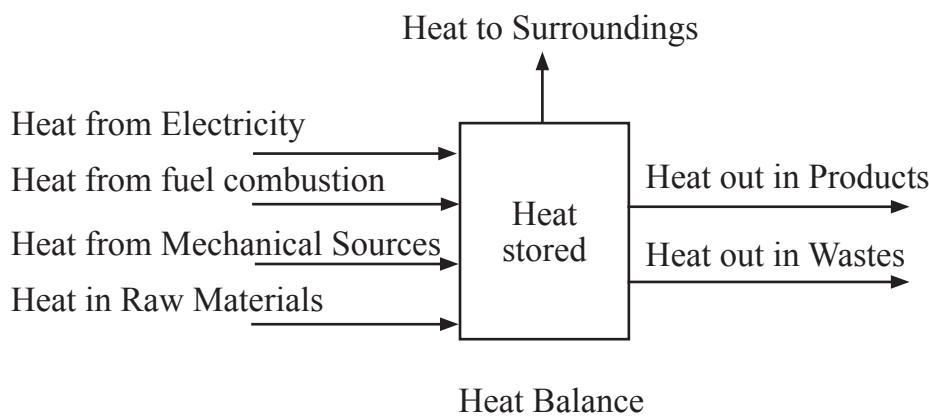
In the SI system there is only one energy unit, the joule. However, kilocalories are still used by some nutritionists and British thermal units (Btu) in some heat-balance work.

The two applications used in this chapter are heat balances, which are the basis for heat transfer, and the energy balances used in analysing fluid flow.

### Heat Balances

The most common important energy form is heat energy and the conservation of this can be illustrated by considering operations such as heating and drying. In these, enthalpy (total heat) is conserved and as with the mass balances so enthalpy balances can be written round the various items of equipment or process stages, or round the whole plant, and it is assumed that no appreciable heat is converted to other forms of energy such as work.

Enthalpy (H) is always referred to some reference level or datum, so that the quantities are relative to this datum. Working out energy balances is then just a matter of considering the various quantities of materials involved, their specific heats, and their changes in temperature or state (as quite frequently latent heats arising from phase changes are encountered). Fig. 4.3 illustrates the heat balance.



**Fig. 4.3 Heat balance**

- Heat is absorbed or evolved by some reactions in processing but usually the quantities are small when compared with the other forms of energy entering into food processing such as sensible heat and latent heat.
- Latent heat is the heat required to change, at constant temperature, the physical state of materials from solid to liquid, liquid to gas, or solid to gas.
- Sensible heat is that heat which when added or subtracted from materials changes their temperature and thus can be sensed.
- The units of specific heat are J/kg K and sensible heat change is calculated by multiplying the mass by the specific heat by the change in temperature, ( $m \times c \times \Delta T$ ).
- The units of latent heat are J/kg and total latent heat change is calculated by multiplying the mass of the material, which changes its phase by the latent heat.
- Having determined those factors that are significant in the overall energy balance, the simplified heat balance can then be used with confidence in industrial energy studies.
- Such calculations can be quite simple and straight forward but they give a quantitative feeling for the situation and can be of great use in design of equipment and process.

### Example of dryer heat balance:

#### Dryer heat balance

A textile dryer is found to consume 4 m<sup>3</sup>/hr of natural gas with a calorific value of 800 kJ/mole. If the throughput of the dryer is 60 kg of wet cloth per hour, drying it from 55% moisture to 10% moisture, estimate the overall thermal efficiency of the dryer taking into account the latent heat of evaporation only.

60 kg of wet cloth contains

$60 \times 0.55$  kg water = 33 kg moisture and  $60 \times (1-0.55) = 27$  kg bone dry cloth.

As the final product contains 10% moisture, the moisture in the product is  $27/9 = 3$  kg

And so Moisture removed / hr =  $33 - 3 = 30$  kg/hr

Latent heat of evaporation = 2257 kJ/K

Heat necessary to supply =  $30 \times 2257 = 6.8 \times 104$  kJ/hr

Assuming the natural gas to be at standard temperature and pressure at which 1 mole occupies 22.4 litres

Rate of flow of natural gas =  $4 \text{ m}^3/\text{hr} = (4 \times 1000)/22.4 = 179$  moles/hr

Heat available from combustion =  $179 \times 800 = 14.3 \times 104$  kJ/hr

Approximate thermal efficiency of dryer = heat needed / heat used

$$= 6.8 \times 104 / 14.3 \times 104 = 48\%$$

To evaluate this efficiency more completely it would be necessary to take into account the sensible heat of the dry cloth and the moisture, and the changes in temperature and humidity of the combustion air, which would be combined with the natural gas. However, as the latent heat of evaporation is the dominant term the above calculation gives a quick estimate and shows how a simple energy balance can give useful information.

Similarly energy balances can be carried out over thermal processing operations, and indeed any processing operations in which heat or other forms of energy are used.

### Example

#### Autoclave heat balance in canning

An autoclave contains 1000 cans of pea soup. It is heated to an overall temperature of  $100^\circ\text{C}$ . If the cans are to be cooled to  $40^\circ\text{C}$  before leaving the autoclave, how much cooling water is required if it enters at  $15^\circ\text{C}$  and leaves at  $35^\circ\text{C}$ ?

The specific heats of the pea soup and the can metal are respectively  $4.1 \text{ kJ/kg}^\circ\text{C}$  and  $0.50 \text{ kJ/kg}^\circ\text{C}$ . The weight of each can is 60g and it contains 0.45 kg of pea soup.

Assume that the heat content of the autoclave walls above  $40^\circ\text{C}$  is  $1.6 \times 104$  kJ and that there is no heat loss through the walls.

Let  $w$  = the weight of cooling water required; and the datum temperature be  $40^\circ\text{C}$ , the temperature of the cans leaving the autoclave.

#### Heat entering

Heat in cans = weight of cans  $\times$  specific heat  $\times$  temperature above datum

$$= 1000 \times 0.06 \times 0.50 \times (100-40) \text{ kJ} = 1.8 \times 10^3 \text{ kJ}$$

Heat in can contents = weight pea soup  $\times$  specific heat  $\times$  temperature above datum

$$= 1000 \times 0.45 \times 4.1 \times (100 - 40) = 1.1 \times 10^5 \text{ kJ}$$

Heat in water = weight of water  $\times$  specific heat  $\times$  temperature above datum

$$= w \times 4.186 \times (15-40)$$

$$= -104.6 w \text{ kJ.}$$

#### Heat leaving

Heat in cans =  $1000 \times 0.06 \times 0.50 \times (40-40)$  (cans leave at datum temperature) = 0

Heat in can contents =  $1000 \times 0.45 \times 4.1 \times (40-40) = 0$

Heat in water =  $w \times 4.186 \times (35-40) = -20.9 w$

#### Heat-energy balance of cooling process; $40^\circ\text{C}$ as datum line

Heat Entering (kJ)		Heat Leaving (kJ)	
Heat in cans	1800	Heat in cans	0
Heat in can contents	110000	Heat in can contents	0
Heat in autoclave wall	16000	Heat in autoclave wall	0
Heat in water	-104.6 w	Heat in water	-20.9 W
Total heat entering	$127.800 - 104.6 w$	Total heat leaving	-20.9 W

	Total heat entering = Total heat leaving	
	$127800 - 104.6 \text{ w} = -20.9 \text{ w}$	
	$w = 1527 \text{ kg}$	

**Table 4.1 Heat-energy balance of cooling process**

Amount of cooling water required = 1527 kg.

## 4.7 Other Forms of Energy

- Motor power is usually derived, in factories, from electrical energy but it can be produced from steam engines or waterpower.
- The electrical energy input can be measured by a suitable wattmeter, and the power used in the drive estimated.
- There are always losses from the motors due to heating, friction and wind-age; the motor efficiency, which can normally be obtained from the motor manufacturer, expresses the proportion (usually as a percentage) of the electrical input energy, which emerges usefully at the motor shaft and so is available.
- When considering movement, whether of fluids in pumping, of solids in solids handling, or of foodstuffs in mixers; the energy input is largely mechanical.
- The flow situations can be analysed by recognising the conservation of total energy whether as energy of motion, or potential energy such as pressure energy, or energy lost in friction.
- Similarly, chemical energy released in combustion can be calculated from the heats of combustion of the fuels and their rates of consumption.
- Eventually energy emerges in the form of heat and its quantity can be estimated by summing the various sources.

### Example

#### Refrigeration load

It is desired to freeze 10,000 loaves of bread each weighing 0.75 kg from an initial room temperature of 18°C to a final temperature of -18°C. The bread-freezing operation is to be carried out in an air-blast freezing tunnel. It is found that the fan motors are rated at a total of 80 horsepower and measurements suggest that they are operating at around 90% of their rating, under which conditions their manufacturer's data claims a motor efficiency of 86%. If 1 ton of refrigeration is 3.52 kW, estimate the maximum refrigeration load imposed by this freezing installation assuming

- a. that fans and motors are all within the freezing tunnel insulation and
- b. the fans but not their motors are in the tunnel. The heat-loss rate from the tunnel to the ambient air has been found to be 6.3 kW.

Extraction rate from freezing bread (maximum) = 104 kW

Fan rated horsepower = 80

Now  $0.746 \text{ kW} = 1 \text{ horsepower}$  and the motor is operating at 90% of rating,

And so (fan + motor) power =  $(80 \times 0.9) \times 0.746 = 53.7 \text{ kW}$

**a.** With motors + fans in tunnel

Heat load from fans + motors = 53.7 kW

Heat load from ambient = 6.3 kW

Total heat load =  $(104 + 53.7 + 6.3) \text{ kW} = 164 \text{ kW}$

= 46 tons of refrigeration

**b.** With motors outside, the motor inefficiency =  $(1 - 0.86)$  does not impose a load on the refrigeration

Total heat load =  $(104 + [0.86 \times 53.7] + 6.3)$

= 156 kW

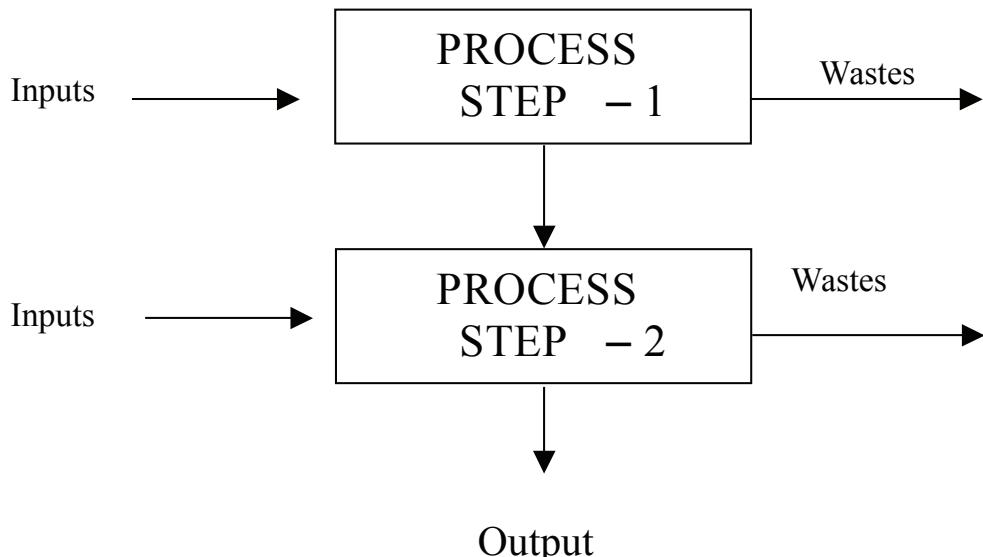
= 44.5 tons of refrigeration

In practice, material and energy balances are often combined as the same stoichiometric information is needed for both.

## 4.8 Method for Preparing Process Flow Chart

The identification and drawing up a unit operation/process is prerequisite for energy and material balance. The procedure for drawing up the process flow diagrams is explained below.

Flow charts are schematic representation of the production process, involving various input resources, conversion steps and output and recycle streams. The process flow may be constructed stepwise i.e. by identifying the inputs / output / wastes at each stage of the process, as shown in the Fig. 4.4.



**Fig. 4.4 Process flow chart**

**Inputs of the process** could include raw materials, water, steam, energy (electricity, etc);

**Process Steps** should be sequentially drawn from raw material to finished product. Intermediates and any other by product should also be represented. The operating process parameters such as temperature, pressure, % concentration, etc. should be represented.

The flow rate of various streams should also be represented in appropriate units like m<sup>3</sup>/h or kg/h. In case of batch process the total cycle time should be included.

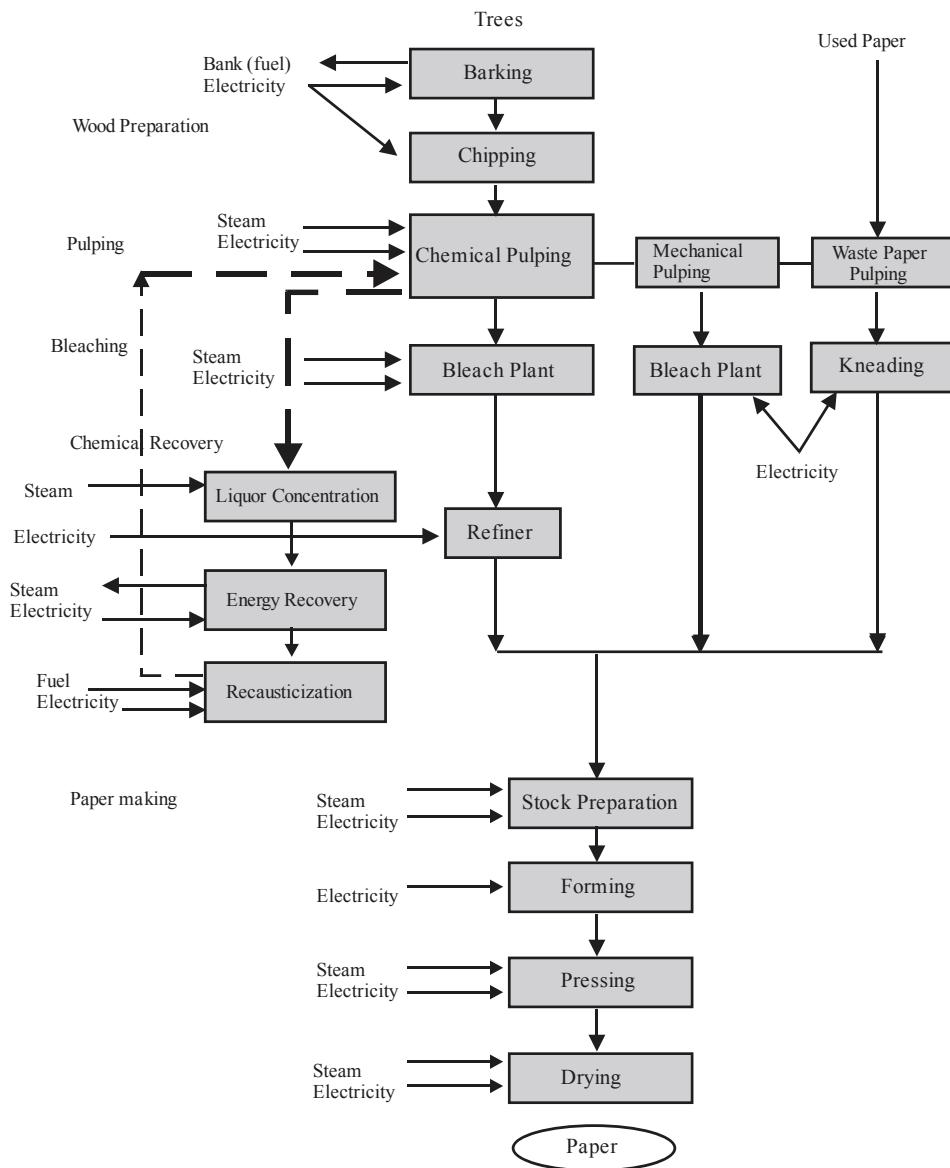
**Wastes** / by products could include solids, water, chemicals, energy etc. For each process steps (unit operation) as well as for an entire plant, energy and mass balance diagram should be drawn.

**Output of the process** is the final product produced in the plant.

**Example**

**Process flow diagram**

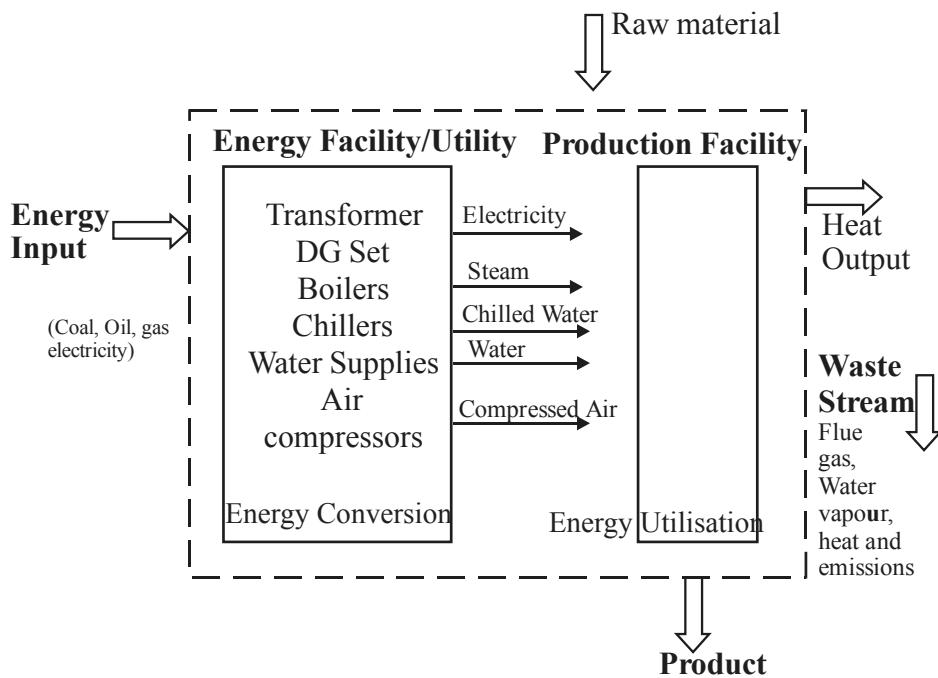
Raw material to finished product: Papermaking is a high energy consuming process. A typical process flow with electrical & thermal energy flow for an integrated waste paper based mill is given in Fig. 4.5



**Fig. 4.5 Process flow diagram of pulp and paper industry**

#### 4.9 Facility as an Energy System

There are various energy systems/utility services provides the required type of secondary energy such as steam, compressed air, chilled water etc to the production facility in the manufacturing plant. A typical plant energy system is shown in Fig. 4.6. Although various forms of energy such as coal, oil, electricity etc enters the facility and does its work or heating, the outgoing energy is usually in the form of low temperature heat.



**Fig. 4.6 Plant energy system**

The energy usage in the overall plant can be split up into various forms such as

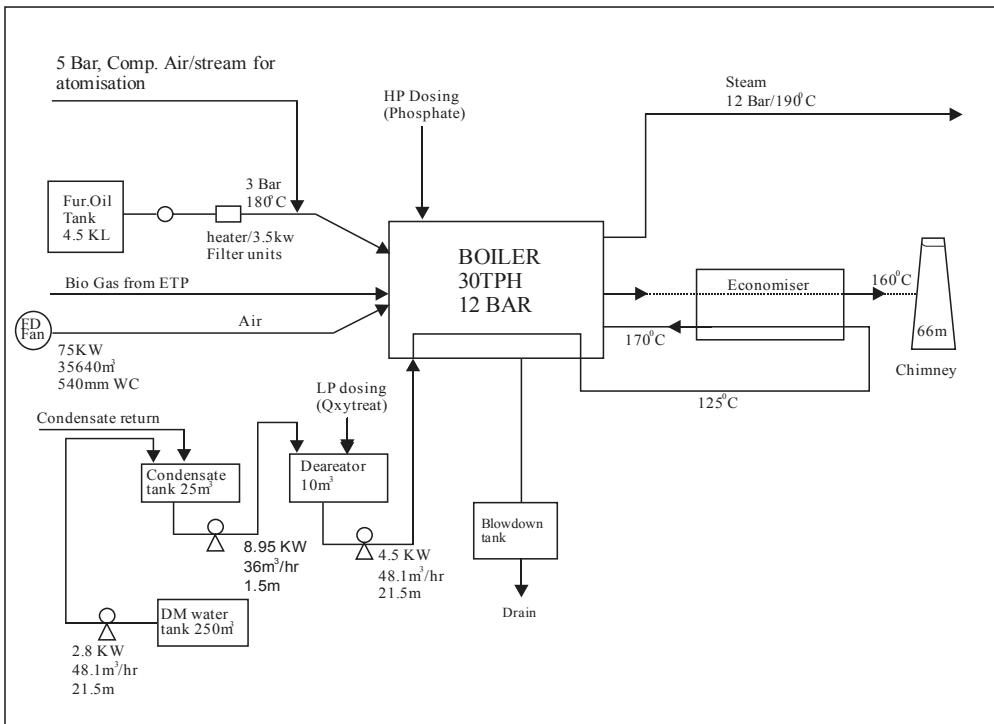
- Electrical energy, which is usually purchased as HT and converted into LT supply for end use.
- Some plants generate their own electricity using DG sets or captive power plants.
- Fuels such as furnace oil, coal are purchased and then converted into steam or electricity.
- Boiler generates steam for heating and drying demand
- Cooling tower and cooling water supply system for cooling demand
- Air compressors and compressed air supply system for compressed air needs

All energy/utility system can be classified into three areas like generation, distribution and utilisation for the system approach and energy analysis.

A few examples for energy generation, distribution and utilization are shown below for boiler, cooling tower and compressed air energy system.

### Boiler System

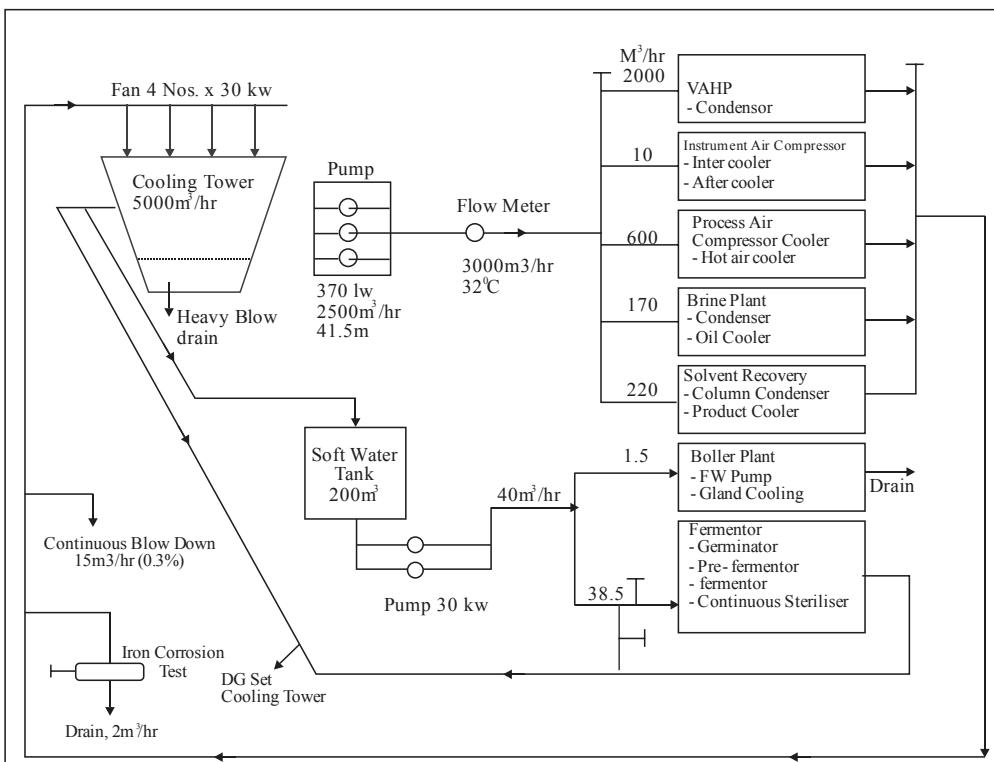
Boiler and its auxiliaries should be considered as a system for energy analyses. Energy manager can draw up a diagram as given in Fig. 4.7 for energy and material balance and analysis. This diagram includes many subsystems such as fuel supply system, combustion air system, boiler feed water supply system, steam supply and flue gas exhaust system.



**Fig. 4.7 Boiler plant system energy flow diagram**

### Cooling tower & cooling water supply system

Cooling water is one of the common utility demands in industry. A complete diagram can be drawn showing cooling tower, pumps, fans, process heat exchangers and return line as given in Fig. 4.8 for energy audit and analysis. All the end use of cooling water with flow quantities should be indicated in the diagram.



**Fig. 4.8 Cooling tower water system**

### Compressed air System

Compressed air is a versatile and safe media for energy use in the plants. A typical compressed air generation, distribution and utilization diagram is given in Fig. 4.9. Energy analysis and best practices measures should be listed in all the three areas.

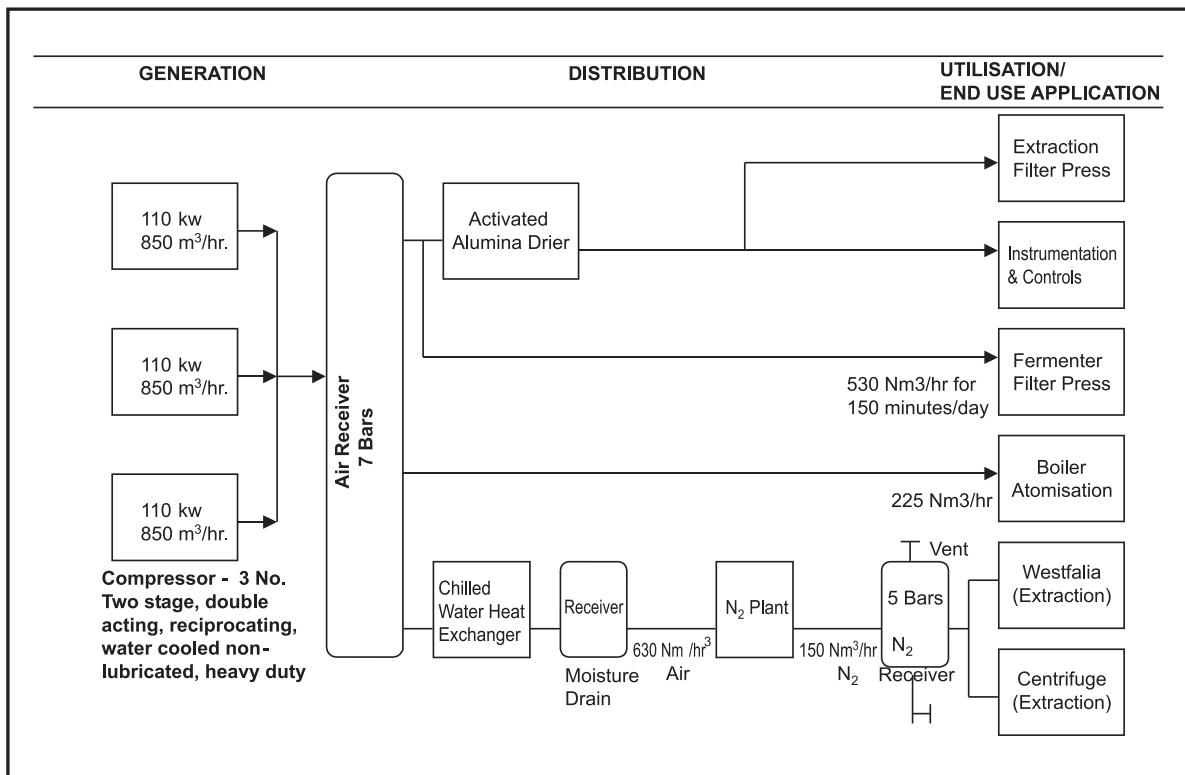


Fig. 4.9 Instrument air system

### 4.10 How to Carryout Material and Energy (M&E) Balance

- Material and Energy balances are important, since they make it possible to identify and quantify previously unknown losses and emissions.
- These balances are also useful for monitoring the improvements made in an ongoing project, while evaluating cost benefits.
- Raw materials and energy in any manufacturing activity are not only major cost components but also major sources of environmental pollution.
- Inefficient use of raw materials and energy in production processes are reflected as wastes.

