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ßEducation is a liberating force, and in our age it is also a democratising force, cutting across the barriers of caste and class, smoothing out inequalities imposed by birth and other circumstances.Þ

μ Indira Gandhi

Indira Gandhi
National Open University
School of Engineering and Technology

OEY-003
ENERGY MANAGEMENT : AUDIT AND CONSERVATION

Block

4

ENERGY CONSERVATION MEASURES-II

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ENERGY CONSERVATION MEASURES - II

The adequate and right kind of energy is necessary for the sustainable development of human society. Today, we need energy for various activities like cooking, lighting, heating, air-conditioning, transport, agriculture and industrial applications. Most of the energy for these applications is derived from burning of fossil fuels (coal, oil and natural gas). The excessive use of these finite sources is posing a serious challenge to human society. On one hand, their use is deteriorating the environment and on the other hand their stock is fast depleting. The only option left to human society is to adopting the policy of interaction of 3E's (Energy, Economy and Environment). In its simplest form, it refers to adopt the policy of Energy Conservation and Energy Substitution. Energy conservation means to use energy efficiently and hence cutting out waste to zero level. Energy substitution means to make use of renewable energy so that dependence on fossil fuels is reduced.

In this Block, we will discuss energy audit of various industrial units so that you get enough exposure of energy audit and conservation measures. We will also discuss how to carry out electrical and thermal energy balance and how to identify energy wastage areas. Finally, we will discuss appropriate energy conservation measures.

UNIT 1 ENERGY AUDIT AND CONSERVATION IN A WIRE MANUFACTURING COMPANY

Structure

1.1 INTRODUCTION

It is widely acknowledged that availability of energy determines the growth potential of economy of a nation. In any industry, the amount and the cost of production of goods are greatly influenced by the availability and cost of energy. The cost of energy is rising rapidly and at the same time the availability of energy is not up to the mark. This aspect of production activities immediately puts great importance on the right and efficient management of energy.

The per capita energy consumption in India has been one of the lowest. Also, India is not as efficient a user of energy as some of the other developing countries.

The energy scenario in our country by and large is represented as follows :

- About 37% gap between demand and supply of petrol,
- About 18% peak power shortage,
- About 7% average power shortage, and
- Indian industries are energy inefficient; there is energy saving potential of about 25-30%.

The sectorial consumption of energy in India is shown in Figure 1.1.

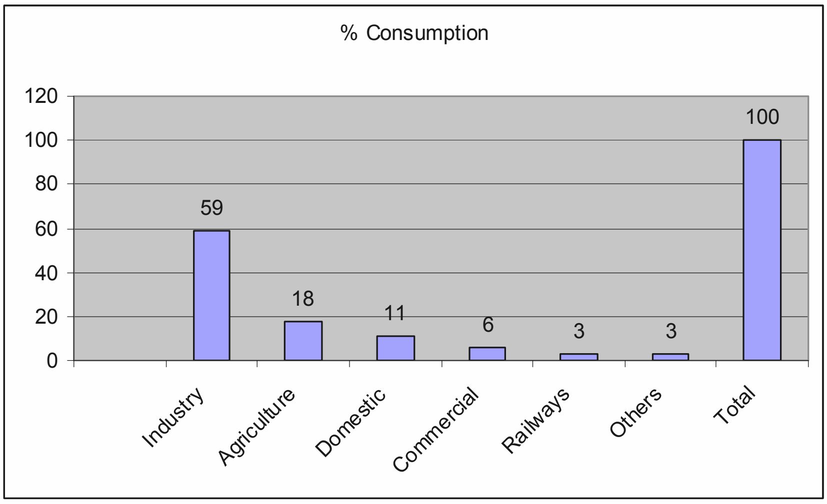

Figure 1.1 : Energy Consumption Pattern

It is therefore clear that industrial sectors make maximum use of electricity and therefore, we must concentrate on energy saving in industrial sector.

In this Unit, we will consider energy audit and energy conservation measures in a wire manufacturing industry with the following objective in the mind :

- Field study at system and equipment level, auditing of energy consumption after examination.
- Analysis of present energy consumption pattern.
- Identification of equipment and services where saving of energy is possible.
- Recommendation of energy efficiency measures and analysis of energy usage.
- Recommendation of alteration/modification/replacement of plant equipments for consumption of energy and its cost.
- Estimation of annual energy saving and pay back period along with of energy saved and produced.

The concern for energy conservation and the insight into various energy related processes gained over the years has led to development of variety of energy conservation measures. Some of them are :

- Housekeeping measures to use the available sources in an optimum way.
- New energy efficient systems for improving efficiency of energy supply and consumption.
- Renewable energy systems to promote energy substitution for energy conservation.

Objectives

After studying this unit, you will be able to understand the following :

- Energy audit of a company manufacturing wires,
- Energy audit of Vanaspati Industries, and
- Identify energy conservation measures in such industries.

1.2ENERGY AUDIT DATA

1.2.1 Equipments and Connected Load

We have audited an industrial unit which is engaged in the production of cast iron wires. The company has the following equipments and load :

(1) Supply voltage is 33 KV

(2) Transformer rating is 759 KVA

(3) Contract demand is 471 KVA

(4) Maximum demand is 390 KVA

(5) Average electricity bill is 83572 KWh/month

(6) Connected load is 1350 HP

(7) Average consumption of furnace oil is 16710 liters.

1.2.2 Energy Consumption

The monthly electric consumption during the period of audit is given in Table 1.1, which also gives maximum demand and power factor. Monthly consumption of furnace oil is given in Table 1.2. The average electricity consumption per month is about 83572 KWh where as the average consumption of furnace oil is 16710 liters. The monthly production data are given in Table 1.3. The average production is 343 tonnes.

1.2.3 Specific Energy Consumption

For calculating specific energy consumption, all kinds of energy used in the industry are to be converted in to same unit (say e.g. GJ). We assume the following conversion units :

1 KWh (electrical) = 0.0036 GJ

1 liter of Furnace oil = 0.039 GJ

The total monthly energy consumption (GJ) and specific energy consumption are shown in Table 1.4. The monthly average consumption of oil energy and electrical energy is as under :

Table 1.1 : Monthly Electric Consumption, Maximum Demand and Power Factor

Month	Consumption (KWh)	Maximum Demand (KVA)	Power Factor (PF)
August	69501	354	0.85
September	65604	348	0.87
October	67047	343	0.86
November	71820	330	0.85
December	93600	372	0.88
January	106344	389	0.90
February	107918	366	0.91
March	97908	366	0.86
April	96720	346	0.87
May	60516	371	0.74
June	80760	361	0.79
July	85116	357	0.80

Total	1002854		

Table 1.2 : Monthly Consumption of Furnace Oil

Month	Consumption (Liters)
August	10731
September	7269
October	10633
November	2761
December	10000
January	27390
February	37891
March	31913
April	24006
May	18369
June	16982
July	2574
Total	200519

Table 1.3 : Monthly Production Data

Month	Production (Tonne)
August	318
September	306
October	311
November	323
December	361
January	384
February	389
March	372
April	368
May	301
June	336
July	345
Total	4114

Electricity = 300.84 GJ (31%)

Furnace oil = 651.65 GJ (69%)

Total monthly energy consumption = 952.5 GJ.

It may be seen that almost 69% of total energy consumed is in the form of furnace oil where as electricity shares 31 %. This is shown in Figure 1.2.

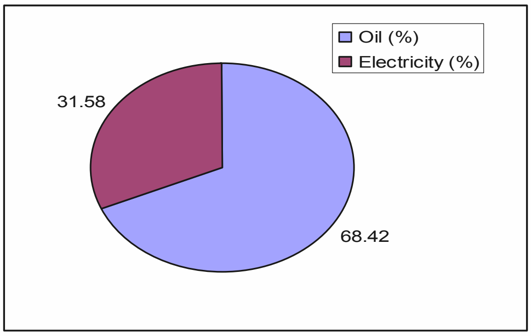

Figure 1.2 : Percentage of Furnace Oil and Electricity Consumed

Table 1.4 : Total Energy Consumption and Specific Energy Consumption

Month	Oil (GJ)	Electricity (GJ)	Total Energy (GJ)	Production (Tonne)	SpecificEnergy Consumption (GJ/Tonne)
August	418.5	250.2	668.7	318	2.10
September	283.4	236.2	519.6	306	1.70
October	414.6	241.4	656	311	2.11
November	107.6	258.5	366.1	323	1.13
December	390	336.9	726.9	361	2.01
January	1068.2	382.8	1451	384	3.78
February	1477.7	388.5	1866.2	389	4.80
March	1244.6	352.5	1597.1	372	4.29
April	936.2	348.2	1284.4	368	3.49
May	716.4	217.8	934.2	301	3.10
June	662.2	290.7	952.9	336	2.84
July	100.4	306.4	406.8	345	1.18
Total	7819.8	3610.1	11429.9	4114	
Monthly Average	651.65	300.84	952.49	342.83	

1.3 ENERGY BALANCE

We will now develop energy balance for thermal as well as electrical energy.