#### Guidelines for M&E Balance

- For a complex production stream, it is better to first draft the overall material and energy balance.
- While splitting up the total system, choose simple discrete sub-systems. The process flow diagram could be useful here.
- Choose the material and energy balance envelope such that, the number of streams entering and leaving, is the smallest possible.
- Always choose recycle streams (material and energy) within the envelope.
- The measurement units may include, time factor or production linkages.
- Consider a full batch as the reference in case of batch operations.
- It is important to include start-up and cleaning operation consumptions (of material and energy resources (M&E)).
- Calculate the gas volumes at standard conditions.

- In case of shutdown losses, averaging over long periods may be necessary.
- Highlight losses and emissions (M&E) at part load operations if prevalent.
- For each stream, where applicable, indicate energy quality (pressure, temperature, enthalpy, Kcal/hr, KW, Amps, and Volts etc.).
- While preparing M&E balances, precision of analytical data, flow and energy measurements have to be accurate especially in case of short time span references.

The material and energy (M&E) balances along the above guidelines, are required to be developed at the various levels.

**Overall M&E balance:** This involves the input and output streams for complete plant.

**Section wise M&E balances:** In the sequence of process flow, material and energy balances are required to be made for each section/department/cost centre. This would help to prioritize focus areas for efficiency improvement.

**Equipment-wise M&E balances:** M&E balances, for key equipment would help assess performance of equipment, which would in turn help identify and quantify energy and material avoidable losses.

## 4.11 Energy and Mass Balance Calculation Procedure

The Energy and Mass balance is a calculation procedure that basically checks if directly or indirectly measured energy and mass flows are in agreement with the energy and mass conservation principles.

This balance is of the utmost importance and is an indispensable tool for a clear understanding of the energy and mass situation achieved in practice.

In order to use it correctly, the following procedure should be used:

- Clearly identify the problem to be studied.
- Define a boundary that encloses the entire system or sub-system to be analysed. Entering and leaving mass and energy flows must be measured at the boundary.
- The boundary must be chosen in such a way that:
  1. All relevant flows must cross it, all non-relevant flows being within the boundary.
  2. Measurements at the boundary must be possible in an easy and accurate manner.
- Select an appropriate test period depending on the type of process and product.
- Carry out the measurements.
- Calculate the energy and mass flow.
- Verify an energy and mass balance. If the balances are outside acceptable limits, then repeat the measurements.
- The energy release or use in endothermic and exothermic processes should be taken into consideration in the energy balance.

### Example/Formula

- Energy Supplied by Combustion:  $Q = \text{Fuel consumed} \times \text{Gross Calorific value}$
- Energy Supplied by Electricity:  $Q = \text{kWh} \times 860 \text{ kCals}$
- Where,  $Q$  = thermal energy flow rate produced by electricity (kCals/hr)
- Continuity Equation  

$$\frac{A_1 v_1}{V_1} = \frac{A_2 v_2}{V_2}$$

Where,

$V_1$  and  $V_2$  are the velocity in m/s, ' $v_1$ ' and ' $v_2$ ' the specific volume in  $\text{m}^3/\text{kg}$  and ' $A$ ' is the cross sectional area of the pipe in  $\text{m}^2$ .

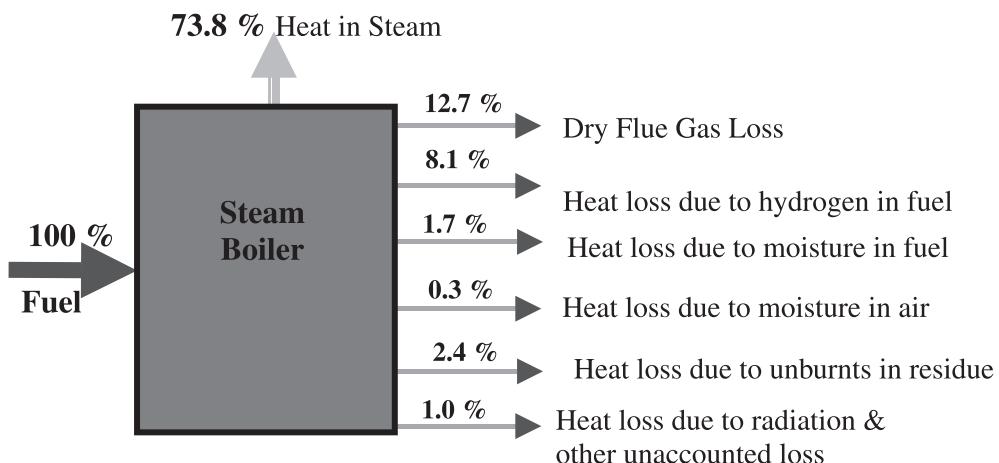
- Heat addition/rejection of a fluid =  $mC_p \Delta T$

- Where,  
m is the mass in kg,  $C_p$  is the specific heat in kCal/kg.C,  $\Delta T$  is the difference in temperature in k.

### Example 1

#### Heat Balance in a Boiler

A heat balance is an attempt to balance the total energy entering a system (e.g. boiler) against that leaving the system in different forms. The Fig.4.10 illustrates the heat balance and different losses occurring while generating steam.



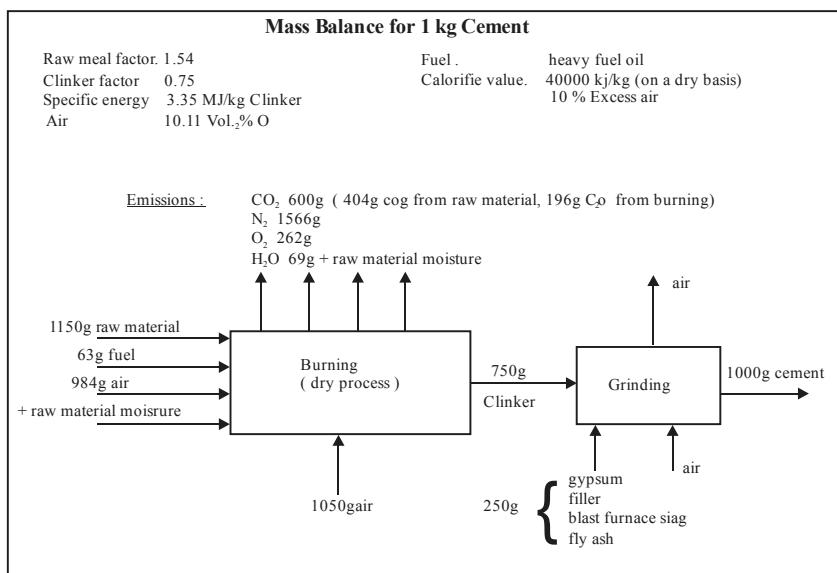
**Fig. 4.10 Heat balance & heat losses during steam generation**

### Example 2

#### Mass Balance in a Cement Plant

The cement process involves gas, liquid and solid flows with heat and mass transfer, combustion of fuel, reactions of clinker compounds and undesired chemical reactions that include sulphur, chlorine, and alkalies.

A typical balance is shown in the fig.4.11 (Source: Based on figure from Austrian BAT proposal 1996, Cembureau for Mass balance for production of 1 Kg cement)



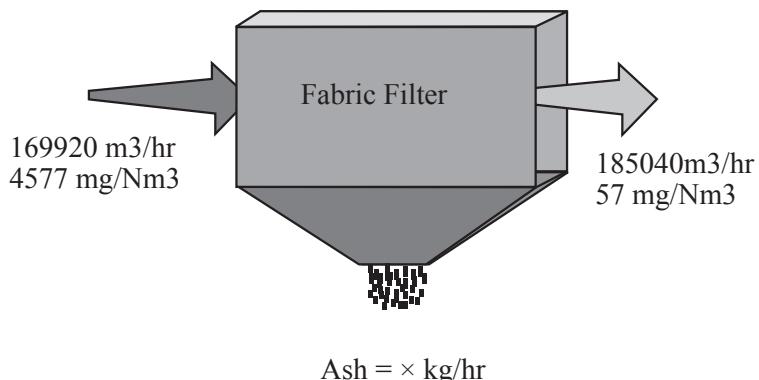
**Fig. 4.11 Mass balance in a cement plant**

### Example 3

#### Mass Balance Calculation

This problem illustrates how a mass balance calculation can be used to check the results of an air pollution monitoring study. A fabric filter (bag filter) is used to remove the dust from the inlet gas stream so that outlet gas stream meets the required emission standards in cement, fertilizer and other chemical industries.

During an air pollution monitoring study, the inlet gas stream to a bag filter is 1,69,920 m<sup>3</sup>/hr and the dust loading is 4577 mg/m<sup>3</sup>. The outlet gas stream from the bag filter is 1,85,040 m<sup>3</sup>/hr and the dust loading is 57 mg/m<sup>3</sup>. What is the maximum quantity of ash that will have to be removed per hour from the bag filter hopper based on these test results?



**Fig. 4.12 Conservation of matter**

Based on dust balance,

$$\text{Mass}_{\text{(in)}} = \text{Mass}_{\text{(out)}} \\ \text{Inlet gas stream dust} = \text{outlet gas stream dust} + \text{Hopper Ash}$$

- Calculate the inlet and outlet dust quantities in kg per hour

$$\text{Inlet dust quantity} = 169920 \text{ (m}^3/\text{hr}) \times 4577 \text{ (mg/m}^3) \times 1/1000000 \text{ (kg/mg)} = 777.7 \text{ kg/hr}$$

$$\text{Outlet dust quantity} = 185040 \text{ (m}^3/\text{hr}) \times 57 \text{ (mg/m}^3) \times 1/1000000 \text{ (kg/mg)} = 10.6 \text{ kg/hr}$$

- Calculate the quantity of ash that will have to be removed from the hopper per hour

$$\text{Hopper ash} = \text{Inlet gas dust quantity} - \text{Outlet gas dust quantity}$$

$$= 777.7 \text{ kg/hr} - 10.6 \text{ kg/hr}$$

$$= 767.1 \text{ kg/hr}$$

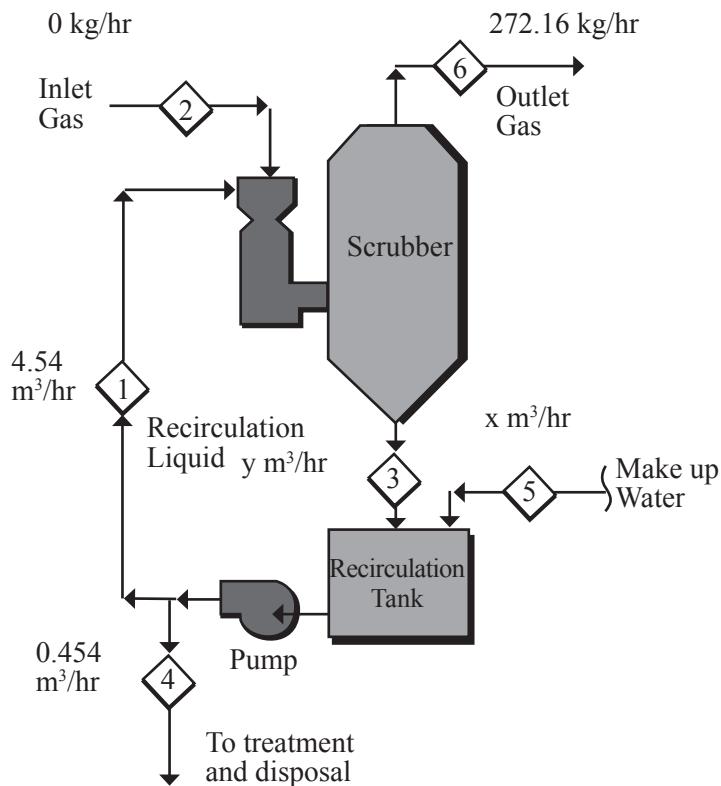
#### **Example: 4**

#### **Material Requirement for Process Operations**

A scrubber is used to remove the fine material or dust from the inlet gas stream with a spray of liquid (typically water) so that outlet gas stream meets the required process or emission standards.

How much water must be continually added to wet scrubber shown in the figure below in order to keep the unit running? Each of the streams is identified by a number located in a diamond symbol. Stream 1 is the recirculation liquid flow stream back to the scrubber and it is 4.54 m<sup>3</sup>/hr. The liquid being withdrawn for treatment and disposal (stream 4) is 0.454 kg m<sup>3</sup>/hr.

Assume that inlet gas stream (number 2) is completely dry and the outlet stream (number 6) has 272.16 kg/hr of moisture evaporated in the scrubber. The water being added to the scrubber is stream number 5.



**Fig. 4.13 Example of material balance**

Step 1. Conduct a material balance around the scrubber.

- For Stream 6, convert from kg/hr to m<sup>3</sup>/hr to keep units consistent. The conversion factor below applies only to pure water.

$$\text{Stream 6} = 272.16 \text{ kg/hr} \times \frac{\text{m}^3}{1000 \text{ kg}} \\ = 0.272 \text{ m}^3/\text{hr}$$

- Set up the material balance equation and solve for Stream 3.

$$\text{Input}_{\text{Scrubber}} = \text{Output}_{\text{Scrubber}} \\ \text{Stream 1} + \text{Stream 2} = \text{Stream 3} + \text{Stream 6} \\ 4.54 \text{ m}^3/\text{hr} + 0 = y \text{ m}^3/\text{hr} + 0.272 \text{ m}^3/\text{hr} \\ \text{Stream 3} = y \text{ m}^3/\text{hr} = 4.27 \text{ m}^3/\text{hr}$$

Step 2. Conduct a material balance around the recirculation tank. Solve for Stream 5.

$$\text{Input}_{\text{Tank}} = \text{Output}_{\text{Tank}} \\ \text{Stream 3} + \text{Stream 5} = \text{Stream 1} + \text{Stream 4} \\ 4.25 \text{ m}^3/\text{hr} + x \text{ m}^3/\text{hr} = 4.54 \text{ m}^3/\text{hr} + 0.454 \text{ m}^3/\text{hr} \\ \text{Stream 5} = x \text{ m}^3/\text{hr} = 5 \text{ m}^3/\text{hr} - 4.27 \text{ m}^3/\text{hr} \\ = 0.73 \text{ m}^3/\text{hr}$$

If it is to calculate only the makeup water at 5,

$$\text{Stream 5} = \text{Stream 4} + \text{Stream 6} \\ = 0.454 + 0.272 \\ = 0.73 \text{ m}^3/\text{hr}$$

One of the key steps in solving Example 4 was drawing a simple sketch of the system. This is absolutely necessary so that it is possible to conduct the material balances. Drawings are a valuable first step when solving a wide variety of problems, even ones that appear simple.

Drawing is a very useful way to summarize what we know and what we need to know. It helps to visualize the solution. If the problem involves dimensional quantities (such as stream flow quantities), the dimensions are needed to be included in the sketch. They serve as reminders of the need to convert the data into consistent units.

## Summary

- Material and energy balances can be worked out quantitatively knowing the amounts of materials entering into a process, and the nature of the process.
- Material quantities, as they pass through processing operations, can be described by material balances. Such balances are statements on the conservation of mass. Just as mass is conserved, so is energy. The energy coming into a unit operation can be balanced with the energy coming out and the energy stored.
- Material and energy balances take the basic form.
- Content of inputs = content of products + wastes/losses + changes in stored materials.
- Material and energy balances are very important in an industry. These are fundamental to the control of processing, particularly in the control of yields of the products.
- Energy includes heat energy (enthalpy), potential energy (energy of pressure or position), kinetic energy, work energy, chemical energy. It is the sum over all of these that are conserved.
- Energy balances are often complicated because forms of energy can be inter converted, for example mechanical energy to heat energy, but overall the quantities must balance.
- Enthalpy balances, considering only heat are useful in many processing situations.
- Material and energy balances can be simple, at times they can be very complicated, but the basic approach is general. Experience in working with the simpler systems such as individual unit operations will develop the facility to extend the methods to the more complicated situations, which do arise.
- Material balances look at the three basic categories- materials in, materials out and materials stored.
- The Energy and Mass balance is a calculation procedure that basically checks if directly or indirectly measured energy and mass flows are in agreement with the energy and mass conservation principles. This balance is of the utmost importance and is an indispensable tool for a clear understanding of the energy and mass situation achieved in practice. In order to use it correctly, there are following procedure that should be used.

## References

- Material and Energy Balance[Pdf] Available at: <<http://www.em-ea.org/Guide%20Books/Book-1/1.4%20MATERIAL%20%20AND%20ENERGY%20BALANCE.pdf>> [Accessed 8 July 2013].
- Basics of Combustion Engineering: Mass and Energy Balance [Pdf] Available at: <[http://www.met.kth.se/asialink/Curriculum/Clausthal%20uni-Germany/Comb\\_Funda\\_L2\\_ppt.pdf](http://www.met.kth.se/asialink/Curriculum/Clausthal%20uni-Germany/Comb_Funda_L2_ppt.pdf)> [Accessed 8 July 2013].
- Olsen, S. E. and Tangstad, M., 2007. Production of Manganese Ferroalloys. Tapir Academic Press.
- Earle, R.L., 1983. Unit Operations in Food Processing. NZIFST Inc.
- Changing Units in an Equation [Video online] Available at: <<http://www.youtube.com/watch?v=qkQEBcrJ5I>&list=PLD4476BAFA5A65111> [Accessed 8 July 2013].
- Material & Energy Balances Final (Review): Part 1[Video online] Available at: <<http://www.youtube.com/watch?v=2rhEZ4ZB3lM>> [Accessed 8 July 2013].

## Recommended Reading

- Reklaitis, G.V., 1983. Introduction to Material and Energy Balances. Wiley.
- Balu, K., Satyamurthi, N., Ramalingam, S. and Deebika, B., 2009. Problems on Material and Energy Balance Calculation. I.K International Publishing House Pvt. Ltd.
- Henley, E.J. and Rosen, E.M., 1969. Material and Energy Balance Computations. Wiley.

## Self Assessment

1. Which of the following is false?
  - a. Raw Materials = Products + Waste Products + Stored Products + Losses
  - b. Mass Out = Mass In + Mass Stored
  - c. Raw Materials = Products + Wastes + Stored Materials
  - d. Energy In = Energy Out + Energy Stored
2. Which is the ratio of the number of moles of the solute to the total number of moles of all species present in the solution?
  - a. The mole fraction
  - b. The mole whole
  - c. The mole odd
  - d. The mole even
3. \_\_\_\_\_ heat is the heat required to change, at constant temperature, the physical state of materials from solid to liquid, liquid to gas, or solid to gas.
  - a. Mutant
  - b. Sensible
  - c. Latent
  - d. Photon
4. \_\_\_\_\_ heat is that heat which when added or subtracted from materials changes their temperature and thus can be sensed.
  - a. Mutant
  - b. Sensible
  - c. Latent
  - d. Photon
5. Which of the following is false?
  - a. Boiler generates steam for heating and drying demand.
  - b. Fuels such as furnace oil, coal are purchased and then converted into steam or electricity.
  - c. Some plants generate their own electricity using DG sets or captive power plants.
  - d. For a complex production stream, it is not better to first draft the overall material and energy balance.
6. Which of the following is false?
  - a. Material and energy balances can be worked out quantitatively knowing the amounts of materials entering into a process, and the nature of the process

- b. Material and energy balances take the basic form.
- c. Content of inputs = content of products + wastes/losses + changes in stored materials
- d. Energy balances are often complicated because forms of energy can be inter converted, example mechanical energy to heat energy, but overall the quantities must balance
- e. Energy balances look at the three basic categories- materials in, materials out and materials stored
7. Match the following
- |  |   |
|--|---|
| 1. Continuity Equation   | a. Fuel consumed $\times \text{ Gross Calorific value}$ |
| 2. The law of conservation of mass leads to what is called a mass or a material balance. | b. $\frac{A_1 v_1}{V_1} = \frac{A_2 v_2}{V_2}$          |
| 3. $n / V = ?$   | c. Mass In = Mass Out $+ \text{ Mass Stored}$           |
| 4. Energy Supplied by Combustion:  | d. $p/RT$   |
- a. 1-b, 2-c, 3-d, 4-a  
b. 1-d, 2-a, 3-b, 4-c  
c. 1-c, 2-d, 3-a, 4-b  
d. 1-b, 2-d, 3-a, 4-c
8. Heat addition/rejection of a fluid is given by
- a.  $mC_p \Delta T + \text{kWh}$   
b.  $mC_p \Delta T + \text{kWh} * 860 \text{kcal}$   
c.  $mC_p \Delta T + 860 \text{ kcal}$   
d.  $mC_p \Delta T$
9. Which diagram is a tool to represent an entire input and output energy flow in any energy equipment or system such as boiler generation?
- a. Tankey  
b. Sankey  
c. Mankey  
d. Lankey
10. The \_\_\_\_\_ diagram is quite an old concept and is being used for several years, especially in thermal energy systems.
- a. Tankey  
b. Mankey  
c. Sankey  
d. Lankey

## Chapter V

# Energy Action Planning

### Aim

The aim of this chapter is to:

- elucidate the key elements for successful energy management
- explain the roles and responsibilities of the top management
- explicate energy information system

### Objectives

The objectives of the chapter are to:

- define the elements of successful energy management
- explain effective energy management
- determine force field analysis

### Learning outcome

At the end of the chapter, the students should be able to:

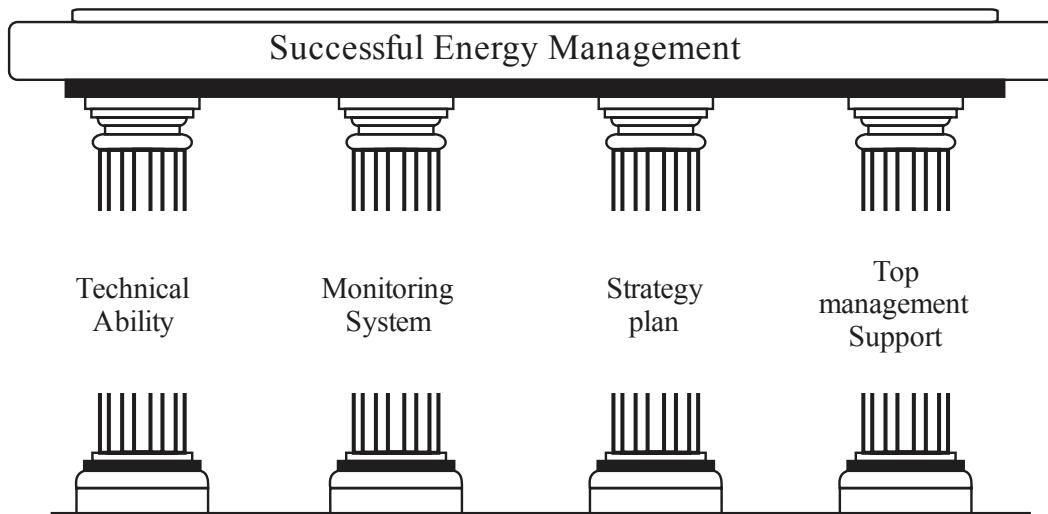
- identify the elements of successful energy management
- explain the promoting energy management
- understand examples of energy conservation

## 5.1 Introduction

Energy efficiency is extremely important to all the organisations, especially those which are energy intensive. The four vital requirements for a successful energy management are: technical ability, monitoring system, strategy plan and top management support. Any successful energy management programme within an organisation needs the total support of top management. Hence, top management support is the key requirement for success.

Top management should give energy efficiency equal importance in their corporate objectives as manpower, raw materials, production and sales. The other important requirements include a well charted strategy plan, an effective monitoring system and adequate technical ability for analysing and implementing energy saving options.

Fig. 5.1 will show the four vital requirements for a successful energy management

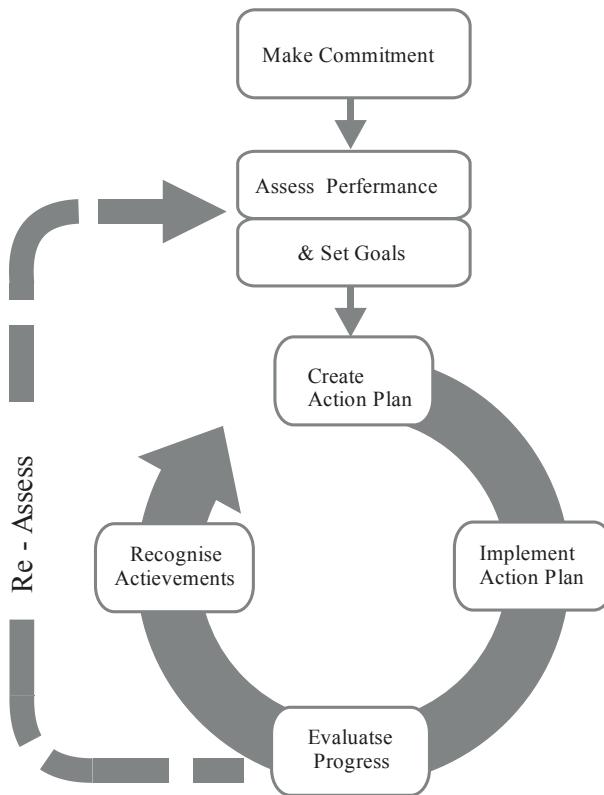


**Fig 5.1 The 4 pillars of successful energy management**

## 5.2 Energy Management System

Organisations seeking financial returns from superior energy management, continuously strive to improve their energy performance. Their success is based on regularly assessing energy performance, planning and implementing action plans to improve energy efficiency.

Hence a sound energy management system is a prerequisite for identifying and implementing energy conservation measures, sustaining the momentum and for effecting improvements on a continuous basis. The various steps for energy action planning are shown in Fig. 5.2



**Fig. 5.2 Steps in energy action planning**

### 5.2.1 Top Management Commitment and Support

Top management shall make a commitment to allocate manpower and funds to achieve continuous improvement. To establish the energy management programme, leading organisations appoint energy manager, form a dedicated energy team and institute an energy policy.

### 5.3 Energy Manager

Responsibilities and duties to be assigned under the Energy Conservation Act, 2001 are:

#### Responsibilities:

- prepare an annual activity plan and present it to the management concerning financially attractive investments to reduce energy costs
- establish an energy conservation cell within the firm with management's consent about the mandate and task of the cell
- initiate activities to improve monitoring and process control reduce the energy costs
- analyse equipment performance with respect to energy efficiency
- ensure proper functioning and calibration of instrumentation required to assess level of energy consumption directly or indirectly
- prepare information material and conduct internal workshops about the topic for other staff
- improve disaggregating of energy consumption data down to shop level or profit centre of a firm
- establish a methodology how to accurately calculate the specific energy consumption of various products/ services or activity of the firm.
- develop and manage training programme for energy efficiency at operating levels
- co-ordinate nomination of management personnel to external programs
- create knowledge bank on sectoral, national and inter-national development of energy efficiency technology, management system and information denomination

- develop integrated system of energy efficiency and environmental up gradation
- co-ordinate implementation of energy audit/efficiency improvement projects through external agencies
- establish and/or participate in information exchange with other energy managers of the same sector through association

**Duties:**

- Report the information once a year to the BEE and state level designated agency regarding the energy consumed and actions taken on the recommendation of the accredited energy auditor, as per BEE format
- establish an improved data recording, collection and analysis system to keep a track of energy consumption
- provide support to Accredited Energy Audit firm retained by the company for the conduct of energy audit
- provide information to BEE as demanded in the Act, with respect to the tasks given by a mandate, and the job description
- prepare a scheme for efficient use of energy and its conservation. Implement such scheme keeping in view the economic stability of the investment in such form and manner as may be provided in the regulations of the Energy Conservation Act.

### **5.3.1 Appoint an Energy Manager**

- the tasks of energy manager are setting goals, tracking progress and promoting the energy management program
- an energy manager helps the organisation achieve its goals by establishing energy performance as a core value
- the energy manager is not always an expert in energy and technical systems
- a successful energy manager understands how energy management helps the organisation achieve its financial and environmental goals and objectives
- depending on the size of the organisation, the energy manager role can be a full-time position or an addition to other responsibilities.

### **5.3.2 Location of Energy Manager**

In the energy management function, whether vested in one “energy manager or coordinator” or distributed among a number of middle managers, usually resides somewhere in the organisation between senior management and those who control the end-use of energy.

Exactly how and where that function is placed is a decision that needs to be made in view of the existing organisational structure.

## **5.4 Form a Dedicated Energy Team**

- The tasks of energy team are executing energy management activities across different parts of the organisation and ensuring integration of best practices
- decisions affecting energy use are made every day by employees at all levels in an organisation. Creating an energy team helps to integrate energy management activities in an organisation
- in addition to planning and implementing specific improvements, the energy team measures and tracks energy performance and communicates them with the management, employees and other stakeholders

The size of the energy team will vary depending on the size of the organisation. In addition to the energy manager who leads the team and dedicated energy staff, the team can include a representative from each operational area that significantly affects energy use, such as:

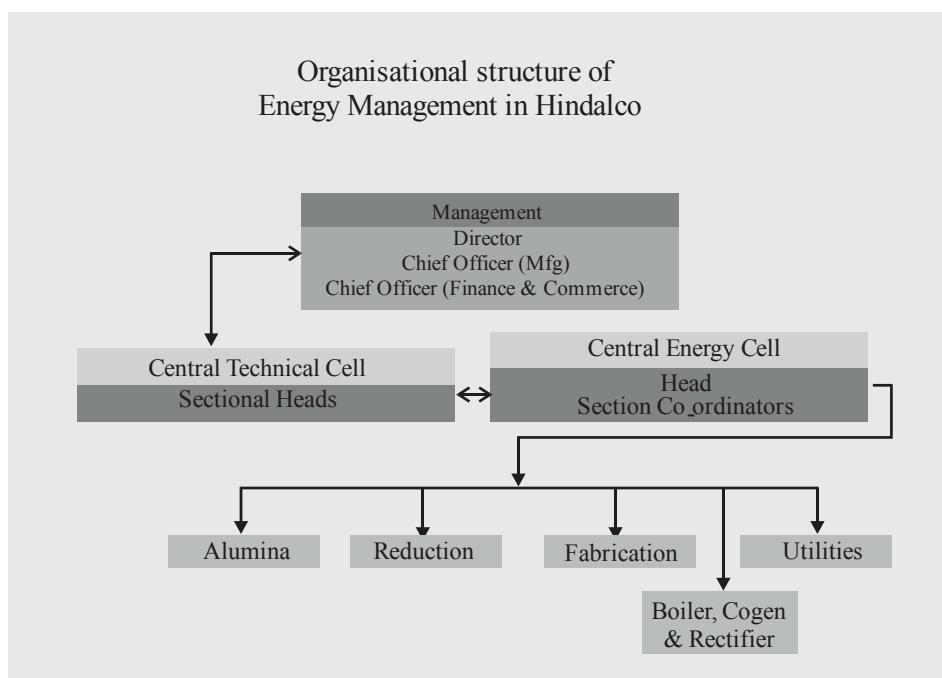
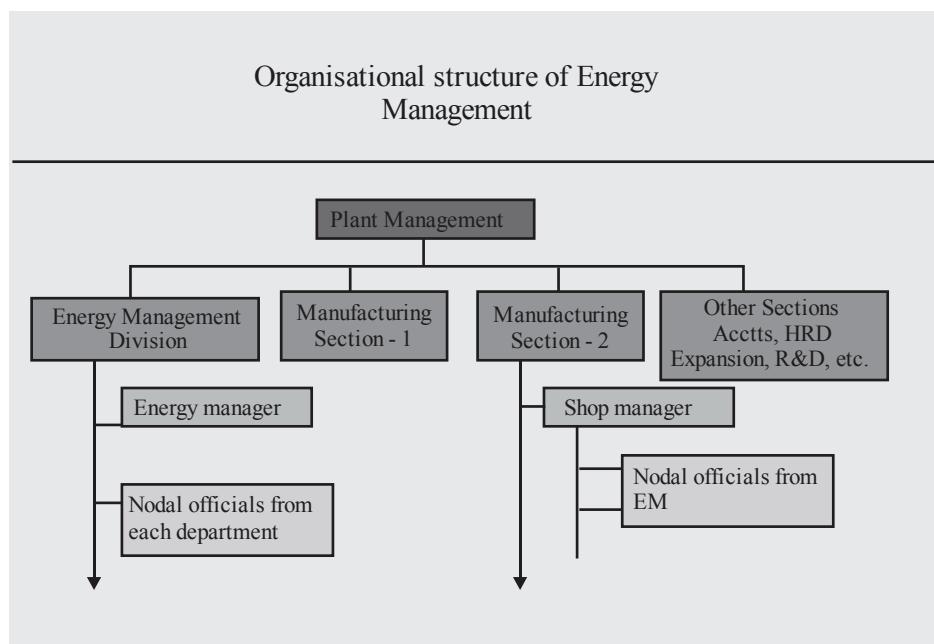
- Engineering
- Purchasing
- Operations and Maintenance

- Building/Facilities Management
- Environmental Health and Safety
- Contractors and Suppliers
- Utilities

Energy team can encourage communications and the sharing of ideas between various departments in an organisation. It can serve to obtain agreements on energy conservation projects, which affect more than one department. It can provide a stronger voice to the top management than a single energy manager normally could.

The composition of the energy team will vary from one organisation to another, depending on the existing management structure, the type and quantity of energy used and other company-specific factors.

A typical example of organisational structure of energy management and location of an energy manager are shown in Fig. 5.3. The location of energy management functions in a typical corporate sector and larger organisation is shown in Fig. 5.4.



The frequency of team meetings depend on the importance of energy costs in the overall cost structure of the company and what projects are in progress at any time. Normally a monthly meeting is usual, so that monthly production and energy consumptions may be reviewed together by the committee. This review would include a comparison of actual performance against previously set targets and budget figures, as well as against previous months. Other items for the agenda should be a review of the status of energy conservation investments in progress or planned.

## 5.5 Institute an Energy Policy

Energy policy provides the foundation for setting performance goals and integrating energy management into an organisation's culture and operations.

Energy policy provides the foundation for successful energy management. It formalizes top management's support and articulates the organisation's commitment to energy efficiency for employees, shareholders, the community and other stakeholders.

### A formal written energy policy acts both as

- a public expression of the organisation's commitment to energy conservation and environmental protection
- a working document to guide the energy management practices and provides continuity

It is in the company's best interest that support for energy management is expressed in a formal written declaration of commitment accompanied by a set of stated objectives, an action plan for achieving them, and a clear specification of responsibilities.

### Typical format of an energy policy

- declaration of top management's commitment to, and senior and middle management's involvement in, energy management
- statement of policy
- statement of objectives, separated into short and long-term goals

### Actions

- have the CEO or head of the organisation officially issued the policy
- involve key people in policy development to ensure cooperation
- tailor the policy to the organisation's culture
- make it understandable to employees and public alike
- consider the skills and abilities of management and employees
- include details that cover day-to-day operations
- communicate the policy to all employees, and encourage them to get involved

\*Sample energy policies of various organisations are given at the end of this chapter

## 5.6 Assess Energy Performances

Understanding current and past energy use helps an organisation identify opportunities to improve energy performance and gain financial benefits. Assessing energy performance is the periodic process of evaluating energy use for all major facilities and functions in the organisation and establishing a baseline for measuring future results of energy efficiency efforts.

Key aspects include data collection and management, establishing baseline, benchmarking, analysis and evaluation and conducting technical assessment and audit.

## Data collection and management

### Collect and track data

- collect energy use information and document data over time
- evaluating energy performance requires good information on how, when, and where energy is being used
- collecting and tracking this information is necessary for establishing baselines and managing energy use

The following steps are to be considered:

### Collect data

The data must be complete and accurate because it will be used for analysis and goal setting. Consider the following when collecting energy use data:

- **Determine appropriate level of detail:** The level and scope of data collection will vary from organisation to organisation. Some may choose to collect data from sub-meters on individual processes while others may only look at a utility bill.
- **Account for all energy sources:** Make inventory of all energy purchased and generated on-site (electricity, gas, steam, waste fuels) in physical units (kWh, kg of steam, etc.) and on a cost basis.
- **Document all energy uses:** For the sources identified above, assemble energy bills, meter readings, and other use data. Energy data may reside in the accounting department, be held centrally or at each facility, or can be acquired by contacting the appropriate utilities or energy service providers. Gather at least two years of monthly data or a more frequent interval if available. Use the most recent data available.
- **Collect facility and operational data:** To be able to normalize and benchmark, it may be necessary to collect non-energy related data for all facilities and operations, such as building size, production, operating hours, etc.

### Track Data

A system for tracking performance can range from a simple spreadsheet to detailed databases and IT systems. In developing an appropriate tracking system for the organisation, consider the following:

- Scope: The design of the tracking system will be shaped, in large part, by the level and scope of information that will be tracked and the frequency of data collection.
- Maintenance: Tracking systems must be easy to use, update, and maintain.
- Reporting and communicating: Use tracking systems to communicate energy performance to other parts of the organisation and motivate change. Consider developing formats that express energy performance information in ways that are easily understandable across the organisation. A good tracking system should make such reporting easy.

### Actions

- collect data by fuel type at an individual building or facility level
- collect data from sub-meters, if possible
- use data that is current and timely
- use tracking systems to develop quarterly and annual reports that profile energy performance
- use tracking systems to allow facilities to compare their performance to their peers

### Normalize data

The energy use of facilities varies greatly, partly due to factors beyond the energy efficiency of the equipment and operations. These factors may include weather or certain operating characteristics. Normalizing is the process of removing the impact of various factors on energy use so that energy performance of facilities and operations can be compared.

In order to normalize:

Determine normalization factors -Determine key factors that need to be addressed to effectively compare facilities. Relevant factors are frequently organisation-specific.

For industrial facilities common normalization factors include:

- inputs
- product type
- output
- production processes

For commercial and institutional buildings, common normalization factors include:

- climate zone
- facility size
- fuel choice
- price/cost of energy
- actual weather history
- hours of operation
- occupancy levels
- special features

## 5.7 Establishing Baseline

### Establish baselines

- determine the starting point from which to measure progress
- measuring energy performance at a specific time establishes a baseline and provides the starting point for setting goals and evaluating future efforts and overall performance
- baselines should be established for all levels appropriate to your organisation

The main steps involve, using the data collected so far to:

- Establish base year: Establish a base year or an average of several historical years. Use the most complete and relevant sets of data available.
- Identify metrics: Select units of measurement that effectively and appropriately express energy performance for the organisation. (e.g. kcal/ton, kcal/kWh, total energy cost/ton).
- Publish results: Announce performance baselines to facilities, managers, and other key stakeholders in your organisation.

### 5.7.1 Benchmark

Benchmark helps in comparing the energy performance of facilities with each other, peers and competitors, and over time to prioritize which facilities to focus on for improvements.

Benchmarking allows us to compare the energy performance of similar facilities or an established level of performance. It is a useful activity in energy management because it can be used to develop relative measures of energy performance, track change over time, and identify best energy management practices. Benchmarking can be done in variety of ways. Facility or organisational performance may be benchmarked to:

- Past performance: A comparison of current versus historical performance.
- Industry average: Based on an established performance metric, such as the recognized average performance of a similar group.

- Best in class: Benchmarking against the best in the industry and not the average.
- Best practices: A qualitative comparison against certain, established practices considered to be the best in the industry.

### 5.7.2 The Key Steps In Benchmarking Include:

- determine the level of benchmarking (example: equipment, process line, facility or organisational)
- develop metrics
- conduct comparisons
- track performance over time

### 5.7.3 Analysis and Evaluation

**Analyse data:** Understand your energy use patterns and trends.

Analysing data to determine energy use trends can help an organisation gain a better understanding of the factors that affect energy performance and identify steps for reducing energy consumption.

Assessing your energy performance helps you to:

- categorize current energy use by fuel type, operating division, facility, product line, etc.
- identify high performing facilities for recognition and reuse of best practices
- prioritize poor performing facilities for immediate improvement
- understand the contribution of energy expenditures to operating costs
- develop a historical perspective and context for future actions and decisions
- establish reference points for measuring and rewarding good performance

There are a variety of ways by which data can be analysed depending upon the needs of the organisation. The following analyses provides a guideline:

#### Quantitative reviews

- Develop use profiles: Identify energy consumption peaks and valleys, and determine how they relate to operations or key events.
- Compare performance: Compare the use and performance data of similar facilities in your industry.
- Assess the financial impacts: Identify areas of high-cost energy use.
- Identify data gaps: Determine areas where more information is needed.

#### Qualitative reviews

- **Conduct interviews:** Seek informed opinions from colleagues, lessons learned, systems-specific information (e.g., HVAC, lighting, refrigeration), and in-house audits or surveys.
- **Review policies and procedures:** Review organisational policies and operating procedures to determine their impact on energy use.

#### Conduct technical assessments & audits

Evaluate the operating performance of facility systems and equipment to determine improvement potential.

Knowing the organisation's baseline energy use and the relative performance of entire portfolio is only part of the information needed. Periodic assessment of the performance of equipment, processes, and systems will help to identify opportunities for improvement.

Energy audits are comprehensive reviews conducted by energy auditors and/or engineers that evaluate the actual performance of a facility's systems and equipment against its designed performance level or against best available technology. The difference between these is the potential for energy savings.

## **5.8 The Main Steps for Conducting Technical Assessments and Audits**

The main steps for conducting technical assessments and audits are:

- Assemble audit team: Expertise should cover all energy-using systems, processes, and equipment. Include facility engineers, system specialists, and other support. Outside support may be helpful and provide an objective perspective or specific expertise.
- Plan and develop an audit strategy: Identify and prioritize systems for evaluation, assign tasks to team members, and schedule completion dates for the activities. Use benchmarking results to identify poor-performing facilities whose equipment and systems should be targeted for evaluation.
- Create audit report: Based on the audit results, produce a detailed summary of actual steps that can be taken to reduce energy use. The report should recommend actions ranging from simple adjustments in operation to equipment replacement. Estimates of resource requirements for completing actions should also be included.

## **5.9 Set Goals**

Performance goals drive energy management activities and promote continuous improvement. Setting clear and measurable goals is critical for understanding intended results, developing effective strategies, and reaping financial gains.

Well-stated goals guide daily decision-making and are the basis for tracking and measuring progress. Communicating and posting goals can motivate staff to support energy management efforts throughout the organisation. The energy manager in association with the energy team typically develops goals.

Setting goals helps the energy manager:

- set the tone for improvement throughout the organisation
- measure the success of the energy management program
- help the energy team to identify progress and setbacks at a facility level
- foster ownership of energy management, creates a sense of purpose, and motivates staff
- demonstrate commitment to reducing environmental impacts
- create schedules for upgrade activities and identify milestones
- tool called force field analysis can be used to clarify the goals to be achieved
- to develop effective performance goals, determine scope, estimate potential for improvement and finally establish goals

## **5.10 Determine Scope**

Identify organisational and time parameters for goals. The scope of performance goals can include multiple levels of the organisation as well as various time periods for completion of specific goals.

- Organisational level The level at which performance goals will be set depends on the nature of the organisation and how it uses energy. Common organisational levels for setting goals include:
  - Organisation wide -Setting goals at this level provides a big picture of how the entire organisation wants to improve.
  - Organisation-wide goals provide a framework for communicating the success of energy management both to internal and external audiences.
- Facility: At this level, goals may vary to take into account the performance of specific facilities based on benchmarking results or an energy audit. Facility level goals are designed to help the broader organisation to meet its goals.
- Process or equipment: Some organisations may find it useful to establish goals for specific process lines and equipment when energy use is concentrated in specific areas.
- Time periods: Establishing appropriate and realistic target dates for goals, ensures that they are meaningful and promote change. A combination of short and long term goals can be effective.

- Short-term goals: Annual goals provide the necessary markers for tracking and reporting progress on a regular and on going basis.
- Long-term goals: Long-term goals are usually organisation-specific and may be shaped by:
  - internal rates of return
  - internal planning horizons and guidelines
  - organisational strategic plans
  - commitments to voluntary environmental initiatives

## 5.11 Estimate Potential for Improvement

Review baselines, benchmark to determine the potential and order of upgrades, and conduct technical assessments and audits. To set goals, it is important to have a good estimate of what level of performance is achievable and the amount of resources needed. There are a variety of ways to determine potential. The method we choose will depend on a number of factors, such as: available resources, time, the nature of energy use at your facilities, and how the energy program is organised.

Methods used by leading energy programs include:

- Reviewing performance data: Assessing performance and setting baselines should help to identify differences in energy use between similar facilities, giving a limited, point-in-time view of your potential improvement. Performance data covering a longer period of time will be more useful for understanding improvement potential.
- Benchmarking -Benchmarking provides a yardstick for evaluating improvement opportunity when enough data is available to show trends in energy use.
- Evaluating past projects and best practices: Evaluate past projects and best practices at higher-performing facilities to determine the feasibility of transferring these practices to other parts of the organisation.
- Reviewing technical assessments and audits: Identify opportunities to reduce energy use identified during technical assessments and audits of poorer performing facilities to serve as a strong basis for quantifying the potential for improvement.
- Comparing goals of similar organisations: Reviewing performance goals of other organisations can help to guide and inform you of the potential for your own organisation.
- Linking to organisation-wide strategic goals: Strategic as well as operational goals, such as cost reductions, can also help inform the goal setting process.

## 5.12 Establish Goals

Create and express clear, measurable goals, with target dates, for the entire organisation, facilities, and other units. Once the potential for improvement has been estimated, goals can be established at the appropriate organisational levels. Energy performance goals should be formally established and recognized by senior management as a mission for the whole organisation.

Estimating potential for improvement should provide us with a starting point for what is possible. However, some organisations set their final energy performance goals based on organisational factors other than what is technically feasible. Such factors will affect how energy performance goals are expressed.

### Common ways for establishing goals include:

- Defined reduction: Goals are presented in terms of a specific quantity or percentage decrease in energy use, such as decrease of 300 tons of furnace oil or 10 percent reduction of furnace oil.
- Best-in-class: This goal aims for a certain level of performance compared to an established benchmark.
- Efficiency improvement: Goals are expressed as a function of reducing the energy intensity of a specific performance indicator, such as 5 kWh per unit of product.

- Environmental improvement: This goal translates energy savings into pollution prevention or reduction goals.
- Actions: When setting goals, be sure to use the energy team's wide range of knowledge to help set aggressive, yet realistic goals.
- Have management review your goals to enlist their feedback and support.

### 5.13 Force Field Analysis

Before creating the action plan, it can be a useful exercise to clarify the goals to be achieved, and to assess what barriers must be overcome and what influences exist in the organisation that works towards the achievement of the goal. These barriers and influences can be thought of as negative and positive forces respectively.

Force field analysis is a simple tool that can be used to gain additional insight about the change process to be pursued. The steps involved in force field analysis are:

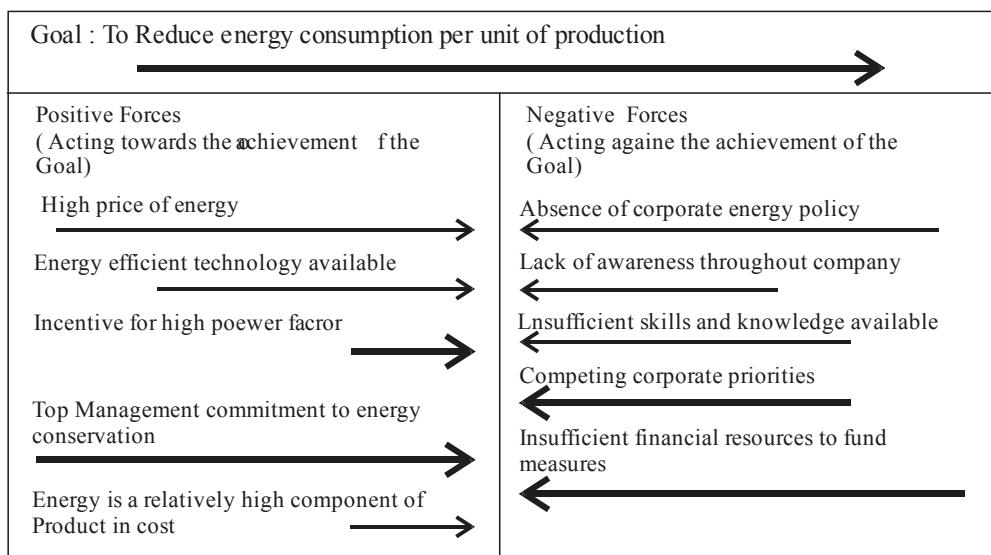
State the organisational goal and indicate the direction (say, left to right) that signifies moving towards that goal: for example, the goal might be “improve energy efficiency in the assembly plant” or “reduce energy consumption in the facility for current occupancy levels”.

Identify barriers that tend to work against the achievement of the goal: these may be internal to the organisation (example, a lack of expertise related to energy management) or external (example, energy rate structures or government regulation).

Identify positive influences or forces that tend to work towards achievement of the goal: these may also be internal or external.

Estimate the relative strength of the negative and positive forces (for simplicity, we may want to identify them as low, medium and high strength).

Prioritize those forces that can be strengthened or weakened through your action plan with the greatest effect on achieving the goal (Tip: It is usually more effective to attempt to minimize negative forces than to try to strengthen forces that are already positive). A typical force field analysis chart is shown in Fig. 5.5



**Fig. 5.3 Force field analysis**

### Create action plan

With goals in place, the organisation is now ready to develop a roadmap to improve energy performance. Successful organisations use a detailed action plan to ensure a systematic process to implement energy performance measures. Unlike the energy policy, the action plan is regularly updated, most often on an annual basis, to reflect recent achievements, changes in performance, and shifting priorities.

While the scope and scale of the action plan is often dependent on the organisation, the steps below outline a basic starting point for creating a plan.

#### 5.14 Define Technical Steps and Targets

Evaluate technical assessments and audit results: Identify gaps between current performance and goals, by reviewing the results of the technical assessments and audits or progress evaluations.

Determine technical steps: Identify the steps necessary for upgrading and moving facilities from current performance to the desired level of performance as defined by the goals.

Create performance targets for each facility, department, and operation of the organisation to track progress towards achieving goals.

Set timelines for actions, including regular meetings among key personnel to evaluate progress, completion dates, milestones and expected outcomes.

Establish a tracking system to track and monitor the progress of action items. This system should track and measure energy use and project/program activities.

#### 5.15 Determine Roles and Resources

Get agreement from management and all organisational areas affected by the action plan before finalising it. Work with the energy team to communicate the action plan to all areas of the organisation.

##### Determine Roles

Identify internal roles: Determine who should be involved and what their responsibilities will be. Depending on your organisation and action plan, this might include departments such as:

- facility and operations management
- financial management: capital investments, budget planning
- human resources: staffing, training, and performance standards
- maintenance
- supply management: procurement procedures, energy purchasing and equipment and materials
- building and plant design
- engineering
- new product/process development teams
- communications marketing
- environment, health and safety

Identify external roles: Determine the degree to which consultants, service providers, vendors, and other product providers will be used. Some organisations may choose to outsource entire aspects of their action plan while others may only want to contract with specific vendors for limited projects.

Establish performance metrics for contractors: If contractors will be used, determine what standards will be used to evaluate bids and incorporate these metrics into agreements with contractors.

## Determine resources

Define resources needs: For each project or program in the action plan, estimate the cost for each item in terms of both human resources and capital/expense outlay.

Secure resources: Develop the business case for justifying and gaining funding approval for action plan projects and resources need.

## Actions

Creating an inclusive strategy that establishes roles and actions throughout the organisation can help to integrate good energy management practices. When developing an action plan, consider:

- brainstorming with various departments to identify ways they can contribute
- holding a competition to seek ideas for energy efficiency from across the organisation
- gathering recommendations from the energy team and other key personnel

## 5.16 Implement Action Plan

People can make or break an energy program. Gaining the support and cooperation of key people at different levels within the organisation is an important factor for successful implementation of the action plan in many organisations.

Reaching your goals frequently depends on the awareness, commitment, and capability of the people who will implement the projects defined in the action plan.

In addition to implementing the technical aspects of the action plan, consider the following:

- **Create communication plan:** Develop targeted information for key audiences about your energy management program.
- **Raise awareness:** Build support at all levels of your organisation for energy management initiatives and goals.
- **Build capacity:** Through training, access to information, and transfer of successful practices, procedures and technologies, you can expand the capacity of your staff.
- **Motivate:** Create incentives that encourage staff to improve energy performance to achieve goals.
- **Track and monitor:** Using the tracking system developed as part of the action plan to track and monitor progress regularly.

## 5.17 Create a Communication Plan

Good communication does not just happen, it requires careful planning and implementation. To communicate strategically, you will need to identify key audiences, determine the information that they need, and adapt your messages appropriately for each one.

### Raise awareness

Everyone has a role in energy management. Effective programs make employees, managers, and other key stakeholders aware of energy performance goals and initiatives, as well as their responsibility in carrying out the program.

Communication strategies and materials for raising awareness of energy use, goals and impacts should be tailored to the needs of the intended audience. To raise awareness, consider doing the following:

### Increase general energy awareness

Most people are unaware of how their everyday actions and activities at home and work affect energy use and impact the environment. Increasing overall awareness can be an effective way to gain greater support for energy initiatives.

Increasing general awareness of energy use can be accomplished through:

- New employee orientation programs: Provide basic information on organisational and individual energy use to new employees.
- Poster campaigns: Develop attractive and informative posters for change rooms, bulletin boards, etc, that discusses energy use.

### **Improve facility energy awareness**

Individuals working in or even managing a facility may have little understanding of the energy performance of the facility or its impact on the organisation and environment. Targeted efforts designed to increase awareness of facility energy use can help build support for energy management programs. Like general awareness efforts, facility-oriented energy awareness can take many forms.

In developing facility energy awareness programs, consider using the following types of information:

- Energy data statistics: Use general facility energy facts and figures, such as overall energy costs, costs to operate equipment, environmental information related to energy use, and so on.
- Energy use of equipment: Provide information on the energy performance of equipment or processes that employees regularly use as part of their jobs.

### **Gain management support**

Frequently, managers who are not directly involved in energy management are not aware of how energy used affects the organisation. Increasing the awareness of managers can help to build support for energy management initiatives.

## **5.18 Build Capacity**

Investing in training and systems to share successful practices helps ensure the success of the action plan by building the overall organisational capacity. Many organisations have found that informed employees are more likely to contribute ideas, operate equipment properly, and follow procedures, helping to guarantee that capital investments in energy improvements will realise their potential.

### **Training**

Using training to help staff understand the importance of energy performance provides the information necessary to make informed decisions. Training also provides an excellent opportunity for gathering employee feedback and evaluations. The type and nature of training will vary by organisation and your specific action plan. Common training programs include:

- Operational and procedural training: Provides instruction on new operating methods or procedures designed to reduce energy use. Such training is typically targeted towards specific audiences, such as facility managers, operations, and maintenance staff.
- Administrative training: Includes reporting, monitoring, data collection, and other administrative efforts that support energy management.
- Specialised training: Gives specific instructions on using and maintaining equipment or tools to ensure more efficient operation.

Knowledge and management information systems Computer-based information systems provide a robust means for sharing information on best practices, technologies, and operational guidance. While these systems can range from complex databases to a simple intranet site, they are a centralized and accessible place to store and transfer energy management information within an organisation.

### **Motivate**

Offering incentives for energy management is one way many organisations create interest in energy initiatives and foster a sense of ownership among employees.

## **Examples**

How organisations motivate staff and employees include:

Internal competition: Use tracking sheets, scorecards, etc. to compare performance of similar facilities and foster a sense of competition.

Recognition: Highlight and reward accomplishments of individuals, departments, and facilities.

Financial bonus and prizes: Offer cash bonuses and other rewards if goals are met. Environmental responsibility:

Use environmental messages to promote a sense of environmental and social responsibility.

Financial responsibility: Use financial messages to promote a sense of fiduciary responsibility.

Performance standards: Tie employee performance standards to energy goals.

## **Track & Monitor**

A tracking system is the means by which an energy program's activities are monitored. The system should be centralized and available for all to use in gauging progress toward established targets, milestones, and deadlines.

Maintaining a tracking system enables you to assess necessary steps, corrective actions, and identify successes. Periodic review of the activities outlined in the action plan is critical to meet energy performance goals.