1.3.1 Thermal Energy Balance

The oil fired furnace is operated with two burners with a blower of 7.5 H.P. and 750 cubic feet per minute (CFM). Furnace is insulated from four sides by insulating bricks of 18 inch thickness. The top of furnace is kept open as threading of wire is done intermittently.

The energy liberated by the combustion of oil is used in the following segments :

(a) Heating the wire surface to 450°C

(b) Heat taken by flue gases

(c) Structural losses

(d) Incomplete combustion associated with formation of CO, un-burnt carbon, etc.

Data for a typical month (October) are :

Furnace oil consumption	= 7140 liters
Total production	= 170 Tonne
Production per hour	= 500 Kg/hr
Oil consumption per hour	= 15.2 Lit/hr
Calorific value of furnace oil	= 44250 KJ/Kg

Specific density of furnace oil = 0.896 Kg./liter

Oil used per hr = 15.2 Lit/hr

= 13.62 Kg/hr

Mass of the wire passing through furnace = 500 Kg./hr

Temperature of hot wire = 450°C

Ambient air temperature = 25°C

Specific heat of wire = 0.48 KJ/Kg.-°C

Energy released per hr = 13.62 Kg./hr × 44250 KJ/Kg

$= 6.03 \times 10^5$ KJ/hr

(a) Energy Used in Heating Wire

Specific heat of wire = 0.48 KJ/Kg °C

Mass of wire passing through furnace, Mi = 500 Kg/hr

Heat taken by wire per hr = $Mi\ Cp\ dt$

$= 500 \times 0.48 \times (450 - 25) = 1.02 \times 10^5$ KJ/hr

% of Heat utilized in heating wire $= \dfrac{102 \times 10^5}{6.03 \times 10^5} \times 100 = 16.9\%$

(b) Energy Taken by Flue Gases

Carbon content of oil (assumed) = 85%

Weight of carbon in the gases = 0.85 * 13.62 = 11.6 Kg/hr

Blower capacity = 750 CFM. (ft^3/min)

Density of air at 30°C = 0.0730 lb/ft^3

Mass of air = 60 (minutes/hr) × 750 (ft^3/minute) × 0.0730 (lb/ft^3) × 0.4536 (Kg/lb) = 1490 Kg/hr

Heat taken by the flue gases = (Blower capacity + carbon in oil burnt/hr) × specific heat of the flue gases × temperature of the fire gases

$= (1490 + 11.6) \times 1.03 \times 250$

$= 3.9 \times 10^5$ KJ/hr

% of Heat in the flue gases $= \dfrac{3.9 \times 10^5}{6.03 \times 10^5} \times 100 = 16.9\%$

% of Heat in the flue gases = 64%.

Out of 64% energy in flue gases, some part of energy is used in heating plates up to 70°C. As a result, the temperature of flue gases get reduced to 200°C and heat contained in flue gases to 3.1×10^5 KJ/hr.

Heat in flue gases is now 51%.

(c) Structural losses

The structural losses (radiative, conductive and convective) are worked out to be 0.063×10^5, to be equal to 10%.

(d) Thermal Energy Balance

The thermal energy balance gives the following :

Energy released per hr (6.03×10^5)

= Energy used in heating wire (1.02×10^5)

+ Energy taken by flue gases (3.9×10^5)

+ Structural losses (0.603×10^5)

+ Losses due to incomplete combustion

or 100% = 16.9% + 64.68% + 10% + Losses due to incomplete combustion.

Thus, losses due to incomplete combustion are 8.42%. The Sankey diagram looks like the one shown in Figure 1.3.

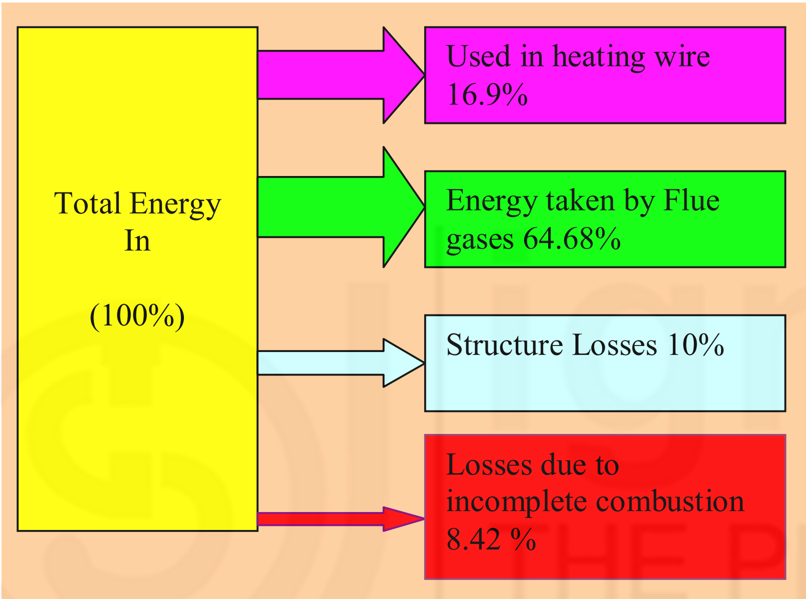

Figure 1.3 : Sankey Diagram for Thermal Energy Balance

1.3.2 Electrical Energy Balance

The electricity consumption in the month of October is 67047 KWh. The electricity consumed in various sections is given in Table 1.5. The actual load on the motor is calculated and operating hours are known by comparing production in the month with the production if motors run for twenty four hours.

Table 1.5 : Electrical Consumption in Different Sections

Sl. No	Actual Load		Operating Hours	Energy Consumed (KWh)
	H.P.	KW		
1.	54	40	178	7171
2.	96	72	192	13750
3.	122	91	127	11559
4.	20	15	150	2238
5.	22	16	152	2495
6.	24	18	142	2542
7.	----	115	120	13800
8.	13	9	200	1880
9.	35	26	250	6490
10.	----	10	280	2716
11.	20	15	100	1492
			Total	**66132**

The difference (67047-66132) of 915 KWh could be due to incorrect observation of operating hours of various equipments. We have seen that about 40% of electrical energy is consumed by various motors of wire drawing section.

1.4 ENERGY CONSERVATION MEASURES

Based on above energy balance (thermal and electrical) the following energy saving measures are visible.

1.4.1 Oxygen Enrichment of the Supplied Air to Furnace

The quality of air blown into the furnace can be improved by increasing oxygen content of air. It has been experienced that for every 2% enrichment of blast with oxygen yields about 20% of energy saving and 3% enrichment yields about 25% of energy saving. Depending upon the practical conditions of furnace 15-25% savings may be achieved. By increasing oxygen in supplied air we are virtually decreasing percentage of un-combustible gases in air which unnecessarily unitizes energy of furnace oil by heating itself.

For burning furnace oil, theoretical amount of air required is 14.3 Kg air per Kg of oil (Murgai and Ram Chandra, 2000).

Assuming excess air factor to be 1.5, actual air required for combustion of 14 Kg. of oil per hr. = 14 × 14.3 × 1.5 = 300 Kg.

If we enrich this air by 2 % with oxygen the saving could be 20%

Present consumption = 15.2 lit/hr

Fuel Saved = 3.04 lit/hr

Annual cost of fuel saved = Rs. 80256 (based on 4400 hrs. working annually)

Amount of oxygen required = 0.02 × 300 = 6 Kg/hr.

Annual cost of oxygen required = Rs. 264000/- (@ 10/- per Kg.)

Pay back period = (264000/ 80256) = 3.3 years.

We can call it a long term energy conservation measure.

1.4.2 Improvement in Furnace Insulation

About 10% of energy is lost through radiations, conduction and convection from the surface of furnace. The improvement in the furnace lining with fiber wool material will result in substantial savings.

The dimensions of furnace are 6ft × 3ft × 2ft. The ceramic fiber wool required to cover the four sides and top roof of furnace

$$= 2\,[6 \times 2 + 3 \times 2] + 6 \times 3$$

= 50 sq.ft (say 55 sq.ft.)

Cost of ceramic fiber lining insulation @ 200/- per sq.ft. = 200 × 55 = 11,000/-

Savings as estimated in thermal energy balance = 10% heat lost, i.e. 60300 KJ/hr is saved.

Saving in furnace oil = 60300/44250=1.4 Kg/hr

Annual savings = 6160 Kg (assuming 4400 hrs per year running time)

Cost of saving = Rs. 36960

Pay back period = (11000/36960) × 12 = 4 month.

We can call it a short term energy conservation measure.

1.4.3 Heat Recovery from the Flue Gases

The heat contained in the flue gases can be used either for preheating combustion air fed through blower or preheating fuel oil injected through burner. This will reduce the furnace oil consumption for obtaining the same temperature inside the furnace.

Temperature of flue gases = 200°C. The flue gases can be cooled up to 75°C. The detailed analysis of estimating the area of pre-heater is beyond the scope of this Unit. We have worked out the surface area as 25 m^2.