Perform regular updates: A system is only effective if the information it contains is current and comprehensive. Data needs to be collected and incorporated into the system at an interval of time effective to the program. Many organisations perform weekly and monthly updates to their tracking systems.

Conduct periodic reviews: Periodic reviews of your progress in meeting interim goals and milestones should be conducted with the management team, the energy team, and selected groups of employees. The frequency of these reviews will vary depending upon the audience. Such reviews should focus on progress made, problems encountered, and potential rewards.

Identify necessary corrective actions: A tracking system is a good way to determine whether a program is performing well. It will help identify when a specific activity is not meeting its expected performance and is in need of review.

## **5.19 Evaluate Progress**

Evaluating progress includes formal review of both energy use data and the activities carried out as part of the action plan as compared to your performance goals.

Key aspects are measuring results and reviewing action plans.

### **Measure results**

Compare current performance to established goals. Gather energy use data and compare results to goals to determine accomplishments.

Key steps in measuring results include:

#### **Gather tracking data**

- review energy use and cost data (capital and operating expenses)
- organize reports and data from tracking and monitoring efforts
- analyse energy efficiency achievements based on your established performance metrics

#### **Benchmark**

- compare energy performance to baselines
- compare performance against established goals for:
  - environmental performance
  - financial savings

- Compare energy performance to peers and competitors to establish a relative understanding of where your performance ranks.

### **Review action plan**

Understand what worked well and what didn't in order to identify best practices.

After reviewing performance data, the next steps are to understand the factors affecting the results as well as the additional benefits of the improved energy performance.

Regular evaluation of energy performance and the effectiveness of energy management initiatives also allow energy managers to:

- measure the effectiveness of projects and programs implemented
- make informed decisions about future energy projects
- reward individuals and teams for accomplishments
- document additional saving opportunities as well as non-quantifiable benefits that can be leveraged for future initiatives

This review should look at the effectiveness of your action plan.

Where activities and projects are successful, document best practices to share throughout the organisation.

Where goals were not met, many organisations determine the cause and decide what corrective or preventive actions should be taken.

## **5.20 Key Steps in Reviewing the Action Plan**

Key steps in reviewing the action plan include:

Get feedback: Get feedback and ideas on the plan from the energy team, implementation staff, and other departments.

Assess awareness: Assess changes in employee and organisational awareness of energy issues.

Identify critical factors: Identify factors that contributed to surpassing or missing targets.

Quantify side benefits: Identify and quantify, if possible, side benefits arising from energy management activities such as employee comfort, productivity improvement, impact on sales, reduced operation and maintenance expenses, or better public/community relations.

Action plan review involves a commitment of resources, but also has many advantages:

- creates insight for new actions (technologies/practices/programs)
- avoids repeating failures by identifying activities that were not as effective as expected
- assesses the usefulness of the tracking system and other administrative tools to ensure better management and evaluation
- provides staff the opportunity to contribute to and understand the process of energy management
- provides specific success stories and financial results to communicate to stakeholders inside and outside the organisation

### **Recognize Achievements**

Providing and seeking recognition for energy management achievements is a proven step for sustaining momentum and support for your program. Providing recognition to those who helped the organisation achieve these results motivates staff and employees and brings positive exposure to the energy management program. Receiving recognition from outside sources validates the importance of the energy management program to both internal and external stakeholders, and provides positive exposure for the organisation as a whole.

## **Internal recognition**

Recognising the accomplishments of individuals and teams is a key to sustaining support and momentum for energy management initiatives. Rewarding particular efforts sets the example for what constitutes success and helps motivate employees through increased job satisfaction. Recognition can strengthen the morale of everyone involved in energy management.

### **Key steps are:**

Determine recognition levels: The decision about who should receive recognition in your organisation will likely be shaped by the purpose for providing recognition and your organisational culture.

### **Common recognition levels include:**

Individual: Acknowledges the contributions and accomplishments of specific people.

Teams: Recognizes the achievements of teams, departments and other distinct groups within the organisation.

Facility: Rewards the accomplishments or performance of an entire facility.

Establish recognition criteria: Create criteria for recognition and communicate these criteria and any process eligibility requirements. Recognition criteria might include thresholds of achievement such as:

- offered the best energy savings ideas
- achieved the greatest energy use reduction
- increased savings by quantified amount

### **Determine recognition type**

There are a variety of ways to provide recognition and rewards. Depending on the purpose of the recognition program and your organisational culture, forms of recognition can range from formal acknowledgements and certificates, to salary increases and cash bonuses, to simple forms of appreciation such as shields or energy program shirts.

### **Actions**

- ask senior management to provide the recognition
- use a formal means for providing recognition, such as an award ceremony
- use progress evaluations to inform the recognition process

### **External recognition**

Good work deserves to be acknowledged. Recognition from a third party can provide validation for an organisation's energy management program. Not only does it provide satisfaction to those involved in earning the recognition, but it can also enhance an organisation's public image. A solid reputation contributes to your competitive advantage by making your organisation more attractive to customers, students, current and potential employees, lenders, business partners and other stakeholders.



Reliance  
Industries Limited

Mukesh D. Ambani  
Vic-Cahrm & Managing Director

October 03,2001

### ENERGY MANAGEMENT POLICY

Reliance plays a lead role in national economy by providing quality goods and services in the materials and energy value chains and in infrastructure.

Our mission is

- \* To be the lowest specific energy consumer in the industries we operate.
- \* To maximize the use of renewable fuels and low energy level fuels in our operations.

This we plan to achieve by the following:

- \* Manage efficiently the utilization of energy resources, upgrade hardware and employ cleaner and more efficient technologies.
- \* Train employees to make the Reliance the pace setter in the area of energy conservation
- \* Carry out regular internal and external audits to identify areas for improvement
- \* Benchmark continuously our performance against the best in the world.
- \* Enrich experience on energy conservation by exchange of ideas with other organizations.
- \* Promote awareness among all members of the large Reliance family.

(Mukesh D. Ambani)

A handwritten signature in black ink, appearing to read "Mukesh D. Ambani".



## **Energy Policy Statement**

We, at INDAL Hirakud are committed to continuously improve our energy performance in all our activities, products and services so as to make environmental sustainable for future generation.

To meet the above goals, we will strive for:

- > Energy efficient power generation, aluminum melting and casting.
- > Nurturing energy efficient designs and technology for all future acquisitions, wherever practicable.
- > Enhancing utilization of renewable energy resources, wherever feasible.
- > Recognizing effects of our employees and their family members in energy conservation initiatives.
- > Going beyond standards, wherever economically viable.
- > Yardsticks, which drive us to monitor and improve energy performance through periodic reviews and skill up gradation of our employees.

As a part of our energy conservation and environmental strategy, our organisation is committed to reduce its specific energy consumption by a minimum of 2% from the present level by the year 2010.

The policy shall be made available to interested parties.

23<sup>rd</sup> August 2002

A handwritten signature in black ink, appearing to read "Rabindra Misra".

Rabindra Misra  
Chief Executive

**INDIAN ALUMINIUM COMPANY LIMITED, HIRAKUD**



**ITC Limited  
Bhadrachalam Paperboards Division  
(An ISO 9001, ISO 14001 company)**

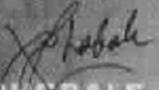


### **ENERGY POLICY**

**We at ITC BHADRACHALAM PAPERBOARDS DIVISION commit ourselves to continuously improve our Energy performance in all our activities, products and services.**

**To meet above goals we will strive for**

- > Maximization of cogeneration
- > Adopting appropriate energy conservation Technologies to all our projects.
- > Replacement of energy inefficient equipment with energy efficient equipment.
- > Conducting conservation studies including audits by engaging external specialists in the respective areas.
- > Creating awareness among employees and nearby population through campaigns, publicity about the need for energy conservation.
- > Bench marking of energy consumption levels with the best in class, Internationally.
- > Recognizing the efforts of employees in energy conservation initiatives and suitably rewarding them.
- > Closely monitoring and controlling the energy consumption by utilizing effective energy management systems.
- > Maximizing the recovery of waste energy.
- > Reducing Specific Energy Consumption at least by 2% annually.

  
**PRADEEP DHABALE**

**Chief Executive**

**ITC Limited-Bhadrachalam Paperboards Division**

## **ENERGY MANAGEMENT POLICY**

**Tata Chemicals Limited**

Fertilizer Division, Babrala

M/s Tata Chemicals Limited in it's endeavour to play leading role in the important economic issue of our Nation, it is committed and continually striving to be the lowest specific energy consumer in the industry it operates.

At Babrala we believe that Communication, Culture and Commitment are the key driving forces for us in making Energy Conservation (ENCON) a way of life at our plant. We plan to achieve this by following:

- Manage efficiently the utilization of energy resources (like Natural gas, Naphtha, HSD), updating hardware, operational practices and employs cleaner and more efficient technology as appropriate.
- Train and educate our Employees/Residents to be the trendsetter in the areas of ENCON.
- Carry out regular internal and external audits to identify and communicate areas of improvements and benchmark continuously our performance against the world best, to identify the ENCON opportunities.
- Share and enrich our experiences on energy conservation with other organisation, and own group companies.

As a part of ENCON strategy, Babrala is committed to reduce our specific energy consumption of urea @ 1.0% minimum every year till 2007, by promoting the culture of innovation and creativity, and aligning the commitment at all levels.

Date: 18<sup>th</sup> April, 2003 P M Khanderia

Place: TCL, Babrala General Manager-Operations

## **ENERGY POLICY**

### **(Hindalco Industries Limited)**

As a way of life, we, the employees of Hindalco Industries Limited are committed and pledge to conserve energy judiciously in all our activities, products and services across the organisation. We shall endeavour to transform energy conservation into a strategic business goal fully aligning with technological advancements by improving the skill and knowledge of our employees for sustainable development.

To achieve excellence, our objectives therefore will be:

- to reduce specific energy consumption in all our operations and activities
- to produce high purity metal with high conductivity to achieve minimum power losses.
- to conserve fossil fuels through enhanced use of renewable energy/recovered waste energy
- to adopt energy efficient technologies/equipment for all new projects
- to ensure energy conservation awareness programme throughout the organisation
- to recognize efforts of our employee and their family members in energy conservation initiatives
- to replace old energy inefficient technology/equipment with the latest energy efficient state of art technology / equipment continually
- to control energy consumption by periodic review and improving our processes by motivation and training practices
- to sustain energy efficiency gains by establishing and maintaining a management information system designed to support managerial decision-making
- to conduct regular management reviews to ensure continual improvement and achieve our goal

Date:10.8.02 A.K. Agarwala

Director (whole time)

## **Rashtriya Ispat Nigam Limited**

### **Visakhapatnam Steel Plant**

## **ENERGY POLICY**

We, at Visakhapatnam Steel Plant, are committed to optimally utilise various forms of energy in a cost effective manner to effect conservation of energy resources. To accomplish this we will :

- monitor closely and control the consumption of various forms of energy through an effective energy management system
- adopt appropriate energy conservation technologies
- maximise the use of cheaper and easily available forms of energy

- make energy conservation a mass movement with the involvement of all employees
- Maximise recovery of waste energy
- Reduce specific energy consumption by 1% per year by 2010

14-06-2002

Date Dr. B.N. Singh  
Chairman-cum-Managing Director

**KESORAM RAYON**  
**(Division of Kesoram Industries Ltd.)**

**ENERGY POLICY**

We shall strive for continuous energy economy by,

- formulation of overall energy strategy and targets
- all round participation of all employees through small group activities
- Improved capacity utilization
- upgradation of process, technology and equipment
- better plant layout

As a part of our energy conservation and environment protection, we are committed to reduce specific energy consumption by 1% every year till 2010.

**J.D. PALOD**

President

**NRC LIMITED**

**ENERGY CONSERVATION POLICY**

NRC Limited is committed to energy conservation for all its products & related operations. Efforts will be made to reduce energy consumption in every possible ways as under:

- Replacing old & outdated machinery, equipment by new energy efficient equipment
- Benchmarking all products/services for energy consumption by comparison at regional as well as national level
- Conducting energy conservation studies including audits with a view to minimise waste.
- **Creating awareness among employees & nearby population through campaigns, publicity about need for energy conservation**
- We are committed to reduce our energy consumption by minimum 1% every year till 2010.

P.S. Sharma

Managing Director

Maral Overseas Limited

**P.O.Maral Sarovar, A.B.Road**

**Khalbijurg – 451660**

**District Khargone (M.P.)**

**ENERGY CONSERVATION POLICY**

We are committed to conserve the energy which is a scarce resource with the requisite consistency in the efficiency, effectiveness in the cost involved in the operations and ensuring that production quality and quantity, environment, safety, health of people are maintained.

**We are also committed to monitoring continuously the saving achieved and reduce its specific energy consumption by minimum of 1% every year.**

M S. ANJANE

PRESIDENT

## Summary

- Energy efficiency is extremely important to all organisations, especially those that are energy intensive.
- The four vital requirements for a successful energy management is
  - technical ability
  - monitoring system
  - strategy plan
  - top management support
- Organisations seeking financial returns from superior energy management continuously strive to improve their energy performance.
- Their success is based on regularly assessing energy performance, planning and implementing action plans to improve energy efficiency.
- Top management shall make a commitment to allocate manpower and funds to achieve continuous improvement.
- To establish the energy management programme, leading organisations appoint energy manager, form a dedicated energy team and institute an energy policy.
- Prepare an annual activity plan and present to management concerning financially attractive investments to reduce energy costs.
- Establish an energy conservation cell within the firm with management's consent about the mandate and task of the cell.
- Initiate activities to improve monitoring and process control to reduce energy costs.
- Report the information once a year to BEE and state level designated agency regarding the energy consumed and action taken on the recommendation of the accredited energy auditor, as per BEE Format.
- Establish an improved data recording, collection and analysis system to keep track of energy consumption.
- The tasks of energy manger are setting goals, tracking progress, and promoting the energy management program.
- An energy Manager helps an organisation achieve its goals by establishing energy performance as a core value.
- The Energy Manager is not always an expert in energy and technical systems.
- In the energy management function, whether vested in one “energy manager or coordinator” or distributed among a number of middle managers.
- The tasks of energy team are executing energy management activities across different parts of the organisation and ensuring integration of best practices.
- Decisions affecting energy use are made every day by employees at all levels in an organisation. Creating an energy team helps to integrate energy management activities in an organisation.
- In addition to the Energy Manager who leads the team and dedicated energy staff, the team can include a representative from each operational area that significantly affects energy use, such as:
  - engineering
  - purchasing
  - operations and maintenance
  - building/facilities management
  - environmental health and safety
  - contractors and suppliers
  - utilities
- Energy policy provides the foundation for setting performance goals and integrating energy management into an organisation's culture and operations.
- A public expression of the organisation's commitment to energy conservation and environmental protection.

- A working document to guide the energy management practices and provides continuity.
- Understanding current and past energy use, helps an organisation identify opportunities to improve energy performance and gain financial benefits.
- A system for tracking performance can range from a simple spreadsheet to detailed databases and IT systems.
- Compare the energy performance of facilities to each other, peers and competitors, and over time to prioritize which facilities to focus on for improvements.
- Using training to help staff understand the importance of energy performance provides the information necessary to make informed decisions.
- Training also provides an excellent opportunity for gathering employee feedback and evaluations.
- Offering incentives for energy management is one way many organisations create interest in energy initiatives and foster a sense of ownership among employees.
- A tracking system is the means by which an energy program's activities are monitored. The system should be centralized and available for all to use in gauging progress toward established targets, milestones, and deadlines.
- Evaluating progress includes formal review of both energy use data and the activities carried out as part of the action plan as compared to your performance goals.
- Compare energy performance to baselines
- Compare performance against established goals for, environmental performance, financial savings and compare energy performance to peers and competitors to establish a relative understanding of where your performance ranks
- Providing and seeking recognition for energy management achievements is a proven step for sustaining momentum and support for your program.
- Recognizing the accomplishments of individuals and teams is key to sustaining support and momentum for energy management initiatives.
- There are a variety of ways to provide recognition and rewards. Depending on the purpose of the recognition program and your organisational culture, forms of recognition can range from formal acknowledgements and certificates, to salary increases and cash bonuses, to simple forms of appreciation such as shields or energy program shirts.

## References

- EnergyAction Planning[Pdf] Available at: <<http://www.em-ea.org/Guide%20Books/Book-1/1.5%20Energy%20Action%20Planning.pdf>> [Accessed 8 July 2013].
- How to develop a SustainableEnergyAction Plan [Pdf] Available at: <[http://www.eumayors.eu/IMG/pdf/seap\\_guidelines\\_en.pdf](http://www.eumayors.eu/IMG/pdf/seap_guidelines_en.pdf)> [Accessed 8 July 2013].
- Doty, S. and Turner, W. C., 2009. Energy management handbook. The Fairmont Press, Inc.
- Capehart, B.L., Turner, W.C. and Kennedy, W.J., 2008. Guide to Energy Management. The Fairmont Press.
- Big Switch Projects: Energy Action Plan - the next steps[Video online] Available at: <[http://www.youtube.com/watch?v=AFO\\_as2EaS4](http://www.youtube.com/watch?v=AFO_as2EaS4)> [Accessed 8 July 2013].
- USFWS's Region 6 Landscape-scale Energy Action Plan (LEAP)[Video online] Available at: <<http://www.youtube.com/watch?v=ekaybgRLOXs>> [Accessed 8 July 2013].

## Recommended Reading

- Thumann, A. and Mehta, D.P., 2008. Handbook of Energy Engineering. The Fairmont Press.
- Lamb, J., 2009. The greening of IT: how companies can make a difference for the environment. Pearson Education.
- Cotts, D. G., Roper, K. O. and Payant, R.P., 2010. The facility management handbook. AMACOM Div American Mgmt Assn.

## Self Assessment

1. \_\_\_\_\_ provides the foundation for setting performance goals and integrating energy management into an organisation's culture and operations.
  - a. Energy policy
  - b. Energy team
  - c. Energy manager
  - d. Shop manager
2. What can motivate staff to support energy management efforts throughout the organisation?
  - a. plan and develop an audit strategy
  - b. review policies and procedures
  - c. communicating and posting goals
  - d. process or equipment
3. Which of the following statement is true?
  - a. Goals are expressed as a function of increasing the energy intensity of a specific performance indicator, such as 5 kWh per unit of product.
  - b. Good communication does not require careful planning and implementation.
  - c. Successful organisations use a detailed action plan to ensure a disorganised process to implement energy performance measures.
  - d. Gaining the support and cooperation of key people at different levels within the organisation is an important factor for successful implementation of the action plan in many organisations.
4. Which is a simple tool that can be used to gain additional insight about the change process to be pursued?
  - a. Efficiency improvement
  - b. Force field analysis
  - c. Benchmarking
  - d. Reviewing performance data
5. Recognising the accomplishments of individuals and teams is a key to sustaining support and momentum for \_\_\_\_\_ initiatives.
  - a. review action plan
  - b. feedback
  - c. energy management
  - d. capital investments
6. Which type of information systems provide a robust means for sharing information on best practices, technologies, and operational guidance?
  - a. Print-based
  - b. Computer-based
  - c. Audio-based
  - d. Video-based

7. Setting goals helps the energy manager
  - a. To develop effective performance goals, determine scope, estimate potential for improvement and finally establish goals.
  - b. Review organisational policies and operating procedures to determine their impact on energy use.
  - c. Determine the starting point from which to measure progress
  - d. Energy policy provides the foundation for setting performance goals and integrating energy management into an organisation's culture and operations
8. Which of the following is true?
  - a. Reporting and communicating allows comparing the energy performance of similar facilities or an established level of performance.
  - b. Energy team can encourage communication and the sharing of ideas with only one department in an organisation.
  - c. Providing and seeking recognition for energy management achievements is a proven step for sustaining momentum and support for the program.
  - d. Assesses the uselessness of the tracking system and other administrative tools to ensure better management and evaluation.
9. \_\_\_\_\_ allows us to compare the energy performance of similar facilities or an established level of performance.
  - a. Track & Monitor
  - b. Get feedback
  - c. Measure results
  - d. Benchmarking
10. Which of the following statement is false?
  - a. Recognition can strengthen the morale of everyone involved in energy management.
  - b. Providing and seeking recognition for energy management achievements is a proven step for sustaining momentum and support for the program
  - c. Assesses the uselessness of the tracking system and other administrative tools to ensure better management and evaluation
  - d. When setting goals, be sure to use the Energy Team's wide range of knowledge to help set aggressive, yet realistic goals.

# **Chapter VI**

## **Financial Management**

### **Aim**

The aim of this chapter is to:

- introduce the need for investment appraisal and criteria
- explicate financial analysis
- explain return on investment

### **Objectives**

The objectives of the chapter are to:

- explain the investment need, appraisal and criteria
- define the knowledge of financial analysis and its techniques
- explicate cash flow and net present value

### **Learning outcome**

At the end of this chapter you will be able to:

- define the need for investment appraisal and criteria
- recognise the importance of return on investment and internal rate of return
- understand restate net present value and cash flow

## 6.1 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 product 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.

## 6.2 Investment Need, Appraisal and Criteria

To persuade an individual's organisation to commit itself to a program of investment in energy efficiency, they 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 management practices for controlling energy consumption throughout your organisation.

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 services, 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 problem which many energy managers face is justifying why their organisation should

invest money in increasing its energy efficiency, especially when there are other, seemingly more important priorities for the use of its capital.

- Organisation typically gives 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 the organisation to the maximum effect. To do this, they have 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

## **6.3 Financial Analysis**

In most respects, investment in energy efficiency is no different from any other area of financial management. So when your organisation first decides to invest in increasing its energy efficiency 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): measures 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 organisation decides to fund a rolling program of such investments, then over time it will become increasingly difficult for you to identify 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 investment 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 organisation, to people who can employ them on your behalf.

There are two quite separate grounds for arguing that, at least towards the later part of your energy management program, your organisation could begin to apply a slower rate of return to its investments in energy efficiency than it applies elsewhere.

The benefits arising from some energy saving measures may continue 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 the organisation's maintenance policy and practices in order to protect any investment already made in reducing your organisation's energy consumption. 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 realised.

## **6.4 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 recovering the initial investment (First Cost), considering only the Net Annual Saving:

The simple payback period is usually calculated as follows:

$$\text{Simple payback period (SPP)} = \frac{\text{First Cost}}{\text{Yearly Benefits} - \text{Yearly Costs}}$$

### **Examples**

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:

$$SPP = \frac{60}{20 - 15} = 3 \text{ Years } 3 \text{ months}$$

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:

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

**Table 6.1 Cash flow in two projects**

The payback criterion prefers A, which has a payback period of 3 years, in comparison to B, 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 useful 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 various cash flows are related is called discounting, or the present value concept.

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 equivalent 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:

$$\text{Future Value (FV)} = \text{NPV} (1 + i)^n \text{ or } \text{NPV} = \text{FV} / (1+i)^n$$

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 project life or capital cost for comparison.

This is a broad indicator of the annual return expected from initial capital investment, expressed as a percentage:

$$ROI = \frac{\text{Annual Net Cash}}{\text{Capital Cost}} \times 100$$

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,

$$NPV = \frac{CF_0}{(1+k)^0} + \frac{CF_1}{(1+k)^1} + \dots + \frac{CF_n}{(1+k)^n} = \sum_{t=0}^n \frac{CF_t}{(1+k)^t}$$

Where,

NPV = Net Present Value

$CF_t$  = Cash flow occurring at the end of year 't' ( $t_0=0,1,\dots,n$ )

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

**Table 6.2 Cash flow stream in a project**

The cost of capital,  $k$ , 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 (IRR)

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 discounted benefits become just equal to total discounted costs (i.e. net present benefits or net annual 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 present value (NPV) equal to zero. It is the discount rate in the equation:

$$0 = \frac{CF_0}{(1+k)^0} + \frac{CF_1}{(1+k)^1} + \dots + \frac{CF_n}{(1+k)^n} = \sum_{t=0}^n \frac{CF_t}{(1+k)^t}$$

Where,

$CF_t$  = cash flow at the end of year “t”

$\hat{k}$  = discount rate

n = life of the project

$CF_t$  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

**Table 6.3 Cash flow in a project**

The internal rate of return is the value of “k” which satisfies the following equation:

$$100,000 = \frac{30,000}{(1+k)^1} + \frac{30,000}{(1+k)^2} + \frac{40,000}{(1+k)^3} + \frac{45,000}{(1+k)^4}$$

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:

$$\frac{30,000}{(1.15)} + \frac{30,000}{(1.15)^2} + \frac{40,000}{(1.15)^3} + \frac{45,000}{(1.15)^4} = 100,802$$

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  $r$  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 advantages:

- 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:

$$\text{Rs.}500,000 = \text{Rs.}150,000 \times PV(A = 10 \text{ years}, i = ?)$$

To do this, calculate the net present value (NPV) for various i values, selected by visual inspection;

$$NPV \text{ } 25\% = \text{Rs.}150,000 \times 3.571 - \text{Rs.}500,000$$

$$= \text{Rs.}35,650$$

$$NPV \text{ } 30\% = \text{Rs.}150,000 \times 3.092 - \text{Rs.}500,000$$

$$= -\text{Rs.}36,200$$

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:

$$i = 0.25 + (0.30-0.25) \times 35650 / (35650 + 36200)$$

$$= 0.275, \text{ or } 27.5 \text{ percent}$$

### **Cash Flows**

Generally there are two kinds of cash flow; the initial investment as one or more instalments, and the savings arising from the investment. This over simplifies the reality of energy management 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, and installation and commissioning of the project; these are usually one-time costs unaffected by inflation or discount rate factors, although, as in the example, instalments 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, servicing, maintenance, operating labour, and so on. Increases in any of these costs represent 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 project, 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 uncertainty. The present day cash flows, such as capital cost, energy cost savings, maintenance costs, and 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 mitigating 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.

### Risk and Sensitivity Analysis Factors

The various factors taking into account effects of price change, government policy changes (depreciation, interest, and tax related issues), and technology changes with suitable examples are summarised in Table 2.1.

No.	Purpose
1	To determine the future value of a principal sum at an interest rate "i". $FV = P \times (1 + i)^n$
2	To determine the present value of a future principal sum or cost at interest rate "i". $PV = FV \times 1 / (1 + i)^n$
3	To determine the future value of a one time base year cost escalating at a rate "e". $FV = P \times (1 + e)^n$
4	To determine the present value of a cost in year "n", based on a given base year cost, escalating annually at an escalation rate "e" and with an interest rate "i". $PV = P \times (1 + e/1 + i)^n$
5	To determine the future value of a series of uniform annual amounts at an interest rate "i". $FV = A \times [(1 + i)^n - 1]/i$
6	To determine the present value of a series of uniform annual amounts at an interest rate "i". $PV = A \times [(1 + i)^n - 1] / [i \times (1 + i)^n]$
7	To determine the present value of a series of uniform annual amounts increasing at an escalation rate "e" and with interest rate "i". $PV = \frac{A \times 1 - \left[ \frac{1 + e}{1 + i} \right]^n}{\left[ \frac{1 + i}{1 + e} \right] - 1}$ Valid for e.i. If e=i, PV=A×n
8	To determine the future value of a series of uniform annual amounts increasing at an escalation rate "e" and with Interest rate "i". Use two steps: <ul style="list-style-type: none"> <li>• Eq-1 to determine PV</li> <li>• Eq-1 to determine FV</li> </ul>
9	To determine the uniform annual amount required to repay a principal sum at interest rate "i". $PV = \frac{P \times i \times (1 + i)^n}{(1 + i)^n - 1}$

10	To determine the uniform annual amount which at interest rate “i” will have a future value FV.	$A = FV \times \frac{i}{(1+i)n - 1}$
11	To determine the present value of future cash flows by declining balance depreciation of capital expenditure “P” at depreciation rate “d”, tax rate “t”, and interest rate “i”.	$PV = \frac{P \times d \times t}{(1+d)}$

**Note:**

- FV: Future Value
- PV: Present Value
- A: Amount
- i: Interest rate
- d: Depreciation rate
- n: No of years
- e: Escalation rate

**Table 6.4 Risk and sensitivity analysis factors**

### Financing Options

There are various options for financing in-house energy management

- From a central budget
- From a specific departmental or section budget such as engineering
- By obtaining a bank loan
- By raising money from stock market
- By awarding the project to Energy Service Company (ESCO)
- 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 organisation understand 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 organisation 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 organisation ought to be able to make considerable 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 them, 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 organisations 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 realised, 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 revenues from the sale of outputs. The energy cost savings can be turned into incremental cash flows to the lender or ESCO based on the commitment of the energy user (and in some cases, a utility) to pay for the savings.

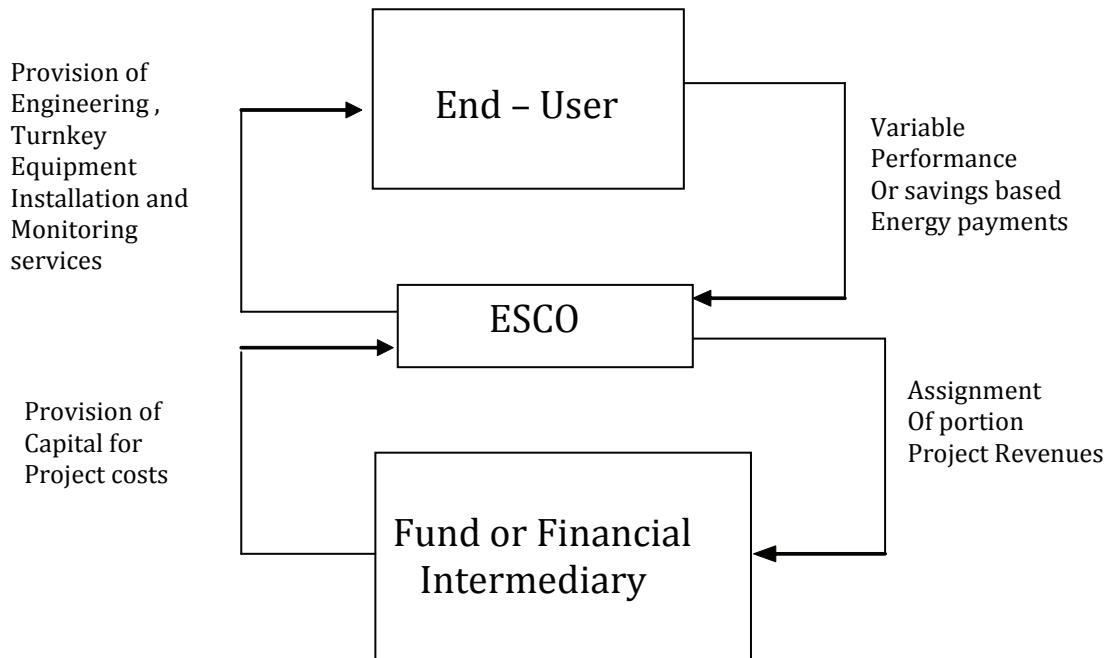
### **What is Performance Contracting?**

The core of performance contracting is an agreement involving a comprehensive package of services provided by an ESCO, including:

- an energy efficiency opportunity analysis
- project development
- engineering
- financing
- construction/Implementation
- training
- monitoring and verification

Monitoring and verification, is key to the successful involvement of an ESCO in performance contracting where energy cost savings are being guaranteed.

ESCos are not “bankers” in the narrow sense. Their strength is in putting together a package of services that can provide guaranteed and measurable energy savings that serve as the basis for guaranteed cost savings. But, the energy savings must be measurable. The Figure 6.1 shows ESCO Role.



**Fig. 6.1 ESCO role**

### What are performance contracts?

Performance contracting represents one of the ways to address several of the most frequently 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 minimizes or eliminates the up-front cash outlay required by the end-user. Payments are made over time as the energy savings are realised.

### Cost Calculation

The following are the main components of cost which are considered for calculations

Capital cost servicing is as follows:

- Interest on borrowings.
- Depreciation.
- Insurance of the asset /year.
- Maintenance cost / year.
- Additional cost of training if any.

Sum total of the above to be compared with the savings accrued per year.

## Summary

- 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.
- To persuade an individual's organisation to commit itself to a program of investment in energy efficiency, they 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.
- Any investment has to be seen as an addition and not as a substitute for having effective management practices for controlling energy consumption throughout your organisation.
- Any investment has to be seen as an addition and not as a substitute for having effective management practices for controlling energy consumption throughout your organisation.
- They have 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
- It is essential to keep a careful watch on your organisation's maintenance policy and practices in order to protect any investment already made in reducing your organisation's energy consumption. There is a clear dependence relationship between energy efficiency and maintenance.
- The simple payback period is usually calculated as follows:

$$\text{Simple payback period (SPP)} = \frac{\text{First Cost}}{\text{Yearly Benefits} - \text{Yearly Costs}}$$

$$ROI = \frac{\text{Annual Net Cash}}{\text{Capital Cost}} \times 100$$

- 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,

$$NPV = \frac{CF_0}{(1 + k)^0} + \frac{CF_1}{(1 + k)^1} + \dots + \frac{CF_n}{(1 + k)^n} = \sum_{t=0}^n \frac{CF_t}{(1 + k)^t}$$

- 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).
- Generally there are two kinds of cash flow; the initial investment as one or more instalments, and the savings arising from the investment. This over simplifies the reality of energy management investment.
- Many of the cash flows in the project are based on assumptions that have an element of uncertainty. The present day cash flows, such as capital cost, energy cost savings, maintenance costs, and etc can usually be estimated fairly accurately.
- 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.

- If the project is to be financed externally, one of the attractive options for many organisations is the use of energy performance contracts delivered by energy service companies, or ESCOs.

## References

- Fundamentals of Financial Management[Pdf] Available at: <<http://www.bhuiyanacademyedu.com/ebooks/Fundamentals%20of%20Financial%20Management.pdf>> [Accessed 8 July 2013].
- Financial management of Business Expansion, Combination and Acquisition [Pdf] Available at: <<http://www.ddejust.ac.in/studymaterial/mcom/mc-204.pdf>> [Accessed 8 July 2013].
- Brigham, E.F. and Ehrhardt, M.C., 2008. Financial management: Theory and Practice. Cengage Learning.
- Correia, C., Flynn, D., Uliana, E. and Wormald, M., 2007. Financial Management. Juta and Company Ltd.
- Financial Management[Video online] Available at: <<http://www.youtube.com/watch?v=iDlFPm3fqbs>> [Accessed 8 July 2013].
- Finance: What Managers Need to Know[Video online] Available at: <<http://www.youtube.com/watch?v=aJsmJsd6GIw>> [Accessed 8 July 2013].

## Recommended Reading

- Chandra, P., 2008. Financial Management. Tata McGraw-Hill.
- Shim, J.K. and Siegal, J. G., 2008. Financial Management. Barron's Educational Series.
- VanHome, J. C. and Wachowicz, J.M., 2008. Fundamentals Of Financial Management. Financial Times/Prentice Hall.

## Self Assessment

1. Spending money on technical improvements for energy management cannot compensate for inadequate attention to gaining control over \_\_\_\_\_.
  - a. energy cost
  - b. energy efficiency
  - c. energy saving
  - d. energy consumption
  
2. Which of the following statement is true?
  - a. 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.
  - b. Energy efficiency projects generate incremental cost savings as similar to incremental revenues from the sale of outputs.
  - c. ESCOs are “bankers” in the narrow sense
  - d. Taxes, using the crucial tax rate applied to positive (i.e. increasing taxes) or negative (i.e. decreasing taxes) Net Present Value.
  
3. \_\_\_\_\_, is key to the successful involvement of an ESCO in performance contracting where energy cost savings are being guaranteed
  - a. Macro economic
  - b. Micro economic
  - c. Monitoring and verification
  - d. Cash Flows
  
4. The simple pay back period is equal to
  - a. Annual net cash/Capital Cost
  - b. First cost/net yearly saving
  - c. Insurance of the asset /year
  - d. Maintenance cost / year
  
5. ESCOs mean
  - a. Energy Service Companies
  - b. Escort Service Companies
  - c. Efficiency Service Companies
  - d. Energy Social Correlation
  
6. Match the following
 

1. Micro factors	a. “annual return”
2. sensitivity analysis	b. Depreciation
3. Return on Investment expresses the	c. Capital structure
4. Cost Calculation	d.” what if”

a. 1-d, 2-a, 3-b, 4-c  
 b. 1-b, 2-c, 3-d, 4-a  
 c. 1-c, 2-d, 3-a, 4-b  
 d. 1-d, 2-c, 3-b, 4-a

7. Which of the following statement is false?
  - a. Energy manager has to identify how cost savings arising from energy management could be redeployed within the organisation to the maximum effect.
  - b. Spending money on technical improvements for energy management cannot compensate for inadequate attention to gaining control over energy efficiency.
  - c. Investment would be required for modifications/retrofitting and for incorporating new technology.
  - d. Energy manager has to identify how cost savings arising from energy management could be redeployed within the organisation to the maximum effect.
8. Financing option for in-house energy management is
  - a. by retaining a proportion of the savings achieved
  - b. changes in interest rates
  - c. costs of debt, equity
  - d. simple payback
9. It is essential to keep a careful watch on the organisation's maintenance policy and practices in order to protect any investment already made in reducing your organisation's energy consumption.
  - a. energy cost
  - b. energy consumption
  - c. energy efficiency
  - d. energy saving
10. ROI must always be \_\_\_\_\_ than cost of money (interest rate); the greater the return on investment better is the investment.
  - a. lower
  - b. medium
  - c. higher
  - d. decreasing

## Chapter VII

# Project Management

### Aim

The aim of this chapter is to:

- introduce project planning and its importance to energy management
- explicate the components of project management
- elucidate project planning and monitoring techniques

### Objectives

The objectives of the chapter are to:

- explain the project management life cycle
- analyse financing options for implementing energy management projects
- define Performance Indicators (PIs)

### Learning outcome

At the end of this chapter you will be able to:

- explain the definition and scope of project
- identify the elements of project management
- understand project planning techniques

## **7.1 Introduction**

Project management is concerned with the overall planning, co-ordinating, securing and managing resources of a project to result in a successful completion of an aimed meeting the stated requirements and ensuring completion on time, within the cost and to the required quality standards. Project management is normally reserved for focused, non-repetitive, time-limited activities with some degree of risk and that are beyond the usual scope of operational activities for which the organisation is responsible.

## **7.2 Steps in Project Management**

The following are the various steps involved in a project management:

- Project Definition and Scope
- Technical Design
- Financing
- Contracting
- Implementation
- Performance Monitoring

## **7.3 Definition and Scope**

### **What is a Project?**

“A project is a one-shot, time-limited, goal-directed, major undertaking, requiring the commitment of varied skills and resources”.

- A project is a temporary endeavour undertaken to create a unique product or service. A project is temporary in that there is a defined start (the decision to proceed) and a defined end (the achievement of the goals and objectives). Ongoing business or maintenance operations are not projects.
- Energy conservation projects and process improvement efforts that result in better business processes or more efficient operations can be defined as projects.
- Projects usually include constraints and risks regarding cost, schedule or performance outcome.

### **Four Basic Elements of Project Management**

A successful Project Manager must simultaneously manage the four basic elements of a project: resources, time, cost, and scope. Each element must be managed effectively. All these elements are interrelated and must be managed together if the project, and the project manager, is to be a success.

#### **Managing Resources**

A successful Project Manager must effectively manage the resources assigned to the project. This includes the labour hours of the project team. It also includes managing labour subcontracts and vendors. Managing the people resources means having the right people, with the right skills and the proper tools, in the right quantity at the right time. However, managing project resources frequently involves more than people management. The project manager musts also manage the equipment (cranes, trucks and other heavy equipment) used for the project and the material (pipe, insulation, computers, manuals) assigned to the project.

#### **Managing Time and Schedule**

Time management is a critical skill for any successful project manager. The most common cause of bloated project budgets is lack of schedule management. Fortunately there is a lot of software on the market today to help you manage your project schedule or timeline.

Any project can be broken down into a number of tasks that have to be performed. To prepare the project schedule, the project manager has to figure out what the tasks are, how long they will take, what resources they require, and in what order they should be done.

### Managing Costs

Often a Project Manager is evaluated on his or her ability to complete a project within budget. The costs include estimated cost, actual cost and variability. Contingency cost takes into account influence of weather, suppliers and design allowances.

### Scope

Scope should be clearly understood by all involved in the project. It includes the objects, methodology and the desired outcome.

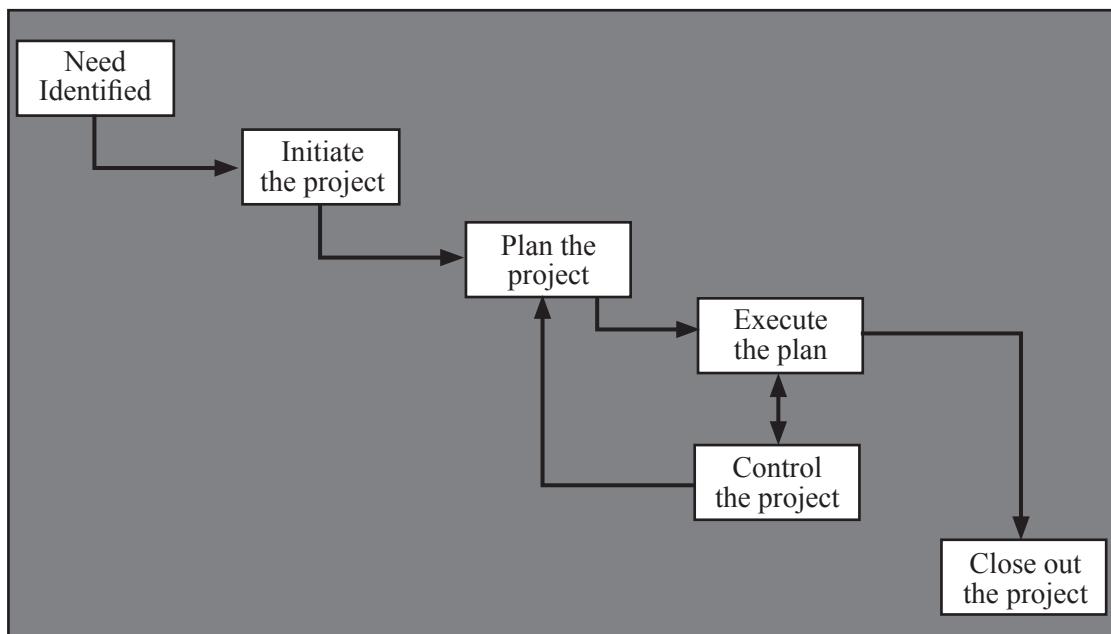
### How the 80/20 Rule can help a project manager

The 80/20 Rule means that in anything a few (20 percent) are vital and many (80 percent) are trivial. Successful Project Managers know that 20 percent of the work (the first 10 percent and the last 10 percent) consumes 80 percent of your time and resources.

## 7.4 Project Management Life Cycle

The process flow of Project management processes is shown in Fig.7.1. The various elements of project management life cycle are

- need identification
- initiation
- planning
- executing
- controlling
- closing out



**Fig. 7.1 Process flow of a project management process**

The first step in the project development cycle is to identify components of the project. Projects may be identified both internally and externally

### Need Identification

- Internal identification takes place when the energy manager identifies a package of energy saving opportunities during the day-to-day energy management activities, or from facility audits.

- External identification of energy savings can occur through systematic energy audits undertaken by a reputable energy auditor or energy service company.

In screening projects, the following criteria should be used to rank-order project opportunities.

- Cost-effectiveness of energy savings of complete package of measures (Internal rate of return, net present value, cash flow, average payback)
- Sustainability of the savings over the life of the equipment.
- Ease of quantifying, monitoring, and verifying electricity and fuel savings.
- Availability of technology, and ease of adaptability of the technology to Indian conditions.
- Other environmental and social cost benefits (such as reduction in local pollutants, e.g. SO<sub>x</sub>)

### **Initiation**

- Initiating is the basic processes that should be performed to get the project started.
- The starting point is critical because those who will deliver the project, those who will use the project, and those who will have a stake in the project need to reach an agreement on its initiation.
- Involving all stakeholders in the project phases generally improves the probability of satisfying customer requirements by shared ownership of the project by the stakeholders.
- The success of the project team depends upon starting with complete and accurate information, management support, and the authorization necessary to manage the project.

### **Planning**

- The planning phase is considered the most important phase in project management.
- Project planning defines project activities that will be performed; the products that will be produced, and describes how these activities will be accomplished and managed.
- Project planning defines each major task, estimates the time, resources and cost required, and provides a framework for management review and control.
- Planning involves identifying and documenting scope, tasks, schedules, cost, risk, quality, and staffing needs.
- The result of the project planning, the project plan, will be an approved, comprehensive document that allows a project team to begin and complete the work necessary to achieve the project goals and objectives.
- The project plan will address how the project team will manage the project elements.
- It will provide a high level of confidence in the organisation's ability to meet the scope, timing, cost, and quality requirements by addressing all aspects of the project.

### **Executing**

- Once a project moves into the execution phase, the project team and all necessary resources to carry out the project should be in place and ready to perform project activities.
- The project plan is completed and base lined by this time as well.
- The project team and the project manager's focus now shifts from planning the project efforts to participating, observing, and analysing the work being done.

The execution phase is when the work activities of the project plan are executed, resulting in the completion of the project deliverables and achievement of the project objective(s). This phase brings together all of the project management disciplines, resulting in a product or service that will meet the project deliverable requirements and the customers need. During this phase, elements completed in the planning phase are implemented, time is expended, and money is spent.

In brief, it means coordinating and managing the project resources while executing the project plan, performing the planned project activities, and ensuring they are completed efficiently.

## Controlling

- Project Control function that involves comparing actual performance with planned performance and taking corrective action to get the desired outcome when there are significant differences.
- By monitoring and measuring progress regularly, identifying variances from plan, and taking corrective action if required, project control ensures that project objectives are met.

## Closing out

- Project closeout is performed after all defined project objectives have been met and the customer has formally accepted the project's deliverables and end product or, in some instances, when a project has been cancelled or terminated early.
- Although, project closeout is a routine process, it is an important one.
- By properly completing the project closeout, organisations can benefit from lessons learned and information compiled.
- The project closeout phase is comprised of contract closeout and administrative closure.

### 7.4.1 Technical Design

For a project to be taken up for investment, its proponent must present a sound technical feasibility study that identifies the following components:

- The proposed new technologies, process modifications, equipment replacements and other measures included in the project.
- Product/technology/material supply chain (e.g., locally available, imported, reliability of supply)
- Commercial viability of the complete package of measures (internal rate of return, net present value, cash flow, average payback).
- Any special technical complexities (installation, maintenance, repair), associated skills required.
- Preliminary designs, including schematics, for all major equipment needed, along with design requirements, manufacturer's name and contact details, and capital cost estimate.
- Organisational and management plan for implementation, including timetable, personnel requirements, staff training, project engineering, and other logistical issues.

### 7.4.2 Financing

When considering a new project, it should be remembered that other departments in the organisation would be competing for capital for their projects. However, it is also important to realise that energy efficiency is a major consideration in all types of projects, whether they are:

- Projects designed to improve energy efficiency
- Projects where energy efficiency is not the main objective, but still plays a vital role.

The funding for project is often outside the control of the project manager. However, it is important that you understand the principles behind the provision of scarce funds.

Project funds can be obtained from either internal or external sources.

Internal sources include:

- direct cash provision from company reserves
- from revenue budget (if payback is less than one year)
- new share capital

Funding can become an issue when energy efficiency projects have previously been given a lower priority than other projects. It is worth remembering that while the prioritization of projects may not be under our control, the quality of the project submission is.

External sources of funds include:

- bank loans
- leasing arrangement
- payment by savings i.e. a deal arranged with equipment supplier
- energy services contract
- private finance initiative

The availability of external funds depends on the nature of your organisation. The finance charges on the money you borrow will have a bearing on the validity of your project. Before applying for money, discuss all the options for funding the project with your finance managers. It is reiterated that energy savings often add substantially to the viability of other non-energy projects.

#### **7.4.3 Contracting**

Since a substantial portion of a project is typically executed through contracts, the proper management of contracts is critical to the successful implementation of the project. In this context, the following should be done:

- The competence and capability of all the contractors must be ensured. One weak link can affect the timely performance of the contract.
- Proper discipline must be enforced among contractors and suppliers by insisting that they should develop realistic and detailed resource and time plans that are matching with the project plan.
- Penalties may be imposed for failure to meet contractual obligations. Likewise, incentives may be offered for good performance.
- Help should be extended to contractors and suppliers when they have genuine problems.
- Project authorities must retain independence to off-load contracts (partially or wholly) to other parties where delays are anticipated.

If the project is to be implemented by an outside contractor, several types of contract may be used to undertake the installation and commissioning. These include:

- Traditional contract: All project specifications are provided to a contractor who purchases and installs equipment at cost plus a mark-up or fixed price.
- Extended technical Guarantee/Service: The contractor offers extended guarantees on the performance of selected equipment and / or service/maintenance agreements.
- Extended financing terms: The contractor provides the option of an extended lease or other financing vehicle in which the payment schedule can be based on the expected savings.
- Guaranteed saving performance contract: All or part of savings is guaranteed by the contractor, and all or part of the costs of equipment and/or services is paid down out of savings as they are achieved.
- Shared savings performance contract: The contractor provides the financing and is paid an agreed fraction of actual savings as they are achieved. This payment is used to pay down the debt costs of equipment and/or services.

#### **7.4.4 Implementation**

The main problems faced by project manager during implementation are poor monitoring of progress, not handling risks and poor cost management.

- Poor monitoring of progress: Project managers sometimes tend to spend most of their time in planning activity and surprisingly very less time in following up whether the implementation is following the plan. A proactive report generated by project planner software can really help the project manager to know whether the tasks are progressing as per the plan.
- Not handling risks: Risks have an uncanny habit of appearing at the least expected time. In spite of the best efforts of a project manager they are bound to happen. Risks need immediate and focused attention. Delay in dealing with risks cause the problem to aggravate and has negative consequences for the project.

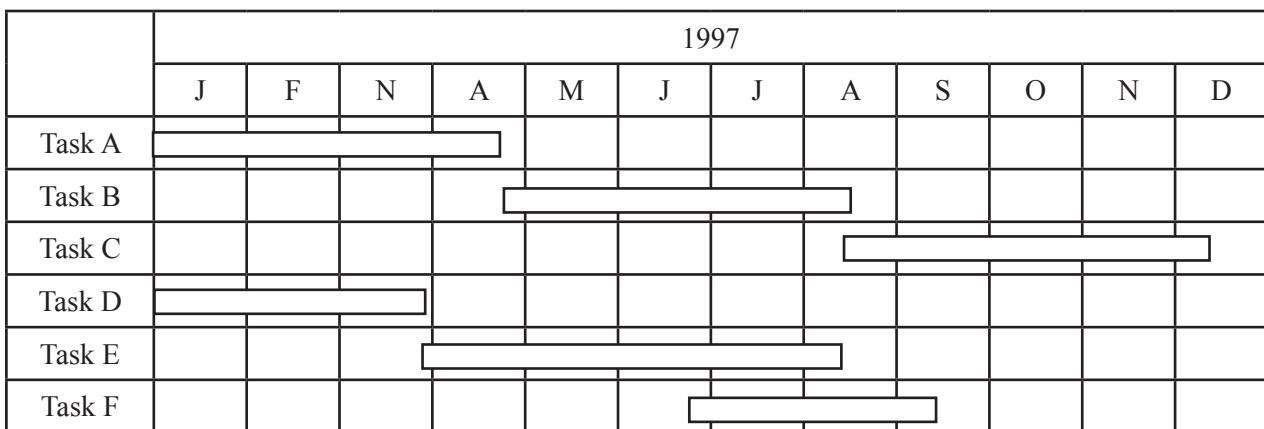
- Poor cost management: A project manager's success is measured by the amount of cost optimization done for a project. Managers frequently do all the cost optimization during the planning stages but fail to follow through during the rest of the stages of the project. The cost graphs in the Project planner software can help a manager to get an update on project cost overflow. The cost variance (The difference between approved cost and the projected cost should be always in the minds of the project managers).

## 7.5 Project Planning Techniques

The three basic project planning techniques are Gantt chart, CPM and PERT. All monitor progress and costs against resource budgets.

### Gantt Chart

- Gantt charts are also called Bar charts.
- The use of Gantt charts started during the industrial revolution of the late 1800's. An early industrial engineer named Henry Gantt developed these charts to improve factory efficiency.
- Gantt chart is now commonly used for scheduling the tasks and tracking the progress of energy management projects. Gantt charts are developed using bars to represent each task.
- The length of the bar shows how long the task is expected to take to complete. Duration is easily shown on Gantt charts. Sequence is not well shown on Gantt Charts (refer Fig. 7.2).



**Figure 7.2 Gantt chart**

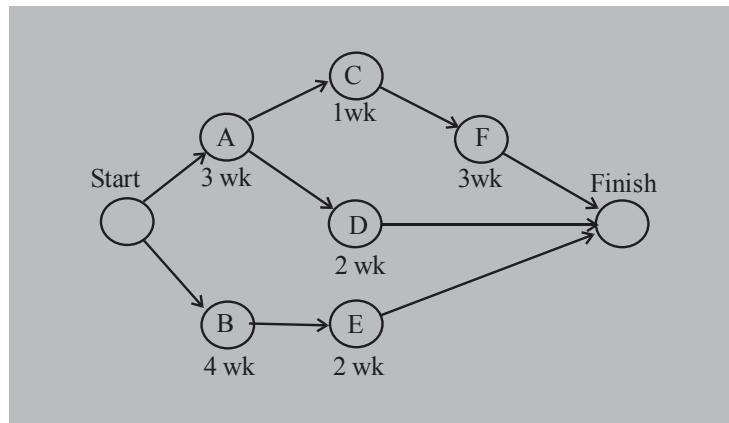
If, take an example, the start of Task C depends on both Activity B and Activity E, then any delay to Task E will also delay Task C. We just don't have enough information on the Gantt chart to know this information.

### CPM - Critical Path Method

“DuPont” developed a Critical Path Method (CPM) designed to address the challenge of shutting down chemical plants for maintenance and then restarting the plants once the maintenance had been completed.

Complex project, like the above example, require a series of activities, some of which must be performed sequentially and others that can be performed in parallel with other activities. This collection of series and parallel tasks can be modelled as a network.

CPM models the activities and events of a project as a network. Activities are shown as nodes on the network and events that signify the beginning or ending of activities are shown as arcs or lines between the nodes. The Fig.7.3 shows an example of a CPM network diagram:



**Fig.7.3 CPM diagram**

### Steps in CPM Project Planning

- Specify the individual activities.
- Determine the sequence of those activities.
- Draw a network diagram.
- Estimate the completion time for each activity.
- Identify the critical path (longest path through the network)
- Update the CPM diagram as the project progresses.

### Specify the individual activities

All the activities in the project are listed. This list can be used as the basis for adding sequence and duration information in later steps.

### Determine the sequence of the activities

Some activities are dependent on the completion of other activities. A list of the immediate predecessors of each activity is useful for constructing the CPM network diagram.

### Draw the Network Diagram

Once the activities and their sequences have been defined, the CPM diagram can be drawn. CPM originally was developed as an activity on node network.

### Estimate activity completion time

The time required to complete each activity can be estimated using past experience. CPM does not take into account variation in the completion time.

### Identify the Critical Path

The critical path is the longest-duration path through the network. The significance of the critical path is that the activities that lie on it cannot be delayed without delaying the project. Because of its impact on the entire project, critical path analysis is an important aspect of project planning.

The critical path can be identified by determining the following four parameters for each activity:

- ES - earliest start time: the earliest time at which the activity can start given that its predecessor activities must be completed first.
- EF - earliest finish time: equal to the earliest start time for the activity plus the time required completing the activity.
- LF - latest finish time: the latest time at which the activity can be completed without delaying the project.
- LS - latest start time: equal to the latest finish time minus the time required to complete the activity.

The slack time for an activity is the time between its earliest and latest start time, or between its earliest and latest finish time. Slack is the amount of time that an activity can be delayed past its earliest start or earliest finish without delaying the project.

The critical path is the path through the project network in which none of the activities have slack, that is, the path for which  $ES=LS$  and  $EF=LF$  for all activities in the path. A delay in the critical path delays the project. Similarly, to accelerate the project it is necessary to reduce the total time required for the activities in the critical path.

### **Update CPM diagram**

As the project progresses, the actual task completion times will be known and the network diagram can be updated to include this information. A new critical path may emerge, and structural changes may be made in the network if project requirements change.