Estimated fabrication cost at Rs. 12000/m^2 = Rs. 3.0 lakhs

Heat required to heat 1490 Kg/hr of air from 30°C to 156°C

$$1490 \times 1.03 \times (156\text{-}30) = 0.190 \text{ MJ/hr}$$

Furnace oil saved = 4.4 Kg/hr (@ 4400 working hours per year)

Annual furnace oil savings =19360 Kg

Annual cost of fuel saving = Rs. 1.16 lakhs

Pay back period = 3/1.16 = 2.6 year

We may call it a long term energy conservation measure.

1.4.4 Addition of Fuel Treatment Chemicals

The furnace oil consumption can be reduced by about 5% with addition of suitable fuel treatment chemicals. The advantage of mixing of fuel treatment chemicals is to overcome common fuel oil problems.

Furnace oil saving after addition of fuel treatment chemicals can be up to 5%.

Total fuel consumption per year = 167000 liters

Fuel savings @ 5% = 8350 liters

Cost of fuel savings = Rs. 50000/-

Cost of fuel treatment chemicals @60 Rs. Per 1000 liters.

= 60 × 167000/1000 = Rs. 10020.

Payback Period = (10020/50000) × 12 = 2.4 months

We may call it a short term energy conservation measure.

1.4.5 Induction Motors

We have found that about 60% of motors are running below 65% loading. However an induction motor should always be loaded to its maximum capacity. These induction motors are designed to be efficient at full rated load. The motor efficiency reduces drastically when load factor on the motor is less than 50-60% of rated load. Below 50% of rated load the efficiency is very less.

To obtain the performance of motors, the current drawn by each motor is measured and the loading is obtained by dividing it by full load current.

The measured data are given in Table 1.6.

Table 1.6 : Loading Pattern of Selective A.C. Motors

Sl. No.	Motor	Rated Full Load	Actual Load Ampere			Loading %
	H.P.	LOAD	R	Y	B	
1.	25	33	22.8	22.4	22.0	69.1
2.	40	53	29.5	29.6	29.6	55.8
3.	50	65	28.8	29.0	29.5	45.3
4.	10	14.5	10.8	10.9	10.5	75.1
5.	15	20	13.7	13.9	13.0	69.5
6.	25	34	19.1	19.0	19.3	56.7
7.	7.5	10.5	4.0	3.6	3.8	38.1

The cost benefit analysis for replacing a standard motor by an energy efficient motor of same rating has been worked out for different loading conditions and is represented in the Table 1.7. Pay back period is calculated by considering that motor is operated each day at full load for two hours, at half load for six hours and at 1/10 load for 13 hrs and assuming 300 working days in a year.

Table 1.7 : Energy Savings by Energy Efficient Motors

Sl. No	Description	Standard Motor	Energy Efficient Motor
1	Motor (KW)	15	15
2	Cost (Rs.)	21000	31500
3	Interest and depreciation 25%	5250	7785
4	Total cost (Rs.)	26250	39375
5	Efficiency@ Full Load	89%	91.8%
6	Efficiency @ half load	85%	90%
7	Efficiency@ 1/10 load	35%	41%
8	Power input@ full load (a)	16.85	16.33
9	@ Half load (b)	8.823	8.33
10	@ 1/10 load (c)	4.285	3.65
11	Energy consumption/year = (a) × 2 × 300+ (b) × 6 × 300 + (c) × 13 × 300	42702	39027
12	Annual savings Rs.	-	6798
13	Pay Back Period	-	2.0 yrs

The cost benefit analysis of replacing under load motors by energy efficient motors of suitable H.P may be done as follows :

Cost of energy saved per year = Power out put in KW × [1/efficiency of standard motor – 1/efficiency of energy efficient motor] × 100 × No. of working hrs in a year × tariff.

The total investment for the replacement work out to be Rs. 1.9 lakhs while the annual savings realized with the current tariff of Rs. 1.85 per KWh works out to be Rs. 0.68 lakhs. The pay back period without considering interest on investment and money earned by selling replaced motor range from 1.5 yrs to 4 yrs for difference motors. Some specific cases are given below :

(1) H.P. =10, R.P.M. = 1440, Full Load Current (FLC) =14.5 amp.

Current drawn = 8.2 amp.

Hence loading = (8.2/14.5) × 100 = 56.5%

Efficiency of 10 H.P. motor at 56.5 % loading = 83%

H.P. delivered =10 × 0.565 = 5.65 H.P.

Now say 7.5 H.P. energy efficient motor is selected to meet the requirement.

Loading of 7.5 H.P. motor = 5.65 × 100/7.5 =75.3%

Efficiency of 7.5 H.P energy efficient motor at 75.3% loading = 91%.

Cost of energy saved based on 16 hrs a day running, 300 days in a year and tariff of Rs. 1.85/-per KWh.

$$= 10 \times 0.746 \times (91 - 83) \times 100 \times 16 \times 300 \times 1.85/(91 \times 83)$$

= Rs. 3964

Cost of 7.5 H.P. energy efficient motor = Rs. 13200/-

Pay back period = 13200/3964 = 3.4 years.

(2) H.P. = 50, R.P.M = 1440, FLC = 65 amp.

Current drawn = 30.6 amp.

Hence loading = (30.6/65) × 100 = 47.1%

Efficiency of 50 H.P. motor at 47.1% loading = 80%

H.P. delivered = 23.5 H.P.

Now say 30 H.P. motor is selected to meet the requirement.

Loading of 30 H.P. motor = (23.5 × 100)/30 = 78.3%

Efficiency of 30 H.P. energy efficient motor at 78.3% loading = 91%

$$\text{Cost of energy saved } = \frac{50 \times 746 \times 471\ (91 - 80) \times 100 \times 16 \times 300 \times 1.85}{91 \times 80}$$

= Rs. 23572

Cost of 30 H.P. energy efficient motor = Rs. 44,120/-

Payback period = 44,120/23572 = 1.9 years.

(3) H.P = 25, R.P.M. = 975, FLC =34 amp.

Current drawn = 19.3

Hence Loading = 56.7%

Efficiency of 25 H.P. motor at 56.7% loading = 82%

Actual H.P delivered = 25 × 0.567 =14.2 H.P.

Now say 20 H.P. energy efficient motor is selected to meet the requirement

Loading of 20 H.P. motor = (14.2 × 100)/20 = 70%

Efficiency of 20 H.P. energy efficient motor at 70% loading = 91%.

$$\text{Cost of energy saved} = \frac{25 \times 0.746 \times 0.567\ (91 - 82) \times 100 \times 16 \times 300 \times 1.85}{91 \times 80}$$

$$= \text{Rs. } 11{,}313$$

Cost of 20 H.P. energy efficient motor = Rs. 45,450/-

Pay back period = 45,450 / 11,313 = 4 yrs.

(4) H.P. = 7.5, R.P.M = 1425, FLC = 10.5 amp.

Current drawn = 40 amp

Hence loading =38.1%

Efficiency of 7.5 H.P. motor at 38.1% loading = 72%

Actual H.P. delivered = 7.5 × 0.381 = 2.81 H.P.

Now say 4 H.P. motor is selected.

Loading of 4 H.P. motor = 2.86/4 = 71.5%

Efficiency of 4 H.P energy efficient motor at 71.5% loading = 90%.

$$\text{Cost of energy saved} = \frac{7.5 \times 746 \times 0.381\ (90 - 72) \times 100 \times 16 \times 300 \times 1.85}{90 \times 72}$$

$$= \text{Rs. } 5258$$

Cost of 4 H.P energy efficient motor = Rs. 7900/-

Pay back period = 7900/5258 = 1.5 yrs.

1.4.6 Lighting

The total connected load of the plant and office is around 10 KW. Although the lighting load is very less, yet there are some recommendations which if implemented, will result in energy savings.

(1) About 15% of energy savings may be realized by using the different luminaries. It is recommended to replace 40 W tube lights by 18 W fluorescent compact tube lights. It offers a good performance over tube lights and lower consumption.

(2) Use of electronic ballasts in place of conventional ballasts will save about 18 W per tube light. It requires 33% less power to operate and does not require a Power Factor capacitor or starter.

(3) Disconnect ballasts where lamps have been removed. Ballasts dissipate energy in much the same manner as a transformer. The energy is lost in the form of heat given off by windings and metal of ballast. Thus, if the circuit is energized the ballast will dissipate energy even if the lamps have been removed.

(4) Use time clocks or photocell controls for automatic switching. A system of on-off switches on individual or specific group of light fixtures is called "Selective Switching". This enables an individual to turn off specific light fixtures when no one is using that particular area.

(5) Use task lighting. This is very effective specially working with very high illumination levels, but small working area. A localized light source such as a flexible arm lamp can be used at work area to provide the required illumination levels.

The efficacy and working life of some of the light sources are given in Table 1.8.

Table 1.8 : Luminous Efficacy and Life of Light Sources

Light Sources	Efficiency (Lumens/W)	Average Working Life (hrs.)
1. Incandescent lamps	10-18	1000
2. Cool daylight fluorescent tubes	61	5000
3. White fluorescent	69	5000
4. High pressure mercury vapour lamp :		
80 W		
125 W	36.9	5000
400 W	41	5000
	52	5000
5. High Pressure sodium lamp		
70 W	82.8	10000
250 W	100	10000
400 W	117.5	10000

(A) Replacing 40 W Tube Light with Compact Fluorescent Lamp of 18 W

Total no. of tube lights = 135

Cost of present power consumption based on 12 hrs. per day working will be = (135 × 12 × 1.85 × 18 × 300)/1000 = Rs. 35,964/- per year.

Cost of power consumption with CFL = (135 × 12 × 1.85 × 18 × 300)/ = Rs. 16183/- per year

Cost of CFL = Rs. 200/- each

For 135 CFL, total cost = 135 × 200 = Rs. 27000

Cost of energy saved per year =35964 − 16183 = 19781

Pay back period = (27000 × 12)/19781 = 17 months.

(B) Use of Electronic Chokes

Total number of tubes in plants = 135 (40 W each)

Per day consumption = 65 KWh

Annual consumption of all the tube lights = 65 × 300 = 19500 KWh

The use of electronic chokes will reduce the electricity consumption by 12 W per tube.

The reduction in annual electricity consumption

= (135 × 28 × 12 × 300)/1000

= 13608 KWh.

Saving in KWh per year = 19500 – 13608 = 5892

Annual cost of saving = Rs. 1.85/KWh × 5892 KWh = Rs. 10900/-

Cost of electronics choke = Rs. 200 each

Total cost (for all tube lights) = 135 × 200 = Rs. 27000

Pay back period = (27000/10900) × 12 = 2.5 yrs.

1.4.7 Power Factor Improvement

The power factor (P.F.) is the ratio of real power KW to the apparent power KVA. Total KVA is the vector sum of real power KW and reactive KVAr. Although reactive KVAr performs no work, an electric utility must maintain an electrical distribution system to accommodate this additional electrical energy. A utility will often pass this cost to the customers in the form of penalty when power factor falls below a certain value. The power factor should be kept high and constant.

A very common way to keep the power factor high is the use of power capacitors. The power capacitors are installed in the form of bank which is our assembly of capacitor modules electrically connected to each other.

The plant power factor can be improved by :

(1) Improving motor loading as shown above since motors operating at low loads have low P.F.

(2) Providing external capacitors. These provide the reactive KVAr or magnetizing power for reactive loads.

The average power factor in the industry observed by us = 0.85

Total load in the plant = 1350 H.P. (1007 KW)

Power factor required = 0.91

The capacitor required = 170 KVAr

Cost of capacitor per KVAr = Rs. 175

Total cost = Rs. 29750

Saving due to penalty for low P.F in this period = Rs. 24000

Pay back period = 1.23 yrs.

It is recommended that as a permanent solution to the monitoring of power factor, an automatic power factor correction panel may be installed. This panel will consist of automatic power factor correction relays which will measure the P.F. of system and give command for addition of subtraction of capacitor from the system and maintain the P.F high.

1.5 LET US SUM UP

The concern for energy conservation and the insight into various energy related processes gained over the years has led to development of variety of energy conservation measures. Some of them are:

- Housekeeping measures to use the available sources in an optimum way.
- New energy efficient systems for improving efficiency of energy supply and consumption.
- Renewable energy systems to promote energy substitution for energy conservation.

The energy conservation measures in all possible sectors in a wire manufacturing company have been pointed out. Their techno-economics have also been evaluated.

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1. M.P Murgai and Ram Chandra, Boiler Operations, Wiley Eastern Ltd, New Delhi, 2000.

2. IBPL Urja Yearbook 1992, IBPL Urja Research Foundation.

Web Links

http://ecep1.usl.edu/ecep/ecep.htm

http://www.energymanagement.umich.edu/ems/Energy_Conservation.html

UNIT 2 ENERGY AUDIT OF VANASPATI INDUSTRIES

Structure

2.1 INTRODUCTION

By now you know that energy audit is a systematic approach to identify the energy conservation opportunities and suitable energy conservation measures. The audit consists of evaluation of technical feasibility and economics viability of energy conservation measures. The scale of the energy audit depends on its comprehensiveness which in turn depends on the level at which the audit is conducted. Accordingly, the energy audits have been classified as either preliminary or detailed energy audit.

The preliminary energy audit considers walk through energy audit in which visits to the sites and data collection at an organizational level is undertaken to identify the areas of energy wastage. The recommended energy conservation measures in this case belong to housekeeping and short term measures.

The detailed energy audit, also referred to as an integrated energy audit, includes detailed cost benefit analysis of identified energy conservation measures, over and above the preliminary energy audit of a unit. The recommended energy conservation measures therefore belong to medium term and long term measures, in addition to the housekeeping and short term measures identified in the preliminary energy audit.

The energy audit analyses the energy consumption patterns in the recent past at the site to identify causes of the observed energy consumption pattern. Each cause is further investigated to identify relevant energy conservation measures.

Vanaspati is an essential commodity world over which is produced from Soyabean oil, Seasam oil, Rapeseed oil, Rice Bran oil, Cotton seed oil, Mustered oil, Sun flower oil, Mahua oil and other type of edible oils, depending upon market availability. Soyabean oil is the main content of vanaspati ghee obtained from solvent extraction plant; other edible oils are obtained from different suppliers.

In this unit, we will discuss the outcome of energy audit of three vanaspati industries (categorized as A, B and C) and will work out energy conservation measures.

Objectives

After studying this unit, you will be able to understand the following :

- Energy audit of Vanaspati industries,
- Identify energy conservation measures, and
- Areas where these measures may be effective.

2.2 ENERGY AUDIT OF VANASPATI INDUSTRY : A

2.2.1 General Audit Data

The main features of the industry noticed during audit were :

1. **Main Products :**
   (1) Soya extraction
   (2) Vanaspati production
2. **Energy Used/Year (During the Period of Audit)**
   (1) Electricity = 983700 KWh
   (2) Coal = 12000 MT
3. **Production**
   (1) Vanaspati - 60 MT/day
   (2) Soya Seed/oil - 200 MT/day
   (3) Soap or acid oil - 1.5 MT/day
   (4) Hydrogen - 80000 CFT/day
   (5) Oxygen - 100000 CFT/day
4. **Contract Demand** : 2990 KVA
5. **Average Power Factor** : 92 %
6. **Main Equipments**
   (1) Transformers : 4 numbers [1250 KVA, 1000 KVA, 1500 KVA and 630 KVA].
   (2) Boilers : 4 numbers; 3 water tube boilers and One FBC Boiler.

2.2.2 Energy Scenario

Coal and electricity were the major energy sources used. Coal was used for steam generation by four coal fired boilers – one Thermax make fludised bed combustion (FBC) boiler of 10 TPH (tonnes per hour) capacity and three water tube boilers, with integral economizer of capacity 0.56 TPH.

Electricity was used for industrial drivers, pumps, lighting, etc. The consumption pattern of coal and electricity is given below :

(a) Coal

The coal was stored in storage yard and fed to the boiler manually.

Total consumption of coal in the year of audit = 12000 MT

Average Coal consumption/month = 1000 MT

Cost of coal = Rs. 1.17 Crores

Average cost of coal/month = Rs. 9.8 lakhs

The consumption pattern is illustrated in Table 2.1.

(b) Electricity

Power was received through four transformers of 1250 KVA, 1000 KVA, 1500 KVA and 630 KVA rating respectively and distributed to six load centres. There were as many as 200 pumps of various capacities. The supply of electrical energy to these pumps was divided among six load centres.

Total electrical energy consumption for a year = 98,37,000 KWh

Average electrical energy consumption per month = 8,19,750 KWh

Total cost of electrical energy consumed in a year = Rs. 1,76,01,493

Average cost of electrical energy consumed per month = Rs. 14,66,791

Contract demand = 2990 KVA.

The consumption is illustrated in Table 2.2.

(c) Production

Total production of vanaspati during the year = 24723 MT

Average monthly production during the year = 2060 MT

Month-wise production is illustrated in Table 2.3.