### **CPM Benefits**

- Provides a graphical view of the project.
- Predicts the time required to complete the project.
- Shows which activities are critical to maintaining the schedule and which are not.

### **CPM Limitations**

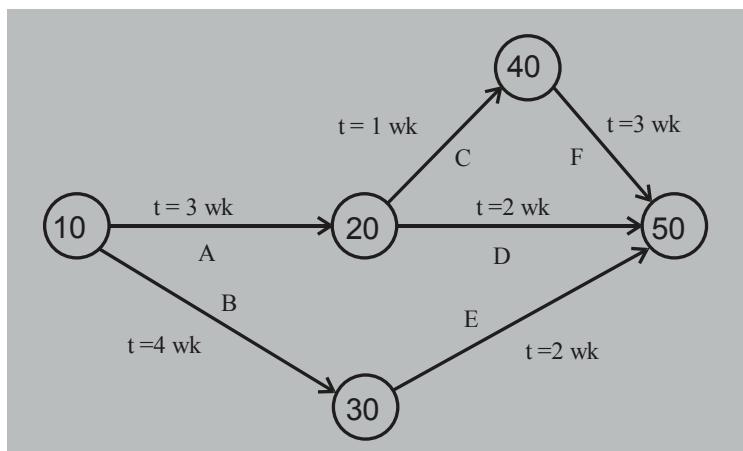
While CPM is easy to understand and use, it does not consider the time variations that can have a great impact on the completion time of a complex project. CPM was developed for complex but fairly routine projects with minimum uncertainty in the project completion times. For less routine projects there is more uncertainty in the completion times, and this uncertainty limits its usefulness.

### **PERT**

The Program Evaluation and Review Technique (PERT) is a network model that allows for randomness in activity completion times. PERT was developed in the late 1950's for the U.S. Navy's Polaris project having thousands of contractors. It has the potential to reduce both the time and cost required to complete a project.

### **The Network Diagram**

In a project, an activity is a task that must be performed and an event is a milestone marking the completion of one or more activities. Before an activity can begin, all of its predecessor activities must be completed. Project network models represent activities and milestones by arcs and nodes. PERT is typically represented as an activity on arc network, in which the activities are represented on the lines and milestones on the nodes. The Fig.7.4 shows a simple example of a PERT diagram.



**Fig.7.4 PERT chart**

The milestones generally are numbered so that the ending node of an activity has a higher number than the beginning node. Incrementing the numbers by 10 allows for new ones to be inserted without modifying the numbering of the entire diagram. The activities in the above diagram are labelled with letters along with the expected time required to complete the activity.

### Steps in the PERT Planning Process

PERT planning involves the following steps:

#### Identify activities and milestones

- The activities are the tasks required to complete the project. The milestones are the events marking the beginning and end of one or more activities.

#### Determine activity sequence

- This step may be combined with the activity identification step since the activity sequence is known for some tasks. Other tasks may require more analysis to determine the exact order in which they must be performed.

#### Construct the Network Diagram

- Using the activity sequence information, a network diagram can be drawn showing the sequence of the serial and parallel activities.

#### Estimate activity times

- Weeks are a commonly used unit of time for activity completion, but any consistent unit of time can be used.
- A distinguishing feature of PERT is its ability to deal with uncertainty in activity completion times. For each activity, the model usually includes three time estimates:
  - Optimistic time (OT): generally the shortest time in which the activity can be completed. (This is what an inexperienced manager believes!)
  - Most likely time (MT):- the completion time having the highest probability. This is different from expected time. Seasoned managers have an amazing way of estimating very close to actual data from prior estimation errors.
  - Pessimistic time (PT): the longest time that an activity might require.
- The expected time for each activity can be approximated using the following weighted average:  
$$\text{Expected time} = (\text{OT} + 4 \times \text{MT} + \text{PT}) / 6$$

This expected time might be displayed on the network diagram.

Variance for each activity is given by:

$$[(\text{PT} - \text{OT}) / 6]^2$$

#### Determine the Critical Path

The critical path is determined by adding the times for the activities in each sequence and determining the longest path in the project. The critical path determines the total time required for the project.

If activities outside the critical path speed up or slow down (within limits) the total project time does not change. The amount of time that a non-critical path activity can be delayed without delaying the project is referred to as slack time.

If the critical path is not immediately obvious, it may be helpful to determine the following four quantities for each activity:

- ES: Earliest Start time
- EF: Earliest Finish time
- LS: Latest Start time
- LF: Latest Finish time

These times are calculated using the expected time for the relevant activities. The ES and EF of each activity are determined by working forward through the network and determining the earliest time at which an activity can start and finish considering its predecessor activities.

The latest start and finish times are the latest times that an activity can start and finish without delaying the project. LS and LF are found by working backward through the network. The difference in the latest and earliest finish of each activity is that activity's slack. The critical path then is the path through the network in which none of the activities have slack.

The variance in the project completion time can be calculated by summing the variances in the completion times of the activities in the critical path. Given this variance, one can calculate the probability that the project will be completed by a certain date.

Since the critical path determines the completion date of the project, the project can be accelerated by adding the resources required to decrease the time for the activities in the critical path. Such a shortening of the project sometimes is referred to as project crashing.

### **Update as project progresses**

Make adjustments in the PERT chart as the project progresses. As the project unfolds, the estimated times can be replaced with actual times. In cases where there are delays, additional resources may be needed to stay on schedule and the PERT chart may be modified to reflect the new situation.

### **Benefits of PERT**

PERT is useful because it provides the following information:

- expected project completion time
- probability of completion before a specified date
- the critical path activities that directly impact the completion time
- the activities that have slack time and that can lend resources to critical path activities
- activities start and end dates

### **Limitations of PERT**

The following are some of PERT's limitations:

- The activity time estimates are somewhat subjective and depend on judgment. In cases where there is little experience in performing an activity, the numbers may be only a guess. In other cases, if the person or group performing the activity estimates the time there may be bias in the estimate.
- The underestimation of the project completion time due to alternate paths becoming critical is perhaps the most serious.

## **7.6 Performance Monitoring**

Once the project is completed, performance review should be done periodically to compare actual performance with projected performance. Feedback on project is useful in several ways:

- It helps us to know how realistic were the assumptions underlying the project.
- It provides a documented log of experience that is highly valuable in decision making in future projects.
- It suggests corrective action to be taken in the light of actual performance.
- It helps in uncovering judgmental biases.
- It includes a desired caution among project sponsors.

Performance Indicators (PIs) are an effective way of communicating a project's benefits, usually as part of a performance measuring and reporting process. Performance Indicators are available for a wide range of industries and allow a measure of energy performance to be assigned to a process against which others can be judged.

Depending on the nature of the project, savings are determined using engineering calculations, or through metering and monitoring, utility meter billing analysis, or computer simulations.

## 7.7 Implementation Plan for Top Management

As a result of energy audit, many energy saving opportunities would emerge. These could be classified broadly as measures with and without investment. House keeping measures and moderate cost measures need no intervention from top management. However, top management need to be apprised of these measures.

In case of projects where considerable investment are required, project manager has to rank the list of projects based on the technical feasibility and financial analysis indicated in the previous chapter (Simple payback, IRR, ROI etc.) and submit the same to the top management for appraisal and approval. This will help top management in allocating resources and other facilities.

### Planning Budget

Budget requirement varies depending upon the duration and size of the project. For projects involving long duration with multiple tasks and procurements, resources have to be allocated judiciously as and when required. Top management should ensure that this is done to ensure successful completion of project.

### Procurement Procedures

Having identified the material and equipment required for the project, the next step is to identify the various vendors, provide specifications, invite quotations, and carryout discussions with select vendors. For medium to high value items, tendering process can be adopted. Tenders have to be evaluated for technical and financial aspects. It would be desirable to have purchase manager as part of energy efficiency team to facilitate smooth procurement process.

### Construction

During the construction phase, plant may need to be shutdown. Careful planning is required, so that the task is carried out without affecting the production. Project manager has to be aware of the annual maintenance schedule, holidays, annual maintenance or any major breakdown period during which anyway plant will be shutdown. Construction activity should be carefully supervised by energy and project manager so as to ensure quality and safety.

### Measurement & Verification (M&V)

Facility energy savings are determined by comparing the energy use before and after the installation of energy conservation measures. The “before” case is called the **baseline**; the “after” case is referred to as the **post-installation** or **performance period**. Proper determination of savings includes adjusting for changes that affect energy use but that are not caused by the conservation measures. Such adjustments may account for differences in capacity utilization, raw material quality, product mix and other parameters, between the baseline and performance periods.

In general,

$$\text{Savings} = (\text{Baseline Energy Use}) \text{ adjusted} - \text{Post-Installation Energy Use}$$

Example: In a paper mill a variety of products depending on thickness (Grams per Square meter) are made. If energy consumption is evaluated as kCals or kWh per tonne of paper the figures could be misleading. Under these circumstances the measurement and verification system is to be designed accounting for these variations.

### Example

Replacing an existing boiler with an energy efficient boiler. Activity code activity duration dependence in days can be viewed below;

Activity Code	Activity	Duration in days	Depends on
A	Prepare technical specifications	10	
B	Tender Processing	25	A
C	Release of work orders	3	B
D	Supply of Boiler equipment	60	C
E	Supply of Auxiliaries	20	C

F	Supply of Pipes and Pipe Fittings	10	C
G	Civil Work	15	C
H	Installation of Auxiliary equipment & piping	5	E,F and G
I	Installation of Boiler	10	D and H
J	Testing and Commissioning	2	I

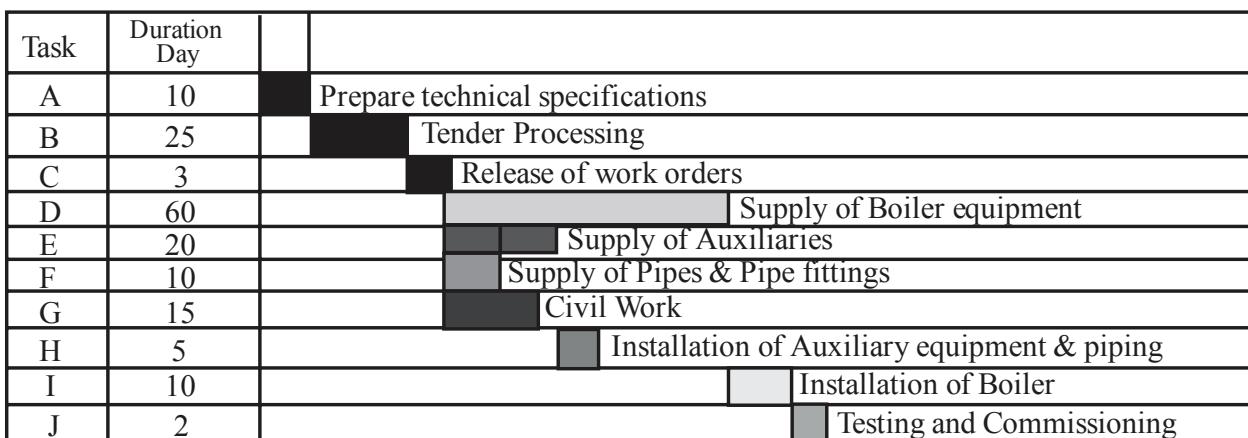
**Table 7.1 Dependence of activity code activity duration in a day****Gantt Chart**

The Fig. 7.5 shows a Gantt chart for a simple energy management project, i.e. ‘Replacing an existing boiler with an energy efficient boiler’.

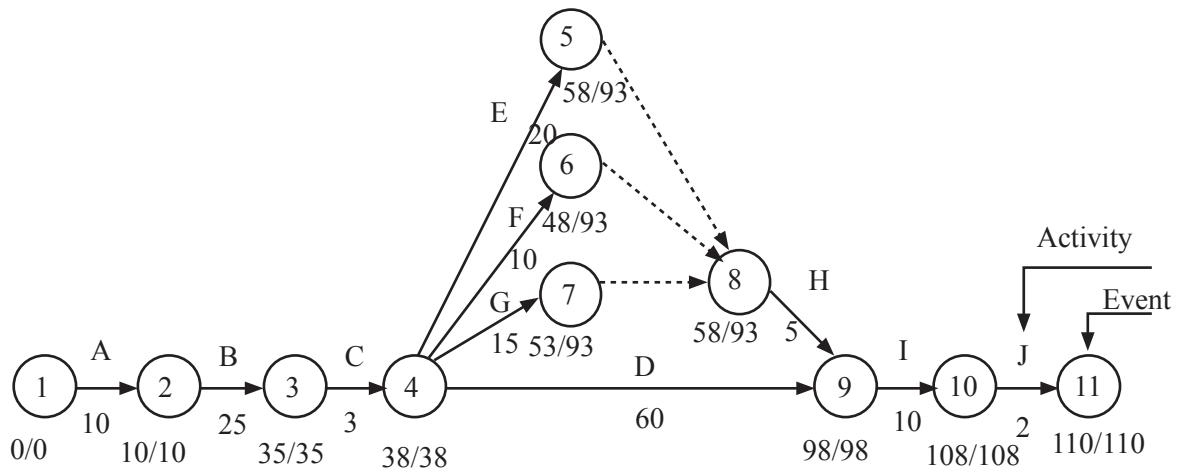
As already mentioned, Gantt chart is the simplest and quickest method for formal planning. Gantt charts can be very useful in planning projects with a limited number of tasks and with few inter-relationships. This chart typically depicts activities as horizontal lines whose length depends on the time needed to complete the activities. These lines can be progressively overprinted to show how much of activity has been completed.

Drawing a Gantt chart requires information on the following;

- logic of the tasks
- duration of the tasks
- resources available to complete the tasks
- task duration (days)

**Fig. 7.5 A simple gantt chart for boiler replacement****PERT / CPM Technique****A PERT/CPM network for Boiler Replacement (Refer Fig.7.6)**

**Activity on Arrow:** Activity and duration of the activity are shown in arrow.



**Fig. 7.6 Activity and duration of the activity in arrows**

- 10/10: In this Numerator denotes the Earliest Event Occurrence Time and Denominator is the Latest Event Occurrence Time.
- The Critical Path for this network is: A-B-C-D-I-J.
- The events on the critical path have zero slack.
- Dummy activity has no duration
- The total duration for the completion of the project is 110 days based on the critical path.

## Summary

- Project management is concerned with the overall planning, co-ordinating, securing and managing resources of a project to result in a successful completion of an aimed meeting the stated requirements and ensuring completion on time, within the cost and to the required quality standards.
- The following are the various steps involved in a project management
  - Project Definition and Scope
  - Technical Design
  - Financing
  - Contracting
  - Implementation
  - Performance Monitoring
- “*A project is a one-shot, time-limited, goal-directed, major undertaking, requiring the commitment of varied skills and resources*”.
- A successful Project Manager must simultaneously manage the four basic elements of a project: resources, time, cost, and scope. Each element must be managed effectively. All these elements are interrelated and must be managed together if the project, and the project manager, is to be a success.
- A successful Project Manager must effectively manage the resources assigned to the project. This includes the labour hours of the project team. It also includes managing labour subcontracts and vendors. Managing the people resources means having the right people, with the right skills and the proper tools, in the right quantity at the right time.
- The various elements of project management life cycle are
  - need identification
  - initiation
  - planning
  - executing
  - controlling
  - closing out
- **Internal identification** takes place when the energy manager identifies a package of energy saving opportunities during the day-to-day energy management activities, or from facility audits.
- **External identification** of energy savings can occur through systematic energy audits undertaken by a reputable energy auditor or energy service company.
- The planning phase is considered the most important phase in project management.
- Project planning defines project activities that will be performed; the products that will be produced, and describes how these activities will be accomplished and managed.
- Project Control function that involves comparing actual performance with planned performance and taking corrective action to get the desired outcome when there are significant differences
- When considering a new project, it should be remembered that other departments in the organisation would be competing for capital for their projects.
- Internal sources include:
  - Direct cash provision from company reserves
  - From revenue budget (if payback is less than one year)
  - New share capital
- The main problems faced by project manager during implementation are poor monitoring of progress, not handling risks and poor cost management.

- As the project progresses, the actual task completion times will be known and the network diagram can be updated to include this information. A new critical path may emerge, and structural changes may be made in the network if project requirements change.
- In a project, an activity is a task that must be performed and an event is a milestone marking the completion of one or more activities. Before an activity can begin, all of its predecessor activities must be completed. Project network models represent activities and milestones by arcs and nodes.
- The activities are the tasks required to complete the project. The milestones are the events marking the beginning and end of one or more activities.

## References

- Project Management Fundamentals[Pdf] Available at: <[http://www.giorgiogiusani.it/project-managemet\\_EN.pdf](http://www.giorgiogiusani.it/project-managemet_EN.pdf)> [Accessed 8 July 2013].
- Project management tutorial [Pdf] Available at: <<http://ocw.mit.edu/courses/mechanical-engineering/2-000-how-and-why-machines-work-spring-2002/tools/management.pdf>> [Accessed 8 July 2013].
- Lock, D., 2007. Project Management. Gower publishing, Ltd.
- Haynes, M.E., 2002. Project Management: Practical Tools for Success. Cengage Learning.
- Project Management in under 8 minutes [Video online] Available at: <<http://www.youtube.com/watch?v=qkuUBcmxBpk>> [Accessed 8 July 2013].
- What is Project Management? Training Video [Video online] Available at: <<http://www.youtube.com/watch?v=9LSnINglkQA>> [Accessed 8 July 2013].

## Recommended Reading

- Cleland, D.I., 2006. Project management: Strategic Design and Implementation. McGraw-Hill Professional.
- Kerzner, H., 2009. Project Management: A Systems Approach to Planning, Scheduling, and Controlling. John Wiley and Sons.
- Meredith, J.R. and Mantel, S.J., 2008. Project Management: A Managerial Approach. John Wiley & Sons.

### Self Assessment

1. A successful Project Manager must simultaneously manage the \_\_\_\_\_ basic elements of a project.
  - a. two
  - b. three
  - c. four
  - d. five
  
2. Which is a critical skill for any successful project manager?
  - a. Time management
  - b. Managing Costs
  - c. Managing Resources
  - d. Scope
  
3. The elements of project management life cycle is
  - a. monitoring
  - b. controlling
  - c. contracting
  - d. supervising
  
4. \_\_\_\_\_ is the simplest and quickest method for formal planning.
  - a. Technical Design
  - b. PERT
  - c. CPM
  - d. Gantt chart
  
5. \_\_\_\_\_ is the basic processes that should be performed to get the project started.
  - a. Planning
  - b. Executing
  - c. Initiating
  - d. Closing out
  
6. Which of the following statement is false?
  - a. Delay in dealing with risks cause the problem to aggravate and has negative consequences for the project.
  - b. The contractor provides the option of an extended lease or other financing vehicle in which the payment schedule can be based on the expected savings.
  - c. The critical path is the longest-duration path through the network.
  - d. Risks have an uncanny habit of appearing at the most expected time.
  
7. Match the following

1.External funds	a. Poor cost management
2.Implementation	b. Critical Path Method
3.Contracting	c. Energy services contract
4. “DuPont”	d. Extended Financing Terms

  - a. 1-c, 2-a, 3-d, 4-b
  - b. 1-b, 2-d, 3-a, 4-c
  - c. 1-d, 2-c, 3-b, 4-a
  - d. 1-d, 2-c, 3-a, 4-b

8. A proactive report generated by project planner software can really help the \_\_\_\_\_ to know whether the tasks are progressing as per the plan.
  - a. finance manager
  - b. project manager
  - c. auditor
  - d. general manager
9. Which of the following is false?
  - a. Henry Gantt developed the Gantt Chart.
  - b. The contractor provides the financing and is paid an agreed fraction of actual savings as they are achieved. This payment is used to pay down the debt costs of equipment and/or services.
  - c. A finance manager's success is measured by the amount of cost optimisation done for a project.
  - d. CPM (Critical Path Method) models the activities and events of a project as a network.
10. Which of the following is true?
  - a. The time required to complete each activity can be estimated using future experience.
  - b. The contractor provides the option of an unintended lease or other financing vehicle in which the payment schedule can be based on the expected savings.
  - c. Funding can become an issue when energy efficiency projects have previously been given a higher priority than other projects.
  - d. The funding for project is often outside the control of the project manager.

## Chapter VIII

# Energy Monitoring and Targeting

### Aim

The aim of this chapter is to:

- elucidate energy monitoring and targeting
- explicate relating energy consumption and production
- explain cumulative sum (CUSUM)

### Objectives

The objectives of the chapter are to:

- explain importance of energy monitoring and targeting
- explicate the rationale for monitoring, targeting and reporting
- define energy consumption and production

### Learning outcomes

At the end of this chapter you will be able to:

- identify the elements of the monitoring and targeting system
- describe energy consumption and production
- understand Cumulative Sum (CUSUM) technique

## **8.1 Introduction**

Energy monitoring and targeting is primarily a management technique that uses energy information as a basis to eliminate waste, reduce and control current level of energy use and improve the existing operating procedures. It builds on the principle “you cannot manage what you do not measure”. It essentially combines the principles of energy use and statistics. While, monitoring is essentially aimed at establishing the existing pattern of energy consumption, targeting is the identification of energy consumption level which is desirable as management goal to work towards energy conservation.

Monitoring and Targeting is a management technique in which all plant and building utilities such as fuel, steam, refrigeration, compressed air, water, effluent, and electricity are managed as controllable resources in the same way that raw materials, finished product inventory, building occupancy, personnel and capital are managed.

It involves a systematic, disciplined division of the facility into Energy Cost Centers. The utilities used in each centre are closely monitored, and the energy used is compared with production volume or any other suitable measure of operation. Once this information is available on a regular basis, targets can be set, variances can be spotted and interpreted, and remedial actions can be taken and implemented. The Monitoring and Targeting programs have been so effective that they show typical reductions in annual energy costs in various industrial sectors between 5 and 20%.

## **8.2 Elements of Monitoring & Targeting System**

Following are the essential elements of M&T system

- Recording: measuring and recording energy consumption
- Analysing: correlating energy consumption to a measured output, such as production quantity
- Comparing: comparing energy consumption to an appropriate standard or benchmark
- Setting Targets: Setting targets to reduce or control energy consumption
- Monitoring: comparing energy consumption to the set target on a regular basis
- Reporting: reporting the results including any variances from the targets which have been set
- Controlling: implementing management measures to correct any variances, this may have occurred.

Particularly M&T system will involve the following:

- checking the accuracy of energy invoices
- allocating energy costs to specific departments (Energy Accounting Centres)
- determining energy performance/efficiency
- recording energy use, so that projects intended to improve energy efficiency can be checked
- highlighting performance problems in equipment or systems

## **8.3 A Rationale for Monitoring, Targeting and Reporting**

The energy used by any business varies with production processes, volumes and input. Determining the relationship of energy use to key performance indicators will allow you to determine:

- whether your current energy is better or worse than before
- trends in energy consumption that reflects seasonal, weekly, and other operational parameters
- how much your future energy use is likely to vary if you change aspects of your business
- specific areas of wasted energy
- comparison with other business with similar characteristics - This “benchmarking” process will provide valuable indications of effectiveness of your operations as well as energy use
- how much your business has reacted to changes in the past
- how to develop performance targets for an energy management program

### Benchmarking

With the growing global competition it is absolutely essential to know the performance parameters of competitors so that improvements could be made within the organisation. The definition and meaning of benchmarking is as follows

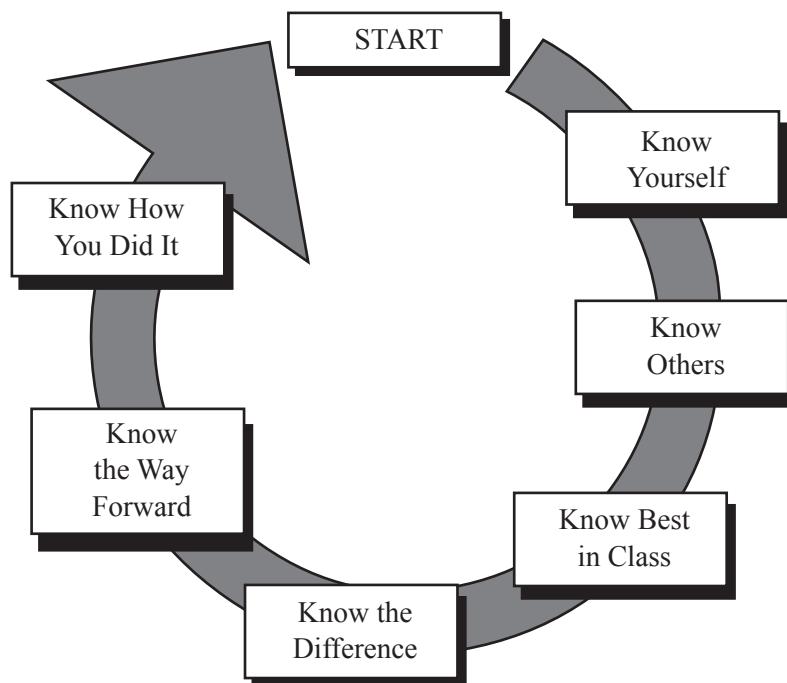
“Benchmarking is the process of identifying, understanding adopting, outstanding practices and processes from organisations anywhere in the world to help your organisation improve its performance.”

### American Productivity and Quality Center

“Benchmarking is an on-going outreach activity; the goal of the outreach is identification of the best operating practices that, when implemented, produce superior performance.”

### Bogan and English, Benchmarking for Best Practices

Benchmarking is the process of studying and adapting the best practices of other organisations to improve the firm's own performance and establish a point of reference by which other internal performance can be measured.



**Fig. 8.1 Benchmarking**

### Types of Benchmarking

There are essentially three types of benchmarking:

- strategic
- data-based
- process-based.

They differ depending on the type of information you are trying to gather. Strategic benchmarking looks at the strategies companies use to compete. Benchmarking to improve improvements in business process performance generally focuses on uncovering how well other companies perform in comparison with you and others, and how they achieve this performance. This is the focus of Data-based and Process-based benchmarking.

### Benchmarking Overviews

The following questions will have to be answered while implementing the benchmarking system:

- How are we doing?
- Are we taking the right measures?

- How do we compare with others?
- Are we making progress fast enough?
- Are we using the best practices?

These are important questions and on the basis of the information gathered, an organisation can plan to improve performance. If the organisation wants to improve processes, the following steps are to be taken:

- document as-is process
- establish measures
- follow processes
- measure performances
- identify and implement improvements

### **Stages in Benchmarking**

- Internal Study and Preliminary Competitive Analysis
- Developing long-term commitment to the Benchmarking Projects and Unite the Benchmarking Team
- Identifying Benchmarking Partners
- Information Gathering and Sharing Methods
- Taking action to meet or exceed the benchmark

Benchmarking was initially used in a quality improvement process. However with the broader and wider definition of quality which includes use of energy, environmental aspects and social obligations, it is now widely used all over the world.

Information related to energy use may be obtained from following sources:

- plant level information can be derived from financial accounting systems—utilities cost centre
- plant department level information can be found in comparative energy consumption data for a group of similar facilities, service entrance meter readings etc.
- system level (example, boiler plant) performance data can be determined from sub-metering data
- equipment level information can be obtained from nameplate data, run-time and schedule information, sub-metered data on specific energy consuming equipment.

The important point to be made here is that all of these data are useful and can be processed to yield information about facility performance. The Fig. 8.1 shows the various steps involved in a comprehensive energy monitoring and targeting system.

### **Instrumentation for Monitoring**

The fast data available has to be used for comparison purposes. With the rapid progress in instrumentation and online computerisation, it has become quite easy to collect data and also compare quickly to take appropriate steps for performance improvement. All the big organisations are now using computerised data collection and also have instrument automation to help control energy costs. Infact, it has now become easier to do the monitoring at a faster rate. Modern instruments are easily available and could be installed in a short time. Although investment in these instruments may be one of the impediments, in the long run such type of investment is to be justified as data analysis is quite easy.

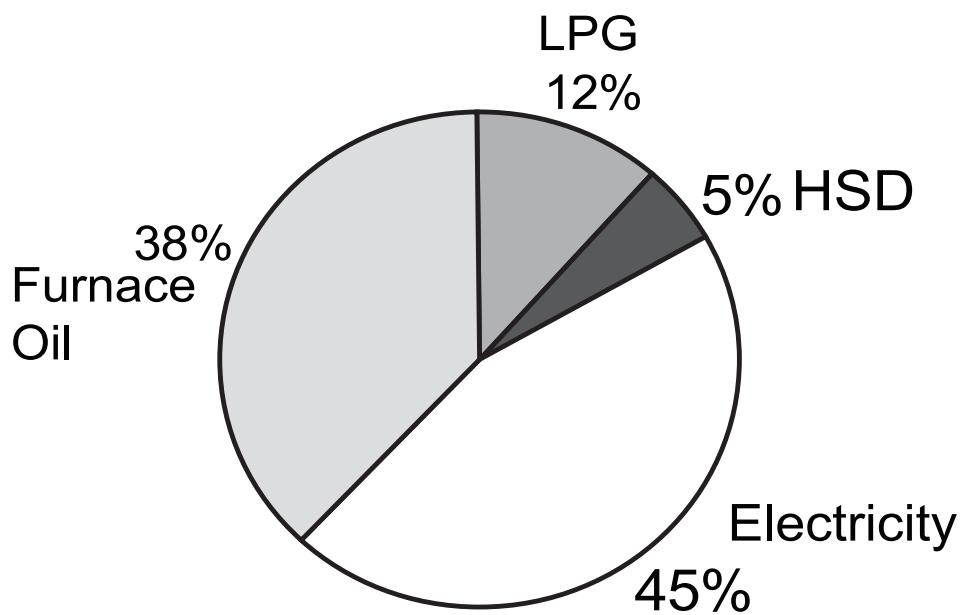
## 8.4 Data and Information Analysis

Electricity bills and other fuel bills should be collected periodically and analysed as below. A typical format for monitoring plant level information is given below in the Table 8.1.

	Thermal Energy Bill				Electricity Bill				Total Energy Bill
Month	Fuel1	Fuel 2	Fuel 3	Total Rs. Lakh	Day kWh	Night kWh	Maximum Demand	Total Rs. Lakh	Rs. Lakh
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
Sub-Total %									

**Table 8.1 Annual energy cost sheet**

After obtaining the respective annual energy cost, a pie chart (see Fig. 8.2) can be drawn as shown below:



**Fig. 8.2 Share of fuels based on energy bill**

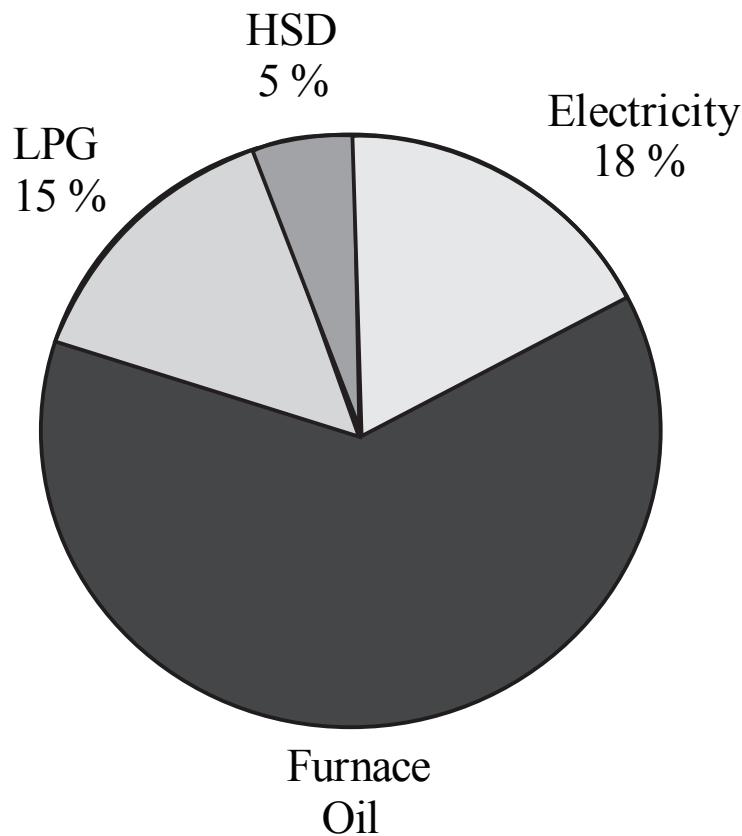
**Pie Chart on Energy Consumption**

All the fuels purchased by the plant should be converted into common units such as kCal. The following Table 8.2 is for that purpose.

Fuel Conversion Data		
Energy Source	Supply Unit	Conversion Factor to kCal
Electricity	kWh	860
HSD	Kg	10,500
Furnace Oil	Kg	10,200
LPG	Kg	12,000

**Table 8.2 Fuel conversion data**

After conversion to a common unit, a pie chart can be drawn showing the percentage distribution of energy consumption as shown in Fig. 8.3.



**Fig. 8.3 %Share of fuels based on consumption in kcals**

## 8.5 Relating Energy Consumption and Production.

### Graphing the Data

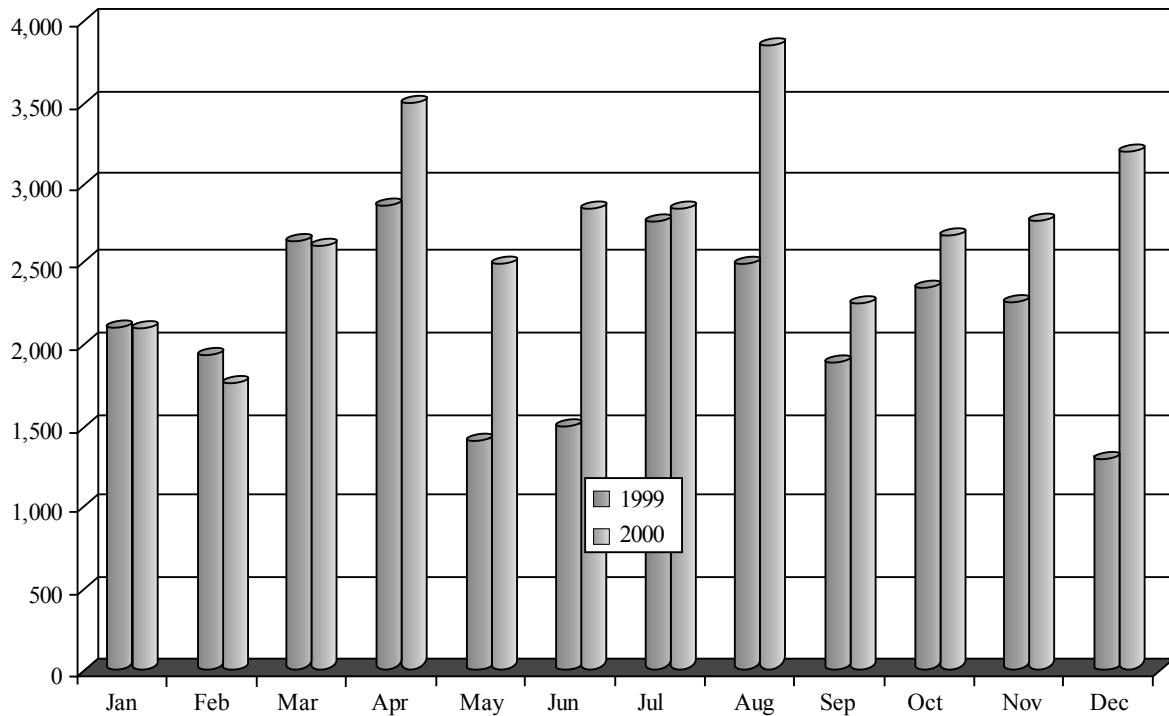
A critical feature of M&T is to understand what drives energy consumption. Is it production, hours of operation or weather? Knowing this, we can then start to analyse the data to see how good our energy management is.

After collection of energy consumption, energy cost and production data, the next stage of the monitoring process is to study and analyse the data to understand what is happening in the plant. It is strongly recommended that the data be presented graphically. A better appreciation of variations is almost always obtained from a visual presentation, rather than from a table of numbers. Graphs generally provide an effective means of developing the energy-production relationships, which explain what is going on in the plant.

### Use of Bar Chart

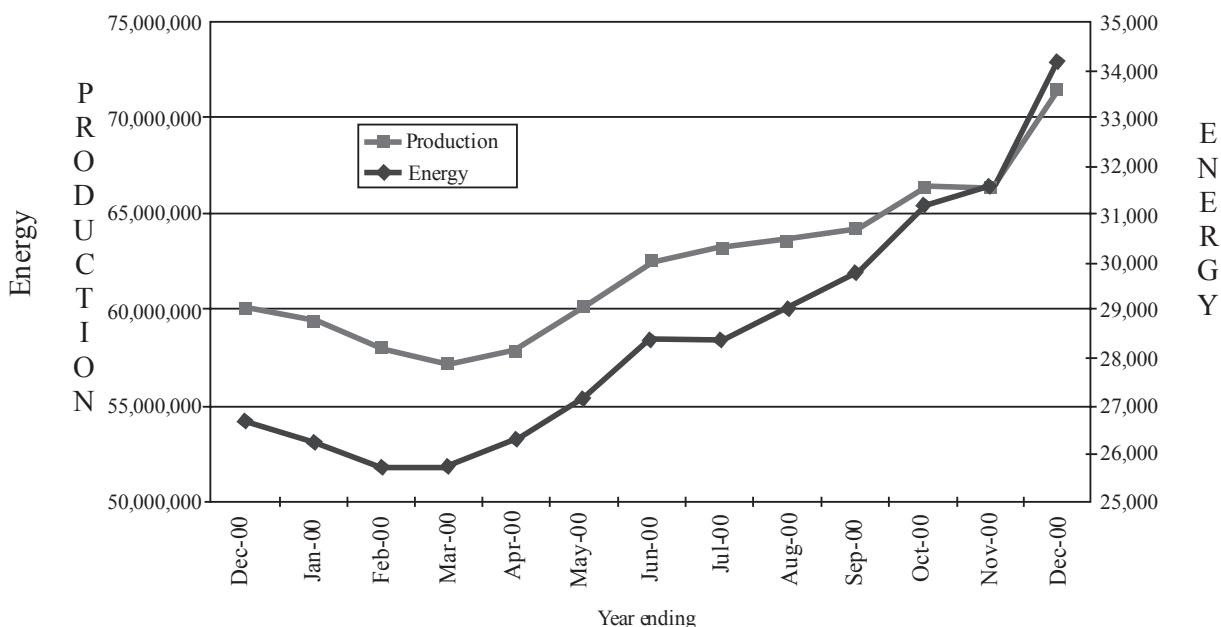
The energy data is then entered into a spreadsheet. It is hard to envisage what is happening from plain data, so we need to present the data using bar chart. The starting point is to collect and collate 24/12 months of energy bills. The most common bar chart application used in energy management is one showing the energy per month for this year and last year (see Fig.8.4) – however, it does not tell us the full story about what is happening. We will also need production data for the same 24/12-month period.

Having more than twelve months of production and energy data, we can plot a moving annual total. For this chart, each point represents the sum of the previous twelve months of data.



**Fig. 8.4 Energy consumption: current year (2002) vs. previous year (1999)**

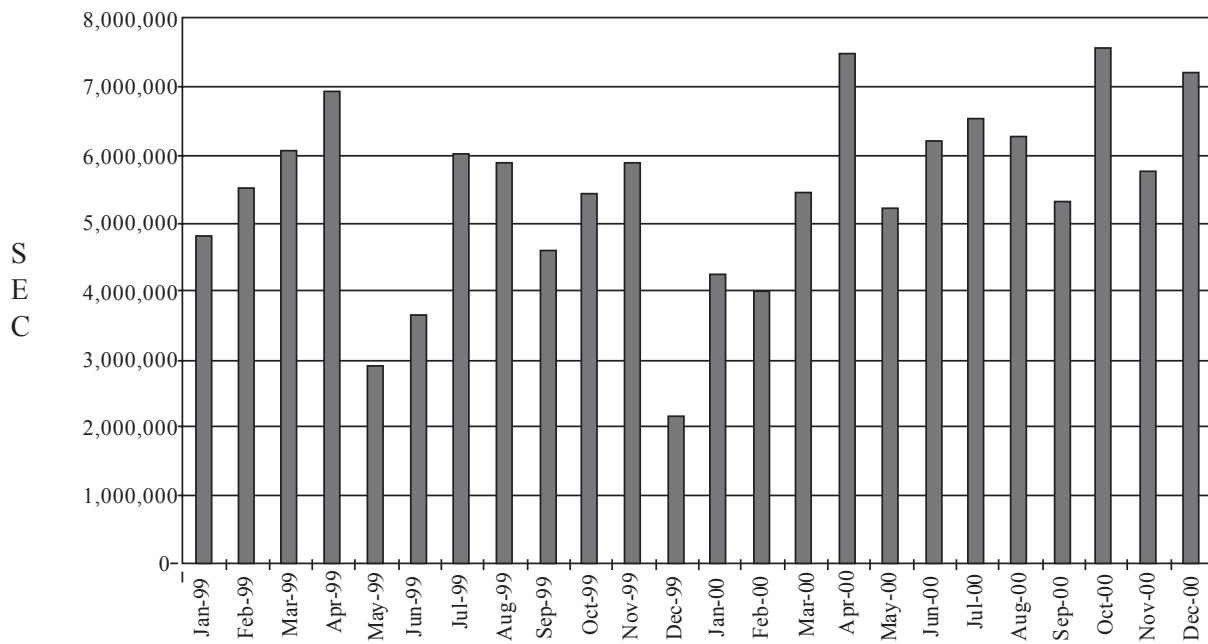
In this way, each point covers a full range of the seasons, holidays, etc. The Figure 8.5 shows a moving annual total for energy and production data.



**Fig. 8.5 Moving annual total – energy and production**

This technique also smoothens out errors in the timing of meter readings. If just plot energy we are only seeing part of the story – so we plot both energy and production on the same chart – most likely using two y-axes. Looking at these charts, both energy and productions seem to be “tracking” each other – this suggests there is no major cause for concern. But we will need to watch for a deviation of the energy line to pick up early warning of waste or to confirm whether energy efficiency measures are making an impact.

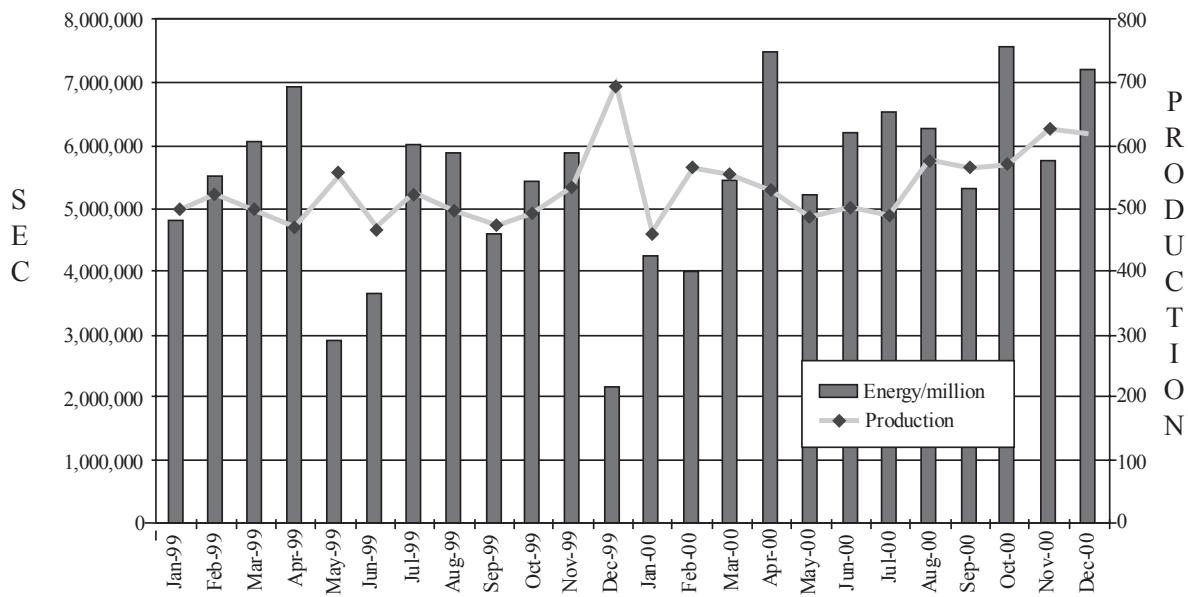
For any company, we also know that energy should directly relate to production. Knowing this, we can calculate Specific Energy Consumption (SEC), which is energy consumption per unit of production. So we now plot a chart of SEC (see Fig.8.6).



**Fig. 8.6 Monthly specific energy consumption**

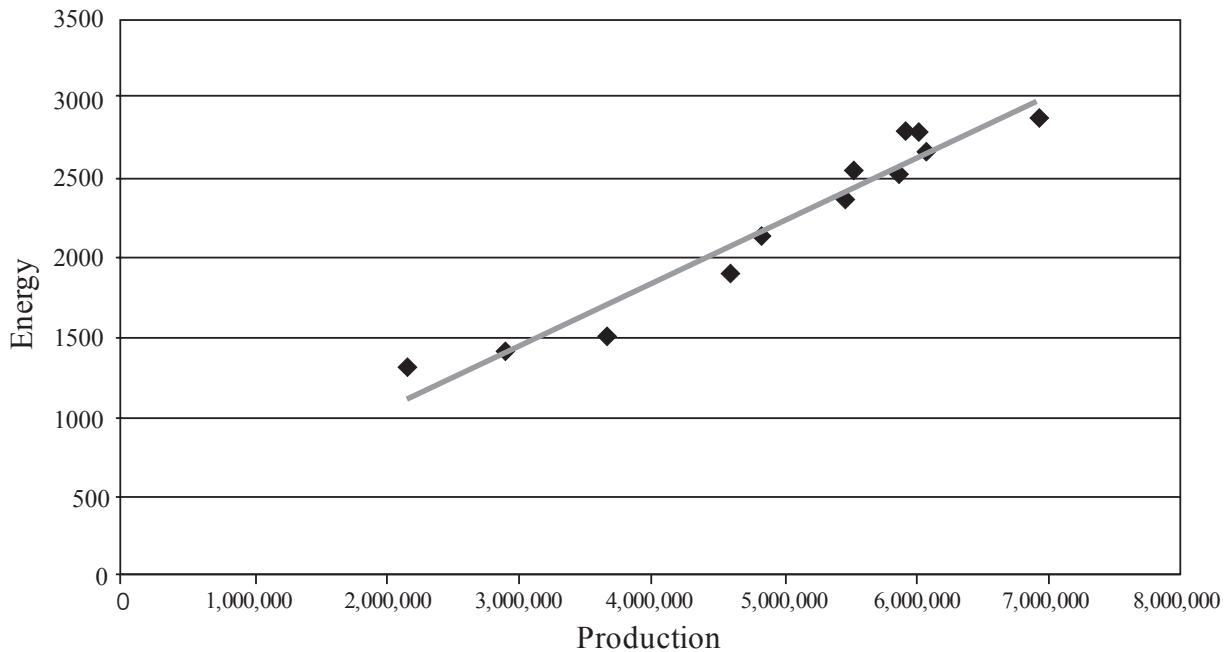
At this point it is worth noting that the quality of your M&T system will only be as good as the quality of your data – both energy and production. The chart shows some variation – an all time low in December 99 followed by a rising trend in SEC.

We also know that the level of production may have an effect on the specific consumption. If we add the production data to the SEC chart, it helps to explain some of the features. For example, the very low SEC occurred when there was a record level of production. This indicates that there might be fixed energy consumption – i.e. consumption that occurs regardless of production levels. Refer Fig. 8.7.



**Fig. 8.7 SEC with production**

The next step is to gain more understanding of the relationship of energy and production, and to provide us with some basis for performance measurement. To do this we plot energy against production – In Microsoft Excel Worksheet, this is an XY chart option. We then add a trend line to the data set on the chart. (In practice what we have done is carried out a single variable regression analysis!). The Fig.8.8 shown is based on the data for 1999.



**Fig. 8.8 Energy vs. production**

We can use it to derive “standard” for the up-coming year’s consumption. This chart shows a low degree of scatter indicative of a good fit. We need not worry if our data fit is not good. If data fit is poor, but we know there should be a relationship, it indicates a poor level of control and hence a potential for energy savings.

In producing the production/energy relationship chart we have also obtained a relationship relating production and energy consumption.

$$\text{Energy consumed for the period} = C + M \times \text{Production for same period}$$

Where M is the energy consumption directly related to production (variable) and C is the “fixed” energy consumption (i.e. energy consumed for lighting, heating/cooling and general ancillary services that are not affected by production levels). Using this, we can calculate the expected or “standard” energy consumption for any level of production within the range of the data set.

We now have the basis for implementing a factory level M&T system. We can predict standard consumption, and also set targets – for example, standard less 5%. A more sophisticated approach might be applying different reductions to the fixed and variable energy consumption. Although, the above approach is at factory level, the same can be extended to individual processes as well with sub metering.

At a simplistic level we could use the chart above and plot each new month’s point to see where it lies. Above the line is the regime of poor energy efficiency and below the line is the regime of an improved one.

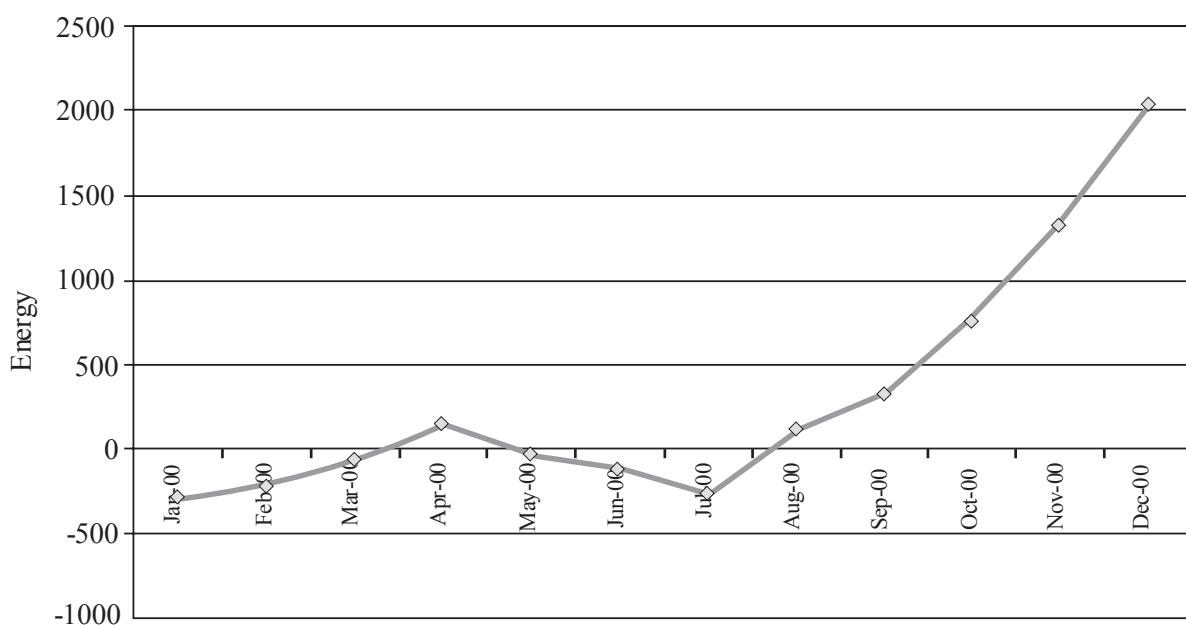
## 8.6 CUSUM

**Cumulative Sum (CUSUM)** represents the difference between the base line (expected or standard consumption) and the actual consumption points over the base line period of time.

This useful technique not only provides a trend line, it also calculates savings/losses to date and shows when the performance changes.

A typical CUSUM graph follows a trend and shows the random fluctuation of energy consumption and should oscillate around zero (standard or expected consumption). This trend will continue until something happens to alter the pattern of consumption such as the effect of an energy saving measure or, conversely, a worsening in energy efficiency (poor control, housekeeping or maintenance).

CUSUM chart (see Fig.8.9) for a generic company is shown. The CUSUM chart shows what is really happening to the energy performance. The formula derived from the 1999 data was used to calculate the expected or standard energy consumption.



**Fig. 8.9 CUSUM chart**

From the chart, it can be seen that starting from year 2000, performance is better than standard. Performance then declined (line going up) until April, and then it started to improve until July. However, from July onwards, there is a marked, ongoing decline in performance – line going up.

When looking at CUSUM chart, the changes in direction of the line indicate events that have relevance to the energy consumption pattern. Clearly, site knowledge is needed to interpret better what they are. For this sample company since we know that there were no planned changes in the energy system, the change in performance can be attributed to poor control, housekeeping or maintenance.

## Summary

- Energy monitoring and targeting is primarily a management technique that uses energy information as a basis to eliminate waste, reduce and control current level of energy use and improve the existing operating procedures.
- Recording: Measuring and recording energy consumption.
- Analysing: Correlating energy consumption to a measured output, such as production quantity.
- Comparing: Comparing energy consumption to an appropriate standard or benchmark.
- Setting Targets: Setting targets to reduce or control energy consumption.
- Monitoring: Comparing energy consumption to the set target on a regular basis.
- Reporting: Reporting the results including any variances from the targets which have been set.
- Controlling: Implementing management measures to correct any variances, this may have occurred.
- The energy used by any business varies with production processes, volumes and input.
- With the growing global competition it is absolutely essential to know the performance parameters of competitors so that improvements could be made within the organisation.
- Benchmarking is the process of identifying, understanding adopting, outstanding practices and processes from organisations anywhere in the world to help your organisation improve its performance. Consider American Productivity and Quality Centre.
- There are essentially three types of benchmarking:
  - strategic
  - data-based
  - process-based
- The following questions will have to be answered while implementing the benchmarking system
  - How are we doing?
  - Are we taking the right measures?
  - How do we compare with others?
  - Are we making progress fast enough?
  - Are we using the best practices?
- The fast data available has to be used for comparison purposes. With the rapid progress in instrumentation and online computerisation, it has become quite easy to collect data and also compare quickly to take appropriate steps for performance improvement.
- A critical feature of M&T is to understand what drives energy consumption. Is it production, hours of operation or weather? Knowing this, we can then start to analyse the data to see how good our energy management is.
- The energy data is then entered into a spreadsheet. It is hard to envisage what is happening from plain data, so we need to present the data using bar chart. The starting point is to collect and collate 24/12 months of energy bills.

## References

- Energy Monitoring and Targeting[Pdf] Available at: <<http://www.em-ea.org/Guide%20Books/Book-1/1.8%20Monitoring%20&%20Targetting.pdf>> [Accessed 8 July 2013].
- Monitoring and Targeting[Pdf] Available at: <[http://www.carbontrust.com/media/31683/ctg008\\_monitoring\\_and\\_targeting.pdf](http://www.carbontrust.com/media/31683/ctg008_monitoring_and_targeting.pdf)> [Accessed 8 July 2013].
- Beggs, C., 2002. Energy: Management, Supply and Conservation. Butterworth-Heinemann.
- Moss, K.J., 2006. Energy Management in Buildings. Taylor & Francis.
- Energy Monitoring and Targeting [Video online] Available at: <<http://www.youtube.com/watch?v=ayzBU-6-uYY>> [Accessed 8 July 2013].
- Energy monitoring and targeting - Management - Part 1[Video online] Available at: <[http://www.youtube.com/watch?v=2k\\_JDI\\_pFdc](http://www.youtube.com/watch?v=2k_JDI_pFdc)> [Accessed 8 July 2013].

### Recommended Reading

- Gotel, D.G., 1989. The Application of Monitoring & Targeting to Energy Management (Home Office Research Study). HMSO Books.
- Levermore, G.J., 1989. Monitoring and Targeting with a Building Energy Management System. BSRIA.
- Levermore, G.J., 2000. Building energy management systems: applications to low-energy HVAC and natural ventilation control. Taylor & Francis.