Table 2.1 : Energy Consumption Pattern of Coal

Month	Coal Consumption in MT	Cost of Coal in Rs.
September	980	960400
October	990	970200
November	1000	980000
December	1010	989800
January	1020	999600
February	1030	1009400
March	1010	989800
April	990	970200
May	1000	980000
June	970	950600
July	1000	980000
August	1000	980000
Total	**12000**	**11760000**

Table 2.2 : Energy Consumption Pattern of Electrical Energy

Month	Energy Consumed in KWh	Cost of Energy in Rs.	Power Factor	Contact Demand KVA	Maximum Demand KVA	Penalty due to Low Power Factor (Rs.)
September	483000	892044	0.89	2990	1533	14490
October	789000	1493549	0.91	2990	1836	Nil
November	720000	1390207	0.87	2990	1772	64800
December	804000	1537768	0.86	2990	2163	96480
January	969000	1721826	0.93	2990	1823	Nil
February	894000	168221	0.93	2990	1972	Nil
March	1032000	2059455	0.91	2990	2625	Nil
April	948000	1874171	0.90	2990	2259	Nil
May	927000	1835187	0.89	2990	941	27810
June	861000	1733758	0.91	2990	24118	Nil
July	711000	1468644	0.93	2990	2013	Nil
August	699000	1446683	0.93	2990	1836	Nil
Total	**9837000**	**17601493**	**0.90**			**203580**

Table 2.3 : Production Pattern

Month	Quantity of Vanaspati in MT
September	1950
October	2000
November	2100
December	1850
January	2300
February	2500
March	2550
April	2200
May	2260
June	1923
July	2180
August	910
Total Production	**24723**

2.2.3 Specific Energy Consumption

$$\text{Specific energy consumption} = \frac{\text{Total energy consumption in a month}}{\text{Total production in a month}}$$

Total energy consumption in a month = Electricity consumption in a month + Equivalent energy in KWh of monthly coal consumption.

Equivalent energy in KWh of coal consumption

$$= \frac{\text{Coal consumption} \times \text{Calorific value of coal}}{860}$$

By using the above formula, the specific energy consumption of vanaspati industry A for each month is shown in Table 2.4.

Table 2.4 : Specific Energy Consumption of Vanaspati Industry A

Month	Specific Energy Consumption in KWh/MT of Production
September	2877
October	2984
November	2834
December	3291
January	2741
February	2513
March	2477
April	2785
May	2725
June	3087
July	2726
August	6518

The average specific energy consumption is 3129 KWh/MT of Vanaspati production.

2.2.4 Loading of Motors

The loading of motors under running condition can be calculated by measuring the current of the motor. The percentage loading can be determined by using following relation :

$$\% \text{ Loading} = \frac{\text{Measured current of motor}}{\text{Rated current of motor}}$$

By using the above relation the loading of different motors running in Vanaspati Industry A is given in Table 2.5.

Table 2.5 : Loading of Motors

Sl. No	Equipment	Rated KW	Rated amp	Actual amp.	Loading in %
1.	NH_3 compressor	45	75	18.9	25.2
2.	I.D Fan	30	40	30	75
3.	Pre-bleacher	14.9	25	14.8	59.2
4.	Cooling tower	44.76	72.4	40.8	55.24
5.	Water pump in boiler house	15.00	24.26	27.0	111.00
6.	Motors in pump house	29.84	60.00	40.0	60.66
7.	Pump	15.00	24.26	9.0	37.00
8.	Neuraliser	14.92	20.00	10.00	50.00

2.3 ENERGY AUDIT OF VANASPATI INDUSTRY: B

2.3.1 About the Industry

This industry produced vanaspati ghee, oxygen and soya oil. The production capacity of the vanaspati ghee of the unit was 70 MT/day but actual production was about 50 MT/day. Coal and electricity were the only energy sources for the plant.

2.3.2 Energy Consumption Scenario

(a) Electricity

Electricity was extensively used for pumps and industries drivers and lighting. The annual consumption of electricity was 13632972 KWh. The cost of electricity in a year was Rs. 2.31 crores. The electricity consumption pattern is illustrated in Table 2.5 for the year of energy audit.

(b) Coal

Coal was the major source of energy in the plant, used in boiler for steam generation. There was a Thermax make fluidized based combustion boiler of 12 TPH capacity.

The annual consumption of coal was 19272 MT. The cost of coal consumption in a year was about Rs. 2.11 crores. The coal consumption pattern is illustrated in Table 2.5.

(c) Production

Total production of vanaspati in a year = 17565 MT

Average monthly production = 1463.75 MT

Month wise production pattern is illustrated in Table 2.5.

(d) Specific Energy Consumption

The specific energy consumption pattern of Vanaspati Industry B is illustrated in Table 2.6.

(e) Loading of Motors

The equipments and loading of selected motors is given in Table 2.7. Average specific energy consumption = 3116 KWh/MT

Table 2.5 : Energy Consumption Pattern (Electrical Energy)

Month	Energy Consumed in Rs.	Cost of Energy in Rs.	Power Factor	Contract Demand	Actual Maximum Demand KVA	Penalty Due to Low Power Factor in Rs.
September	714000	1331858	93	3500	1977	Nil
October	738000	1370498	94	3500	1908	Nil
November	921000	1779563	93	3500	2286	Nil
December	1242000	2359026	88	3500	2763	74520
January	1320000	2487156	90	3500	2913	Nil
February	1245000	2362328	89	3500	2850	37350
March	1218000	2304122	90	3500	2769	Nil
April	1086000	2157960	90	3500	2634	Nil
May	882000	1794219	95	3500	2601	Nil
June	2085972	2085972	93	3500	2478	Nil
July	1032000	2122972	91	3500	2589	Nil
August	1149000	2370244	89	3500	2895	34470
Total	**13632972**	**23194060**	**91.25**			**146340**

Table 2.6 : Specific Energy Consumption Pattern and Production Pattern

Month	Quantity of Coal Consumption in MT	Production in MT	Specific Energy Consumption in KWh/MT
September	1545	910	3918
October	1378	1260	2155
November	1896	1398	4012
December	1718	1603	3121
January	1425	1503	2358
February	1586	1558	2768
March	1606	1568	2799
April	1879	1609	3548
May	1761	1728	2816
June	1385	1318	2197
July	1614	1513	4192
August	1558	1603	3518
Total	8051	17565	37402

Table 2.7 : Selected Equipment and Loading of Motors

Sl. No.	Devices	KW/Hp	Quantity	Total Load in KW	Actual Load Current	Loading (%)
1.	Post Neuraliser Pump	9.3/12.5	2	18.6	14	80
2.	Bleacher pump	3.7/5	1	3.7	6	78.95
3.	Bleacher filter pump	3.7/5	1	3.7	6	78.95
4.	Catalystic circular pump	3.7/5	1	3.7	6	78.95
5.	Lye. Refining tank	2.2/3	1	2.2	3.5	77.77
6.	Gum tank	5.5/7.5	1	5.5	8.5	80.95
7.	Stop oil tank	2.2/3	1	2.2	3.6	75
8.	Dead oil pump	3.7/5	1	3.7	6.5	85.53
9.	Dead oil booster pump	2.2/3	1	2.2	3.7	80.43
Boiler House						
10.	Feed water pump	15/20	2	30	25	92.59
11.	I.D Fan	30/40	1	30	32	60.30
12.	Dust Collector	0.37/0.5	2	0.74	0.8	66.66
Coal House						
13.	Blower	8.0/10.5	1	8.0	11.5	79.31
14.	Raidar	5.5/7.5	1	5.5	8.4	76.36
15.	I.D Fan	8/10.5	1	8	5.5	50
16.	D.C. tank	1	1	5.5	5.5	50
Power Section						
17.	Pulveriser	75/100	1	75	87	68.5
18.	Blowe	22/25	1	22	32	80
19.	Screw conveyor	3.7/5	4	14.8	8	72.72
20	Lifter	5.5/7.5	3	16.5	8.5	77.27

Compressor Room						
21.	Water pump	5.5/7.5	2	11	8.5	77.27
22.	Water pump	15/20	1	15	22	80
23.	Compressor	30/40	3	90	44	80
24.	Cold room	3.7/5	3	11.1	3.4	44.73
25.	Blower	3.7/5	1	3.7	6	78.94
Vanaspati and filling section						
26.	Vanaspati tank	3.7/5.0	1	3.7	6	78.94
27.	Packing, machine	0.37/5	3	0.37	6.9	66.66
28.	Hydrogen compressor	37/50	1	37	40	59.70
29.	Water tank	3.7/5.0	7	6	6	85.71

All the above motors run for 24 hrs. Cell room consumption in a year = 3023500 KWh.

2.4 ENERGY AUDIT OF VANASPATI INDUSTRY : C

2.4.1 About the Industry

This unit produced vanaspati ghee, oxygen, soap or acid oil. Coal and electricity were the main sources of energy used in the plant. The electricity consumption of the plant was 84,97,29 KWh/year and coal consumption was 13901 MT/year. The contract demand of unit was 2200 KVA and average power factor was 0.9.

2.4.2 Energy Scenario

Coal and electricity were the main sources of energy. Coal was consumed in boilers to generate steam and electricity was used for industrial drives, pumps, compressors and lighting. The electricity consumption pattern is given in Table 2.8. The consumption of coal and specific energy consumption is given in Table 2.9.

Table 2.8 : Electricity Consumption Pattern

Month	Electricity Consumption in KWh	Power Factor 0.91	Maximum Demand in KVA	Penalty due to Low Power Factor (Rs.)
September	708117	0.92	1532	Nil
October	695843	0.89	1677	20875
November	812604	0.88	1422	48756
December	961916	0.92	1800	Nil
January	511386	0.93	1819	Nil
February	687785	0.91	1732	Nil
March	564272	0.91	1649	Nil
April	711330	0.90	1809	Nil
May	549677	0.87	1790	49470
June	794042	0.89	1689	23821
July	801097	0.88	1420	48065
August	699228	0.91	1544	Nil
Total	8497297			190987

Contract demand = 2200 KVA

Average monthly consumption = 708108 KWh

Average power factor = 0.9

Table 2.9 : Energy Consumption Patterns

Month	Coal Consumption in MT	Production in MT	Specific Energy Consumption
September	1318	2801	2715
October	1249	2711	2668
November	886	2548	2139
December	1120	2678	2548
January	1071	2100	2914
February	860	2248	2298
March	1196	2340	2917
April	1225	8219	3211
May	1119	2188	2927
June	1291	2615	2887
July	1177	2514	2768
August	1389	2482	3211
Total	13901	29444	33203

Average coal consumption = 1158.4 MT/month

Average production of vanaspati ghee = 2453.66 MT

Average specific energy consumption = 2766.91/ MT of Vanaspati production.

2.5 LET US SUM UP

Vanaspati industries are energy intensive. These consist of large size of utilities like boilers, compressed air, water pumps and cold room for vanaspati storage. There is large material handling also. Steam is a heat transfer medium for different process operations.

We have discussed energy audit of three vanaspati industries. The energy conservation measures will be discussed in the next unit.

UNIT 3 ENERGY CONSERVATION MEASURES IN VANASPATI INDUSTRIES

Structure

3.1 INTRODUCTION

Energy audit data of three vanaspati industries has been presented in the previous Unit. From the audit data you would have noted that the industries under consideration are large consumers of energy. You are also aware that earning profits is one of the principal objectives of industries. They will generally not invest in energy conservation until it is an economically viable, and preferably a profitable proposition. It is therefore important to evaluate the technical feasibility as well as the economic viability of such measures before deciding about their implementation. In this Unit we shall discuss the techno-economics of various energy conservation measures.

Objectives

After studying this unit, you will be able to understand

- various energy conservation measures in vanaspati industries, and
- techno-economics of energy conservation measures.

3.2 STORAGE AND HANDLING OF COAL

Coal was a vital fuel source for the unit. During the audit, it was observed that storage and handling of coal had not been given much importance. Preventing wastage or contamination of primary fuels before use is important. Fuel which has been degraded by poor storage and handling procedures is often difficult to burn, requiring greater excess air and consequently has lower over all thermal efficiency.

The coal received was stored on open ground. The fine particles in coal got mixed with earth floor causing gradual but continuous loss called 'carpet loss'. You have learnt about carpet loss in the context of wire manufacturing industry in Block 3.

The optimum stack height recommended is 150 cm to reduce the carpet loss to a minimum of 1 to 1.75%. Another important aspect concerning coal storage is that it degrades with time. When freshly mined it contains volatile liquids and gases which are released, generating heat. In large, unventilated stacks, this can lead to "Spontaneous Combustion". Limiting stack height to 1.5 meters is sufficient to prevent both contamination and carpet loss.

3.3 LOW POWER FACTOR

We will use the audit data for Vanaspati Industry A. The electrical power consumption for one year was 983700 KWh and average power factor was 0.90. On the basis of above data, the power wastage can be calculated.

The required power factor = 0.95

$\cos \varphi_1 = 0.9; \quad \varphi_1 = 25.8$

$\cos \varphi_2 = 0.95; \quad \varphi_2 = 18.19$

Saving = penalty due to low P.F. = 203580 Rs./Yr.

Rating of capacitor bank = KW ($\tan \varphi_1 - \tan \varphi_2$)

= 1125 (tan 25.8 – tan 18.19)

= 174 KVAr

Investment on modification = Rs. 18720

$$\text{Payback period} = \frac{\text{Investment on modification}}{\text{Net saving per year}} \times 12$$

$$= \frac{1870 \times 12}{203580} = 1.1 \text{ months}$$

The summary of calculations for all the three units is given in Table 3.1 below.

Table 3.1 : Capacitors Installation for P.F. Improvement

Vanaspati Industry	Capacitor Rating (KVAr)	Investment (Rs.)	Saving (Rs.)	Pay Back Period (Months)
A	174	18720	203508	1
B	209	44750	190987	3
C	202	64250	146340	5

3.4 STEAM LEAKAGE THROUGH VALVES

During audit, it was observed that a lot of steam was leaking through different valves and joints. The measured steam leakages in Vanaspati Industry A are given in Table 3.2.

Table 3.2 : Steam Leakages Through Different Locations

Sl. No.	Location	Quantity in Kg/hr
1.	Deodriser valve No.2	2.3 Kg/hr
2.	Pressure Reducing valve in Boiler House	1.5 Kg/hr
3.	Joint Near Filter Press	1 Kg/hr
4.	Autoclave No.3	3 Kg/hr
Total leakages		8.2 Kg/hr

Wastage of steam in a month = 5904 Kg

So the yearly wastage of 70848 Kg (5904 × 12) of steam can be saved by replacing the valves and joints.

Investment required for replacement of valves = Rs. 14,000

Labour cost = Rs. 6000

Total Investment = Rs. 20,000

Energy saving in year = 70848 × 656 (Enthalpy of steam at 150ºC)

$= 4.6 \times 10^7$ KCal

Coal saved = 10.3 MT

Cost of coal saved = 10.3 × Rs. 1100/MT = Rs. 11330

$$\text{Payback period} = \frac{\text{Investment}}{\text{Saving}} \times 12$$

$$= \frac{20000}{11330} \times 12 = 21 \text{ months}$$

3.5 INSULATION OF STEAM PIPE LINES

It was also observed that 14 m of pipeline carrying steam was without insulation, resulting in substantial heat loss. Detailed calculations showed that

Total cost of insulation = Rs. 22800/-

Cost of annual energy saved = Rs. 9259

$$\text{Payback period} = \frac{\text{Investment on modification}}{\text{Net saving per year}} \times 12$$

$$= \frac{22800}{9259} \times 12 = 30 \text{ months}$$

3.6 REPLACEMENT OF UNDER LOADED MOTORS

The motors operated under 50% loading of their full load current capacity. Summary of motors recommended is given in Table 3.3.

A sample calculation is given below :

Rating of ammonia compressor motor	=	60 HP
Full load Current	=	75 Amp.
Current drawn	=	18.9 Amp
Loading	=	25.2 %
Efficiency of the motor at 25.2% loading	=	62 %
Power delivered	=	15 HP

Now if 17.5 Hp motor is selected, % loading is

$$\% \text{ Loading} = \frac{15}{17.5} \times 100 = 85.7$$

Efficiency of 17.5 HP motor at 85.7% loading = 90%

Energy saving cost in a year

$$= \frac{\text{KW} \times (\text{Eff. Diff.}) \times (\text{hrs./day}) \times \text{No. of the days} \times 100 \times \text{tariff}}{\text{Multiplication of two efficiencies}}$$

$$= \frac{44.76 \times (92 - 62) \times 16 \times 300 \times 1.9}{62 \times 90} = \text{Rs. } 204837$$

Investment = Rs. 18,421/-

$$\text{Payback period} = \frac{\text{Investment}}{\text{Net saving per year}} \times 12$$

Pay back period = 1 month.

Table 3.3 : Summary of Motor Recommended for Replacement

Vanaspati Industry	Old H.P. Motors	% Load	New HP Motors	Savings		Investment Rs.	Pay Back Period Month
				KWh	Rs.		
A	20	37	10	117426	22000	14392	1.2
A	5	30	2	19604	37600	5758	1.8
A	15	44	7.5	40284	80568	8897	1.32
B	30	40	15	80568	161136	23530	1.75
C	40	30	15	150393	300787	23530	0.93

3.7 LOADING OF TRANSFORMERS

The loading of transformers is given in Table 3.4. The feasibility analysis of Vanaspati Industry C is as follows :

Transformer rating	= 2000 KVA
Rated secondary current	= 2782.4 Amp.
Measured current	= 1280 Amp.

Loading of transformer = 56.78 %

Cost of electricity = Rs. 1.9/KWh

Power factor = 0.9

The annual losses in KW due to under loading of transformer works out to be

Annual loss (KW) = (A – C/PF) × PF

= (2000 –1280/0.9) × 0.9 = 520 KW

Annual loss (KWh) = 520 KW × 8760 Hrs = 455520 KWh

Saving of energy in Rs. = 4555200 × 1.9

= Rs. 8654880 = Rs. 8.65 lakhs

Recommended capacity of Transformer was 1500 KVA. The analysis for all the three industries is summarized in Table 3.4.