## Self Assessment

1. A critical feature of M&T is to understand what drives \_\_\_\_\_.
  - a. energy cost
  - b. energy efficiency
  - c. energy saving
  - d. energy consumption
  
2. Energy monitoring and targeting is built on the principle of \_\_\_\_\_.
  - a. “you cant manage what you do measure”
  - b. “you cannot manage what you do not measure”
  - c. “production can be reduced to achieve reduced energy consumption”
  - d. “consumption of energy is proportional to production rate”
  
3. Which of the following is not the element of energy monitoring and targeting?
  - a. Recording
  - b. Controlling
  - c. Reducing
  - d. Comparing
  
4. Which of the following is false?
  - a. With the rapid progress in instrumentation and online computerisation, it has become quite easy to collect data and also compare quickly to take appropriate steps for performance improvement.
  - b. A better appreciation of variations is almost always obtained from a table of numbers, rather than from a visual presentation.
  - c. Electricity bills and other fuel bills should be collected periodically and analysed.
  - d. Equipment level information can be obtained from nameplate data, run-time and schedule information, sub-metered data on specific energy consuming equipment.
  
5. Energy consumed for the period equals to
  - a.  $C + M \times$  Production for same period
  - b.  $C \times M +$  Production for same period
  - c.  $C + M +$  Production for same period
  - d.  $C \div M +$  Production for same period
  
6. CUSUM means
  - a. Cumbersome
  - b. Cumulative sum
  - c. Calculated sum
  - d. Cross sum
  
7. A CUSUM graph follows a trend and shows the random fluctuation of energy consumption and should oscillate around \_\_\_\_\_.
  - a. 1,000
  - b. 100
  - c. 10
  - d. 0

8. Energy and production data is useful to calculate
  - a. Specific cost
  - b. Specific fuel consumption
  - c. Specific energy consumption
  - d. Specific energy efficiency
9. The energy used by any business varies with production processes, volumes and \_\_\_\_\_.
  - a. input
  - b. over turn
  - c. output
  - d. out turn
10. Graphs generally provide an effective means of developing the energy-production relationships, which explain what is going on in the plant.
  - a. Texts
  - b. Tables
  - c. Graphs
  - d. Visuals

## Case Study I

Energy consumption and production data were collected for a plant over a period of 18 months. During month 9, a heat recovery system was installed. Using the plant monthly data, estimate the savings made with the heat recovery system. The plant data is given in Table 1.1

Month	Monthly Energy Use (toe*/month)	P.Monthly Production (tonnes/month)
1	340	380
2	340	440
3	380	460
4	380	520
5	300	320
6	400	520
7	280	240
8	424	620
9	420	600
10	400	560
11	360	440
12	320	360
13	340	420
14	372	480
15	380	540
16	280	280
17	280	260
18	380	500

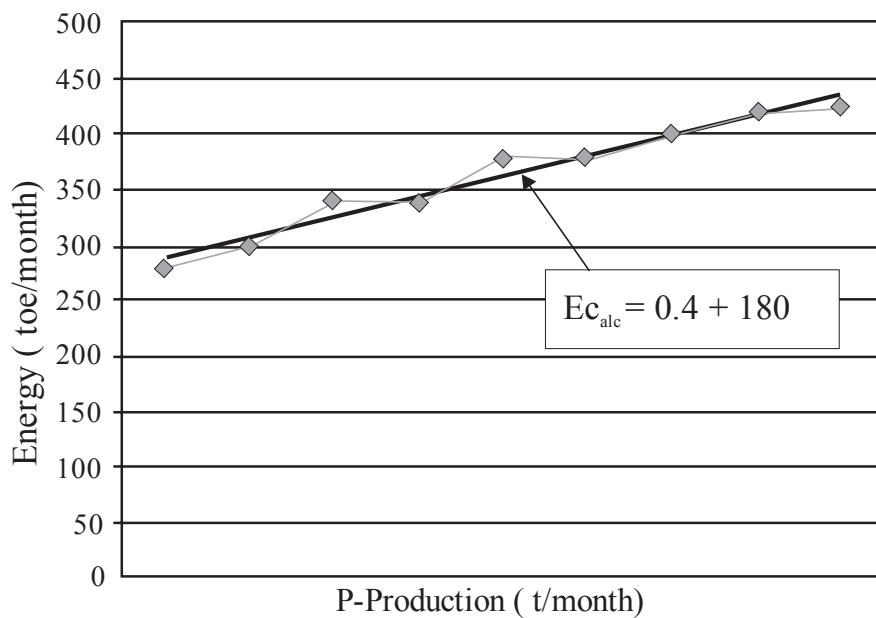
**Table: 1.1 Month wise production with energy consumption**

\*toe = tonnes of oil equivalent

### Steps for CUSUM Analysis

1. Plot the energy production graph for the first 9 months
2. Draw the best fit straight line
3. Derive the equation of the line
4. The above steps are completed in Figure 4.9, the equation derived is
5.  $E=0.4P+180$
6. Calculate the expected energy consumption based on the equation
7. Calculate the difference between calculated and actual energy use
8. Compute CUSUM. These steps are lumped in the table below
9. Plot the CUSUM graph
10. Estimate the savings from the heat recovery system

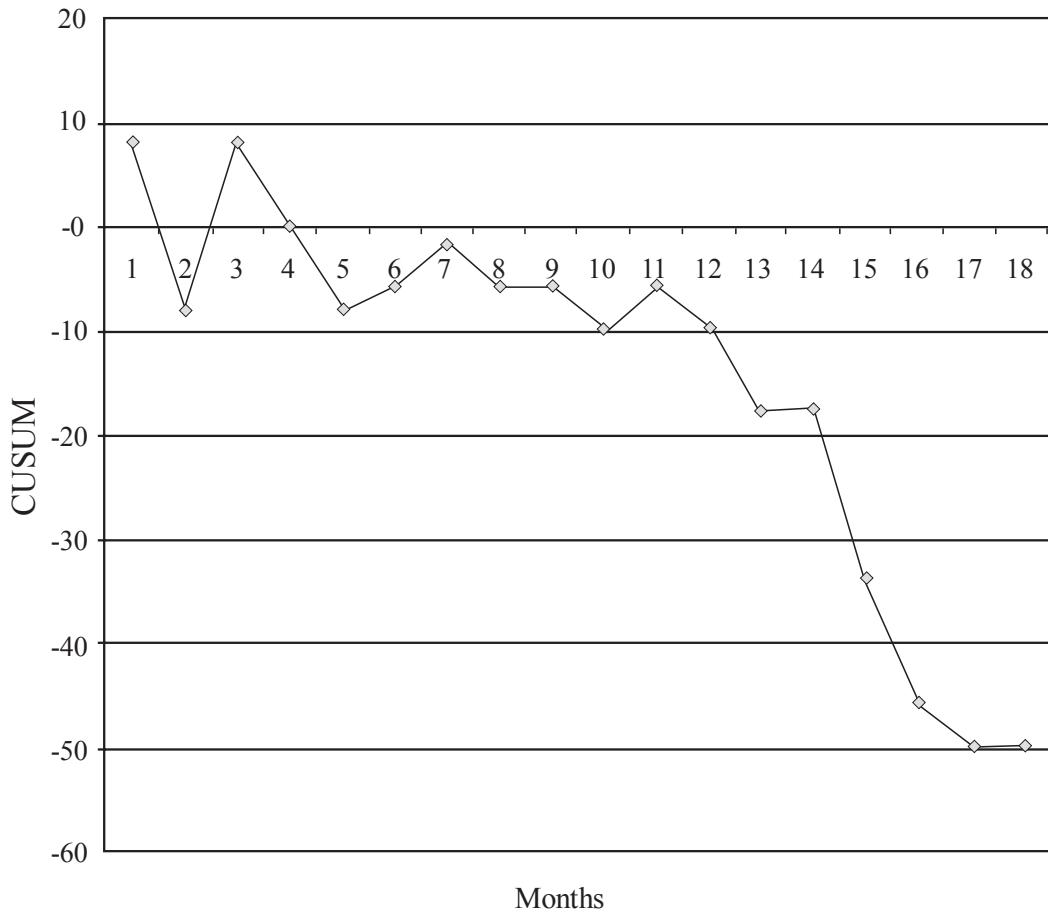
Month	.Monthly Energy Use (toe*/month)	P.Monthly Production (tonnes/month)	$E_{alc}$ (0.4 P + 180)	$E_{act} - E_{alc}$	(Cumulative Sum)
1	340	380	332	+8	+8
2	340	440	356	-16	-8
3	380	460	364	+16	+8
4	380	520	388	-8	0
5	300	320	308	-8	-8
6	400	520	388	+2	-6
7	280	240	276	+4	-2
8	424	620	428	-4	-6
9	420	600	420	0	-6
10	400	560	404	4	-10
11	360	440	356	+4	-6
12	320	360	324	-4	-10
13	340	420	348	-8	-18
14	372	480	372	0	-18
15	380	540	396	-16	-34
16	280	280	292	-12	-46
17	280	260	284	-4	-50
18	380	500	380	0	-50

**Table 1.2 Actual energy consumption – calculated energy consumption****Fig. 4.9 Energy production graph**

It can be seen that the CUSUM graph (Refer the above Fig.) oscillates around the zero line for several months and then drops sharply after month 11. This suggests that the heat recovery system took almost two months to commission and reach proper operating conditions, after which steady savings have been achieved. Based on the graph (see Table 4.4), savings of 44 toe (50-6) have been accumulated in the last 7 months. This represents savings of almost 2% of energy consumption.

$$\frac{\frac{44}{2352}}{\#E_{act}} \times 100 = 1.8\%$$

#E<sub>act</sub> for the last 7 months (From month 12 to month 18 in Table 1.2)



**Fig. 4.10 Example CUSUM graph**

The CUSUM technique is a simple but remarkably powerful statistical method, which highlights small differences in energy efficiency performances. Regular use of the procedure allows the energy manager to follow plant performance and spot any trends early.

## Case Study II

### Energy Audit in XYZ Engineering Unit Refrigeration & Air Conditioning Compressors

#### Introduction

The XYZ plant, manufacturing Refrigeration & Air-Conditioning Compressors, has annual electricity consumption of about 3,164,000 KWh/year for main plant and 48,54,400 KWh/year for Ancillary plant. Annual HSD consumption is about 45.75 KL/Annum, annual furnace oil consumption is about 493.62 KL/Annum & annual LPG consumption is about 107 MT/Annum. Annual production of compressors is 2,50,000 nos. Total energy bill is Rs. 64.17 Million.

#### The Assignment

Detailed Energy Audit has been carried out in order to identify and recommend energy cost saving measures. This includes detail mass and energy balance of major energy consuming equipments like Decarb Annealing Furnace, Thermic Fluid Heater including its distribution & consumption points, Compressed air generation distribution & consumption and performance evaluation of Transformers, Motors, Air-conditioning units, Cooling towers, Lighting & others with the objective of identifying energy losses, quantifying various energy flows and comparing with benchmarks.

#### Phases used during energy audit

Energy audit has been carried out in two phases:

- Preliminary Energy Audit (PEA)
- Detail Energy Audit (DEA)

Focus during PEA & DEA has been as follows:

#### Preliminary Audit (PEA)

- Identifying quantity & cost of energy used in various form and total energy bill
- Departmental/Section/Process/Equipment wise energy consumption
- Correlating every energy input to production.

#### Detail Audit(DEA)

In this portion “Scope of Audit” is focused and pursued in detail. Various measurements have been carried out to facilitate mass & energy balance and performance evaluation of all the energy guzzlers listed above. This Energy Balance has been studied and energy conservation measures are identified for optimizing end use energy efficiency and/or cost. Finally, based on the findings, recommendations for implementation of energy conservation measures are made based on technical feasibility, saving potential in energy cost, investment required and likely payback period.

#### Finding and Recommendation

- Maximum demand can be controlled within the contract demand by installation of Maximum Demand (MD) Controller, which automatically trips the equipments for about 10 to 15 min without affecting the production. Savings achieved from this measure are about 8% in MD charges.
- In Thermic Fluid Heater (TFH), It is observed that fresh atmospheric air is entering into it even when TFH is in OFF condition from opening of the blower due to natural convection because of the chimney, which itself is acting as one of the major load on TFH. This air is taking around 4.7 % of total available heat in TF. So it is recommended to make damper arrangement in the blower pipeline, which will avoid air passage through the TFH when it is OFF and will thus avoid air infiltration. Savings achieved from this measure are about 5% of FO consumption and corresponding reduction in GHG.
- In Decarb Furnace, for Exo-gas generation LPG is used. HSD is also used in the furnace in “Burning-Zone” as a support fuel. Now with gasification technology, it is possible to “gasify” agricultural waste based briquettes. The product from this gasification is also “exo-gas” (rich in CO) which can substitute costly and GHG emitting

fuel LPG & HSD. Gasification is conversion of solid fuel (Wood, Briquette, Coal etc.) into a combustible gas mixture normally called producer gas. This process involves partial combustion of such biomass. Partial combustion process occurs when air supply ( $O_2$ ) is less than adequate for complete combustion of biomass. Achievable savings are about 60% of LPG & HSD cost.

- In TFH, further savings are possible by converting to briquette fired TFH. This means 50% savings in FO cost and corresponding GHG reduction.
- In the paint shop paint temperature is to be maintained within a range 26 to 28 °C. For this the paint is first heated through hot water (of about 52 °C), which is heated by TF. The paint is then cooled by chilled water (of about 17 °C). In this continuous heating and cooling process significant amount of energy is wasted. This complete heating and cooling cycle can be replaced with only cooling process for more than 90% of the time. Energy required will be 3% of total energy required earlier.
- In Decarb furnace, moisture free Exo gas is required to avoid oxidation of “stator”. For reducing moisture in Exo-gas, it is cooled to 11°C. In present situation, Exo-gas at 11°C is passed through furnace due to which there is significant cooling effect in the furnace and furnace requires more electrical heating to attain 800°C (which is furnace inside temperature). It is proposed to preheat Exo-gas to a temperature of around 300 °C, so that it will reduce electrical heating required for raising the temperature of Exo-gas from 11 °C to 300 °C. Achievable savings are more than 15% of KWh consumption in the furnace.
- In Exo-gas generation, the Exo-gas temperature is reduced by preheating the air, which in turns is used in burning zone of the furnace. Its present temperature is not sufficient to attain the required temperature in the burning zone. Therefore HSD firing is necessary. At present last stage of Heat Recovery Unit (HRU) is unused. It is recommended to use the last stage too so that the required temperature can be attained and thus HSD fired burners can be completely eliminated. For this present air blower is required to be replace with new “roots-blower” to increase the head. This will eliminate use of 8.2 KL of HSD per annum.
- Cooling water requirement of compressor & decarb furnace is presently being served by three different Cooling Towers, which can be served by only one cooling tower. It is recommended to shift present cooling tower of decarb in between decarb section and the compressor room sheds, which will also reduce the head loss. This head loss is presently very high due to the elevation. This will also reduce pumping power requirement and result in 70 % saving in present cooling tower energy consumption.
- By reducing leakage level in compressed air system to 5% (which is 30% now). The energy consumption reduction will be about 30% of present compressed air consumption.

## Conclusion

Total Savings in Energy Cost (Identified & Recommended) is INR 15.17 Million, which is 23.64% of Annual Energy Bill and GHG reduction of 1860 TCO2-e per annum

## Questions

1. What XYZ plant manufacture? How much it consume energy in a year?
2. How the refrigerator compressor was assigned?
3. Why detail energy audit is carried out?

## Case Study III

### Fuel Substitution

Energy cost can be saved by fuel switch over

### Introduction

ABC plant is using 4 tonnes/day coals to generate steam. The calorific value of the coal is 4000 kcal/kg. The cost of coal is Rs. 2,000/tonne. The plant substitutes coal with rice husks, as a boiler fuel, which has a calorific value of 3000 kcal/kg and cost Rs. 700/tonne.

### Hint:

Effective heat remaining the same quantity of cheaper fuel is to be worked out. The difference is the saving.

Effective heat=  $\text{kg} \times \text{GCV} \times \text{Efficiency}$

1. Calculate the annual cost saving at 300 days of operation, assuming that the boiler efficiency decreases from 78% on coal to 72% on rice husks.
2. Calculate the quantity of rice husk required can be worked out
3. Calculate the cost with rice husk

# Bibliography

## References

- Andrews, J. and Jolley, N., 2007. *Energy Science Principle, Technologies, and Impacts*. Oxford University Press.
- *Basics and energy of the atmosphere 003* [Video online] Available at: <<http://www.youtube.com/watch?v=WMTUjNKEKjA>> [Accessed 5 July 2013].
- *Basics of Combustion Engineering: Mass and Energy Balance* [Pdf] Available at: <[http://www.met.kth.se/asialink/Curriculum/Clausthal%20uni-Germany/Comb\\_Funda\\_L2\\_ppt.pdf](http://www.met.kth.se/asialink/Curriculum/Clausthal%20uni-Germany/Comb_Funda_L2_ppt.pdf)> [Accessed 8 July 2013].
- Beggs, C., 2002. *Energy: Management, Supply and Conservation*. Butterworth-Heinemann.
- Beggs, C., 2009. *Energy: Management, Supply and Conservation*. Elsevier Ltd.
- *Big Switch Projects: Energy Action Plan - the next steps* [Video online] Available at: <[http://www.youtube.com/watch?v=AFO\\_as2EaS4](http://www.youtube.com/watch?v=AFO_as2EaS4)> [Accessed 8 July 2013].
- Brigham, E.F. and Earnhardt, M.C., 2008. *Financial management: Theory and Practice*. Cengage Learning.
- *BSR- Energy Management handbook* [Pdf] Available at: <<http://www.bsr.org/reports/bsr-energy-management-handbook.pdf>> [Accessed 5 July 2013].
- Capehart, B.L., Wayne, C.T. and Kennedy, W.J., 2008. *Guide to Energy Management*. The Fairmont Press, Inc.
- *Changing Units in an Equation* [Video online] Available at: <<http://www.youtube.com/watch?v=qkQEBcrJ5IQ&list=PLD4476BAFA5A65111>> [Accessed 8 July 2013].
- Correia, C., Flynn, D., Uliana, E. and Wormald, M., 2007. *Financial Management*. Juta and Company Ltd.
- Doty, S. and Turner, W. C., 2009. *Energy management handbook*. The Fairmont Press, Inc.
- Earle, R.L., 1983. *Unit Operations in Food Processing*. NZIFST Inc.
- Eden, J.R., 1981. *Energy economics*. Cambridge University Press.
- *Electrical Energy Basics* [Video online] Available at: <<http://www.youtube.com/watch?v=ZRKnVQNpwD4>> [Accessed 5 July 2013].
- *Energy Action Planning* [Pdf] Available at: <<http://www.em-ea.org/Guide%20Books/Book-1/1.5%20Energy%20Action%20Planning.pdf>> [Accessed 8 July 2013].
- *Energy Audits - Energy Consultants - Energy Management Consultants - Global Green Consultancy* [Video online] Available at: <<http://www.youtube.com/watch?v=sFIL2CRoSAg>> [Accessed 5 July 2013].
- *Energy Conservation, Efficiency& Energy Audit* [Pdf] Available at: <<http://www.energymanagertraining.com/Journal/04102006/EnergyConservation,Efficiency&EnergyAudit.pdf>> [Accessed 5 July 2013].
- *Energy monitoring and targeting - Management - Part 1* [Video online] Available at: <[http://www.youtube.com/watch?v=2k\\_JD1\\_pFdc](http://www.youtube.com/watch?v=2k_JD1_pFdc)> [Accessed 8 July 2013].
- *Energy Monitoring and Targeting* [Pdf] Available at: <<http://www.em-ea.org/Guide%20Books/Book-1/1.8%20Monitoring%20&%20Targetting.pdf>> [Accessed 8 July 2013].
- *Energy Monitoring and Targeting* [Video online] Available at: <<http://www.youtube.com/watch?v=ayzBU-6-uYY>> [Accessed 8 July 2013].
- *Energy Savings Toolbox- An energy Audit Manual And Tool* [Pdf] Available at: <<http://oee.nrcan.gc.ca/sites/oee.nrcan.gc.ca/files/files/pdf/energy-audit-manual-and-tool.pdf>> [Accessed 5 July 2013].
- *Energy Scenarios 2050* [Video online] Available at: <<http://www.youtube.com/watch?v=A75GRANfvrQ>> [Accessed 5 July 2013].
- *Finance: What Managers Need to Know* [Video online] Available at: <<http://www.youtube.com/watch?v=aJsmJsd6GIw>> [Accessed 8 July 2013].
- *Financial Management* [Video online] Available at: <<http://www.youtube.com/watch?v=iDlFPm3fqbs>> [Accessed 8 July 2013].

- *Financial management of Business Expansion, Combination and Acquisition* [Pdf] Available at: <<http://www.ddejust.ac.in/studymaterial/mcom/mc-204.pdf>> [Accessed 8 July 2013].
- *Fundamentals of Financial Management* [Pdf] Available at: <<http://www.bhuiyanacademyedu.com/ebooks/Fundamentals%20of%20Financial%20Management.pdf>> [Accessed 8 July 2013].
- Haynes, M.E., 2002. *Project Management: Practical Tools for Success*. Cengage Learning.
- *How to develop a Sustainable Energy Action Plan* [Pdf] Available at: <[http://www.eumayors.eu/IMG/pdf/seap\\_guidelines\\_en.pdf](http://www.eumayors.eu/IMG/pdf/seap_guidelines_en.pdf)> [Accessed 8 July 2013].
- *INDIA'S ENERGY SCENARIO IN 2020* [Pdf] Available at: <[http://www.cesc.co.in/cesc/e-prognya/cms/wp-content/uploads/Energyscenarior\\_at\\_india.pdf](http://www.cesc.co.in/cesc/e-prognya/cms/wp-content/uploads/Energyscenarior_at_india.pdf)> [Accessed 5 July 2013].
- *ISO 50000 Energy Management Systems Auditor Training Course* [Video online] Available at: <<http://www.youtube.com/watch?v=sDfLBL0l7BQ>> [Accessed 5 July 2013].
- Lock, D., 2007. *Project Management*. Gower publishing Ltd.
- *Material & Energy Balances Final (Review): Part I*[Video online] Available at: <<http://www.youtube.com/watch?v=2rhEZ4ZB3lM>> [Accessed 8 July 2013].
- *Material and Energy Balance* [Pdf] Available at: <<http://www.em-ea.org/Guide%20Books/Book-1/1.4%20MATERIAL%20%20AND%20ENERGY%20BALANCE.pdf>> [Accessed 8 July 2013].
- *Module 2: Basic Principles of Energy* [Pdf] Available at: <[http://www.energy.gov.za/EEE/Projects/Building%20Energy%20Audit%20Training/Training%20Modules/Building%20Energy%20Auditing%20Module%202\\_final.pdf](http://www.energy.gov.za/EEE/Projects/Building%20Energy%20Audit%20Training/Training%20Modules/Building%20Energy%20Auditing%20Module%202_final.pdf)> [Accessed 5 July 2013].
- *Monitoring and Targeting* [Pdf] Available at: <[http://www.carbontrust.com/media/31683/ctg008\\_monitoring\\_and\\_targeting.pdf](http://www.carbontrust.com/media/31683/ctg008_monitoring_and_targeting.pdf)> [Accessed 8 July 2013].
- Moss, K.J., 2006. *Energy Management in Buildings*. Taylor & Francis.
- Olsen, S. E. and Tangstad, M., 2007. *Production of Manganese Ferroalloys*. Tapir Academic Press.
- *Project Management Fundamentals* [Pdf] Available at: <[http://www.giorgiogiuissani.it/project-managemet\\_EN.pdf](http://www.giorgiogiuissani.it/project-managemet_EN.pdf)> [Accessed 8 July 2013].
- *Project Management in under 8 minutes* [Video online] Available at: <<http://www.youtube.com/watch?v=qkuUBcmxBpk>> [Accessed 8 July 2013].
- *Project management tutorial* [Pdf] Available at: <<http://ocw.mit.edu/courses/mechanical-engineering/2-000-how-and-why-machines-work-spring-2002/tools/management.pdf>> [Accessed 8 July 2013].
- *The Energy Report - A fully sustainable and renewable global energy system is possible by 2050* [Video online] Available at: <[http://www.youtube.com/watch?v=wG6b\\_amCmHw](http://www.youtube.com/watch?v=wG6b_amCmHw)> [Accessed 5 July 2013].
- *USFWS's Region 6 Landscape-scale Energy Action Plan (LEAP)*[Video online] Available at: <<http://www.youtube.com/watch?v=ekaybgRLOXs>> [Accessed 8 July 2013].
- *What is Project Management? Training Video* [Video online] Available at: <<http://www.youtube.com/watch?v=9LSnINglkQA>> [Accessed 8 July 2013].
- *World Energy Scenarios to 2050: Issues and Options* [Pdf] Available at: <<http://www.nezhadpmd.com/worldenergyscenarios.pdf>> [Accessed 5 July 2013].

### Recommended Reading

- Andrews, J. and Jolley, N. A., 2007. *Energy science: Principles, Technologies, and Impacts*. Oxford University Press.
- Balu, K., Satyamurthi, N., Ramalingam, S. and Deebika, B., 2009. *Problems on Material and Energy Balance Calculation*. I.K International Publishing House Pvt. Ltd.
- Beggs, C., 2009. *Energy: Management, Supply and Conservation*. Elsevier Ltd.
- Chandra, P., 2008. *Financial Management*. Tata McGraw-Hill.
- Cleland, D.I., 2006. *Project management: Strategic Design and Implementation*. McGraw-Hill Professional.
- Cotts, D. G., Roper, K. O. and Payant, R.P., 2010. *The facility management handbook*. AMACOM Div American Mgmt Assn.

- Doty, S. and Turner, W.C., 2009. Energy management handbook. The Fairmont Press, Inc.
- Geller, H., 2003. Energy Revolution: Policies for a Sustainable Future. Island Press.
- Ghosh, T.K. and Prelas, M.A., 2009. Energy Resources and Systems: Fundamentals and non-renewable resources. Springer.
- Gotel, D.G., 1989. The Application of Monitoring & Targeting to Energy Management (Home Office Research Study). HMSO Books.
- Henley, E.J. and Rosen, E.M., 1969. Material and Energy Balance Computations. Wiley.
- Jayamaha, L., 2006. Energy-efficient building systems: green strategies for operation and maintenance. The McGraw-Hill Companies, Inc
- Kerzner, H., 2009. Project Management: A Systems Approach to Planning, Scheduling, and Controlling. John Wiley and Sons.
- Lamb, J., 2009. The greening of IT: how companies can make a difference for the environment. Pearson Education.
- Levermore, G.J., 1989. Monitoring and Targeting with a Building Energy Management System. BSRIA.
- Levermore, G.J., 2000. Building energy management systems: applications to low-energy HVAC and natural ventilation control. Taylor & Francis.
- Meredith, J.R. and Mantel, S.J., 2008. Project Management: A Managerial Approach. John Wiley & Sons.
- Raja, A.K. and Srivastava, A.P., 2007. Power Plant Engineering. New Age International.
- Reklaitis, G.V., 1983. Introduction to Material and Energy Balances. Wiley.
- Shim, J.K. and Siegal, J. G., 2008. Financial Management. Barron's Educational Series.
- Thumann, A. and Mehta, D.P., 2008. Handbook of Energy Engineering. The Fairmont Press.
- Thumann, A., Younger, W.J. and Niehus, T., 2009. Handbook of Energy Audits. The Fairmount Press, Inc.
- VanHome, J. C. and Wachowicz, J.M., 2008. Fundamentals of Financial Management. Financial Times/Prentice Hall.
- Wesley, M., 2007. Energy Security in Asia. Routledge.

## Self Assessment Answers

### Chapter I

1. c
2. d
3. c
4. a
5. a
6. b
7. d
8. a
9. b
10. b

### Chapter II

1. c
2. d
3. c
4. b
5. d
6. a
7. b
8. d
9. a
10. d

### Chapter III

1. b
2. b
3. c
4. c
5. d
6. d
7. a
8. a
9. b
10. c

### Chapter IV

1. b
2. a
3. c
4. b
5. d
6. d
7. a
8. d
9. b
10. c

**Chapter V**

1. a
2. c
3. d
4. b
5. c
6. b
7. a
8. c
9. d
10. c

**Chapter VI**

1. d
2. a
3. c
4. b
5. a
6. c
7. b
8. a
9. b
10. c

**Chapter VII**

1. c
2. a
3. b
4. d
5. c
6. d
7. a
8. b
9. c
10. d

**Chapter VIII**

1. d
2. b
3. c
4. b
5. a
6. b
7. d
8. c
9. a
10. c