Table 3.4 : Analysis of Loading of Transformers

Name	Ratings (KVA)	Rated Actual Load Current (Amp.)	Load Current (Amp.)	% Loading of Transformer
Vanaspati Industry A				
(i)	1250	1739	1391	80
(ii)	1000	1392	835	60
(iii)	1500	2087	1296	62.1
(iv)	630	876	448.51	52.1
Vanaspati Industry B				
(i)	1500	2078	1479.5	71.2
(ii)	700	973.8	486.9	50.0
Vanaspati Industry C				
(i)	2000	2783	1600	57.49

3.8 REDUCTION OF CONTRACT DEMAND

The contract demand of Vanaspati Industry C was 3500 KVA. However, the maximum demand during last one year never exceeded 2913 KVA. it was therefore recommended that tthe contract demand be reduced from 3500 KVA to 3000 KVA.

Savings per year = (Present C.D. × 0.75 – Suggested C.D. × 0.75)

× Tariff per KVA × 12 Rs/yr.

= (3500 × 0.75 – 3000 × 0.75) × 74 × 12

= Rs. 3.33 lacs.

A summary of the recommended contract demand is given in Table 3.5.

Table 3.5: Summary of Recommended Contract Demand

Sl. No.	Vanaspati Industry	Present C.D. (KVA)	Recommended C.D. (KVA)	Projected Savings/yr
1.	A	2990	2700	1.93 lacs
2.	B	2000	1800	1.33 lacs

3.9 HEAT RECOVERY FROM FLUE GASES

Air-Preheater Design

The potential of heat recovery from flue gases through the use of air pre-heater (APH) for Vanaspati Industry A is presented below. The flue gas temperature is 275ºC.

Outlet to Air Pre-heater (APH) = 180ºC

Mass flow rate of flue gases = 25312 Kg/hr

Air temperature inlet = 30ºC

Outlet temperature of air at APH temperature = 110ºC

The temperature of the flue gases after giving heat to air (T_o) may be determined as follows :

Heat given by flue gases = Heat taken by air

$$(1600 + 25312) \times 0.26 \times (275 - T_o) = 25312 \times 0.24 \times 80$$

So $T_o = 205$ºC

The area of the heat exchanger comes out to 147 m^2 say 150 m^2

Cost of Air Pre-heater = Rs. 1030000

$$\text{Coal saved (Kg./hr)} = \frac{25312 \times 0.26 \times 80}{4500} = 117 \text{ Kg/hr}$$

Coal saving in a year = 925 MT

Cost of coal saved in a year = Rs. 10.20 lakhs

$$\text{Payback period} = \frac{\text{Investment}}{\text{Saving}} = 1 \text{ Year}$$

3.10 IMPROVEMENT IN LIGHTING SYSTEM

(a) Replacing 40 W Tube lights with Compact Fluorescent Lamps of 18 W

In Vanaspati Industry A, 500 tube lights of 40 W were reported to be replaced every year. These could be replaced by 18 W compact fluorescent tubes having electronic ballasts thus consuming 18 + 4 (electronic ballast) = 22 W as against 40 + 14 (Conventional Ballast) = 54 W. The cost of power consumption based on 300 working days in a year, 10 hours per day and Rs. 2/KWh is given by.

Cost of power consumption with C. F. tubes

$$= \frac{500 \times 10 \times 2 \times [54 - 22] \times 300}{1000} = \text{Rs. } 96000$$

Cost of one compact fluorescent tube fixture = Rs. 300

Total Cost of 500 C.F. tubes = 500 × 300 = Rs. 15,00,000

$$\text{Payback period} = \frac{\text{Investment}}{\text{Net saving per year}} \times 12$$

$$= \frac{15000}{96000} \times 12 = 18 \text{ Months}$$

(b) Replacing 250 W HPMV lamp by HPSV 100 W

In Vanaspati Industry A, 50 HPMV lamps of 250 W were in use at the time of audit. These could be replaced by 100 watt HPSV lamps.

Saving in connected load per point 150 W.

Conversion cost (Material + labour) per lamp from HPMV to HPSV = Rs. 1500/-

Saving per year by replacement $= \dfrac{150 \times 300 \times 10 \times 2}{1000} = \text{Rs. } 900$

By replacing 50 HPMV lamps by HPSV lamps, the saving per year

= 900 × 50 = Rs. 45000/-.

$$\text{Payback period} = \frac{\text{Investment}}{\text{Net saving per year}} \times 12$$

$$\text{Payback period} = \frac{50 \times 15000}{45000} \times 12 = 20 \text{ Months}$$

(c) Replacing 1026 Incandescent Lamps of 100 W

These 100 W lamps could be replaced by tube lights with electronic chokes.

Present cost of power consumption $= \dfrac{1026 \times 100 \times 12 \times 2}{1000} = \text{Rs. } 738720$

After using tube lights in place of incandescent bulb

Cost of power consumption $= \dfrac{1026 \times 44 \times 300 \times 12 \times 2}{1000} = \text{Rs. } 325036$

Total savings in a year = Rs. 4136684

Cost of replacement = Rs. 300 per lamp

Total investment required = 300 × 1026 = Rs. 307800

$$\text{Payback period} = \frac{307800}{413684} \times 12 = 9 \text{ Months}$$

A summary of the payback period is given in Table 3.6

Table 3.6 : Replacement of Lighting Source

VI	W	No.	Suggested Lamps			Savings		Investment	Pay Back Period
			Type	W	No.	KWh	Rs.	Rs.	Yr.
A	100	18	LPSY	35	18	3510	7020	36720	5.23
A	40	800	CFL	18	800	52800	1.05 (lacs)	4.8 (lacs)	4.57
C	250 (HPMV)	4	HPSY	100	4	1800	3600	6000	1.66
B	200 W Incandescent	60	CFL	36	60	29520	59040	7200	1.2
B	1 KW Arc Lamp	10	HPSV	100	16	2550	5100	22500	0.44

VI = Vanaspati Industry

3.11 ENERGY CONSERVATION IN COOLING TOWER FANS

During the energy audit, it was observed that the temperature drop across cooling tower was only about 4 to 6ºC most of the time. It was recommended that thermostatic switches be installed to switch off the cooling tower fans when the temperature fell below a pre-determined level, say 28ºC. The potential for saving was about 1500 KWh even if the fans remained off for about 1700 hours/annum. This would result in a saving of about Rs. 35,000/- per annum. The investment in controllers was about Rs. 40,000/- giving a payback period of about 1 year.

3.12 GUIDELINES FOR ENERGY CONSERVATION IN VANASPATI INDUSTRIES

Based on the energy audit of three vanaspati industries, the generalized guidelines for energy conservation are given below.

3.12.1 Good House Keeping Measures

(a) Switch off lights, fans and other machines whenever not in use.

(b) Building colour should be light.

(c) The scaling should be removed periodically.

(d) Defective conventional fan regulators should be replaced. While replacing the fan regulators the electronic fan regulator should be considered. The use of day light should be encouraged.

(e) Filters of compressor should be cleaned periodically. Also, compressor should be installed in cool and open air place to increase the life of compressor.

(f) Operate the compressor at an average suction and discharge pressure.

(g) Improve cooling tower ventilation.

(h) Use light synthetic material for fan blades of cooling tower.

(i) Stop cooling tower fans when temperature drops below set levels.

(j) Operate the compressor within the specified limit prescribed by the manufacturer.

(k) Use cold water from defrost tray in cooling tower.

(l) Ensure that automatic controls are working properly.

3.12.2 Guidelines for Energy Management

A. Boilers

- Use waste heat recovery from flue gases.
- Air pre-heater for waste heat recovery from flue gases above 150ºC is economical.
- Minimise boiler blow down.

B. Insulation

- Insulate steam and condensate lines.
- Upgrade insulation and lining in furnaces, boilers.

C. Motors

- The motors below 50 % loading may be considered for replacement.
- Improve the power factor of the motor by installing power capacitors.
- Improve and maintain overall power factor by microprocessor based power factor improving devices.

E. Cold Room

- Mount air curtains at the entrance passages.
- Use suction line regulators for better compressor utilization.
- Maintain space temperature lower during the winter season and higher during the summer season.
- Install air seals around truck loading dock doors.

F. Guidelines for Preventive Maintenance

- Check belt tensions to ensure higher mechanical transmission efficiency. All belts should be replaced simultaneously.
- Prevent vanaspati leakages in pipeline fittings and valve by exposing the joint to fire.
- Ensure cleanliness of heat transfer surface in heat exchanger.
- Oiling and greasing should be done regularly
- Reduce the noise and vibrations of the machines.

G. Pumps

- Replace the damaged ball bearing.
- Head of the pump should be maintained.
- In order to reduce mechanical friction, check whether shaft is bent or not.
- Clean the impeller and suction pipe.

3.13 LET US SUM UP

Detailed audit of the vanaspati industries has helped in identifying areas of energy wastage and has shown that the following conservation measures are technically feasible and economically viable :

- Proper storage and handling of coal;
- Improving the power factor by installing power factor correction devices;
- Replacing valves to prevent leakage of steam;
- Insulation of steam pipelines to prevent heat losses;

- Replacement of under-loaded motors;
- Choosing appropriate capacity of transformer;
- Reduction of contract demand;
- Heat recovery from flue gases;
- Use of energy-efficient lighting system; and
- Regulating the cooling tower fans.

Other than these, good housekeeping measures and regular and preventive maintenance of boilers, motors, pumps, etc. can substantially contribute to the energy conservation efforts.

UNIT 4 ENERGY CONSERVATION BY ENERGY EFFICIENT DEVICES

Structure

4.1 INTRODUCTION

Energy conservation by using energy efficient devices has not gained much importance because of several reasons. Some of them are :

- It is still regarded as an initiative to be taken at personal level, and
- Its impact on the nation as a whole is not considered significant.

This perception needs to change. We have to understand that energy efficiency is a very powerful tool for energy conservation. We have also to understand that energy conservation is not simply about individuals conserving energy or not doing an activity for saving energy. Investment in energy efficiency is more beneficial than simply adopting energy conservation measures.

We will discuss various energy efficient devices, their energy saving potential and payback period.

Objectives

After studying this unit, you should be able to

- understand various energy efficient devices, and

- understand the energy conservation potential of energy efficient devices.

4.2 ENERGY EFFICIENT LIGHTING DEVICES

4.2.1 Artificial Lighting

Artificial lighting is an essential requirement for the modern society. The connected lighting load in the country is about 17.5 percent of the total installed generating capacity which can be reduced by making use of energy efficient light sources.

- New energy efficient light sources are about 20 times more energy efficient than the conventional incandescent lamps.
- The energy efficiency (efficacy) of new light sources is up to 200 lumens per watt.

Efficacy

The efficacy of light sources is defined as lumens per unit watt.

Illuminance

Illuminance is defined as the lighting level in lumens/m^2 available at a certain place. The values of illuminance for various sources/situations are:

A. Nature

Full moon	:	0.25 lux
At noon, full sunshine	:	> 1,00,000 lux
Cloudy day – slightly overcast	:	10,000 lux
- heavily overcast	:	1,000 lux
Bright day : Under tree	:	15,000 lux
Near Window	:	5,000 lux
Inside room at 1 m depth	:	500 lux
Sunrise and sunset	:	500 lux

B. Artificial Lighting (Recommended Values)

Roads	:	5 to 30 lux
Sub-stations	:	100 lux
Recreational play	:	150 lux
Outdoor storage areas	:	20 lux
Interiors – Rough work	:	150 lux
- Medium	:	300 lux
- Fine work	:	500-1000 lux

4.2.2 Energy Consumption Facts of Some Light Sources

The efficacy and average life of some of the lighting devices is given in Table 4.1.

Table 4.1 : Energy Consumption Facts of Some Light Sources

Sl. No.	Light Source	Luminous Efficacy (%)	Average Life (Hours)
1. Incandescent Lamps :			
i.	Incandescent Lamps 25-1000 W	8-20	1000
ii.	Tungsten halogen lamps 500-2000 W	22-27	2000
2. Fluorescent Lamps :			
i.	Conventional fluorescent tubes 20-80 W	61	5000
ii.	Slim line fluorescent tube 36 W	70	7000
iii.	Compact fluorescent lamps 5-25 W	40-50	8-10,000
iv.	TLD 80 series fluorescent lamps	90	8-10,000
3. High Intensity Discharge Lamps :			
i.	Blended light lamps MLL 100-500 W	18-26	5000
ii.	High pressure mercury vapour lamps 80-400 W	37-52	5000
iii.	High pressure sodium vapour lamps 70-1000 W	83-120	12000
iv.	Low pressure sodium vapour lamps 35-180 W	70-140	1200
V.	High pressure metal halide lamps 375-2000 W	67-95	1200
4. Induction Lamps :			
		60-70	60000

4.2.3 Techno-Economic Analysis of Replacing Incandescent Bulbs by CFL

A techno-economic analysis of replacing incandescent bulb by CFL for 7,500 burning hours is given in Table 4.2. A 15 W CFL produces as much light as a 75 W incandescent bulb. The useful life of CFL varies from 7500 to 10000 hrs whereas the incandescent bulb has useful life of about 1000 hrs. This means that a person has to purchase about 10 bulbs for getting light for 10000 hrs whereas a single CFL will provide the same amount of light for the same duration.

Table 4.2 : Techno-Economic Analysis of Replacing Incandescent Bulb by CFL

Characteristics	CFL	Incandescent
Power Rating (W)	9	60
Ballast Loss (W)	3	Nil
Light Output (lumen)	600	600
Efficacy (lumen/W)	50	10
Average Life (hr)	7,500	1,000
Lamp Price (Rs)	150	10
Electricity Cost (Rs./kWh)	2.50	2.50

Energy Costs (Rs.) for 7500 Hrs	168	1125
Total Costs (Rs.) Total Saving (Rs.)	318 887	1205 -

Thus though a CFL costs more initially but during its entire life, it will save Rs. 887 as compared to an incandescent bulb. The energy saving potential of some of the light sources is given in Table 4.3.

Table 4.3 : Energy Saving Potential of Energy Efficient Lamps

If you are using	Switch to	Energy Savings
GLS 100W Incandescent Lamp	Argenta superlux 60 W	40%
GLS 150/200/300 W Lamp	Comptalux 75/100/Reflector Lamp	50%
GLS 200 W Incandescent Lamp	ML-160W Blended Lamp	20%
ML 160 W Blended Lamp	HPL-80W Mercury Vapour Lamp	42%
HPL 400 W/250 W	SON 250 W/150W	35%
2 × TL 40 W	SO 35 W	55%
GlS 1000 W	Halogen 1000W	18%
TL 40 W	TLD 36 W	10%
GLS 40/60/75W	PL-7/9/11 W (CFL)	80%

4.2.4 Electronic Ballasts

The advantages of using electronic ballasts are :

- The energy efficiency of light sources can be further improved by using Electronic Ballast. The overall saving by electronic ballasts can be about 25%.
- It does not require a starter. It inherently provides instantaneous start even at very low supply voltage.
- The power factor is maintained close to unity.
- It can work even at sub zero temperature.
- It operates silently without humming.

4.2.5 Voltage Reducers

The advantages of using voltage reducers are :

- The energy saving resulting from application of voltage reducers can be of the order of 10 to 25%.
- Without voltage reducers the higher voltage at night time leads to higher energy consumption and reduced life of tubes.
- If voltage fluctuations are unpredictable then a separate servo-controlled auto-transformer can also lead to saving.
- Voltage reduction can be done irrespective of whether tube lights have electromagnetic chokes or electronic ballasts.

4.2.6 Light Emitting Diodes (LEDs)

A light-emitting diode (LED) is a semiconductor device that emits incoherent narrow-spectrum light when electrically biased in the forward direction. LED based lighting system consumes about 70% less power and emits more light per watt as compared to any other lamp. LED based lights is green (environment friendly) causing no pollution. LED based light can be beamed, spread or focused in any desired area with total control. A technical comparison of LED with other light sources is given in Table 4.4. The energy conservation potential of LED based lighting system is given in Table 4.5.

Table 4.4 : Technical Comparison of LED vs Other Lamps

Lamp Type	Efficacy (Lumen/Watt)	Rated life (hours)
LED	110-150	50,000 to 100, 000
High-pressure sodium	85 to 90	24,000
Quartz pulse-start metal halide	65 to 75	20,000
Ceramic pulse-start metal	80	20,000
Mercury Vapour	40-50	5000-14000
T5-FTL	90 to 93	18,000-30,000
T8-FTL	66 to 90	5,000-15,000
CFL	65 to 80	5,000 to 12,000
Induction	70 at 60,000 hours; 55 at 100,000 hours	100,000

Source : Superlite

Table 4.5 : Energy Conservation Potential of LED

ENERGY SAVING CHART		
Product	**Replaces**	**Saves Energy**
108 W LED	250 W SV Streetlight	60% of power
75 W LED	150 W SV Streetlight	58% of power
35 W LED	70 W SV Streetlight	58% of power
6 W LED	11 W CFL Streetlight	30% of power
20 W LED	36 W FTL/CFL Streetlight	58% of power
18 W LED Down lighter	2x18 W CFL Down lighter	50% of power
8 W LED Down lighter	18 W CFL Cone Down lighter	55% of power
3/4 LED Down lighter	12V/50 W MR16 Down lighter	85% of power

4.3 ENERGY EFFICIENT FAN REGULATORS

- It has been shown that energy consumption is reduced up to 60% between minimum and maximum speeds.
- Energy consumption is reduced up to 30% between minimum to maximum speeds by using a conventional regulator (resister type).
- On an average, about 25% of energy reduction is possible if existing resister type regulator is replaced by an electronic fan regulator.

- The line current drawn by the electronic fan regulator is 20% less than that of the conventional regulator at low speed.

Example 4.1

A ceiling fan (73.5 W) rating operates for 12 hrs per day and 365 days. If the cost of the electricity is Rs. 2.5/kWh, calculate the energy saving. If the cost of electronic fan regulator is Rs. 200, what would be the payback period?

Solution

Annual energy consumed by the fan

= 73.5 (W) × 12 hrs/day × 365 days/year

= 321930 Wh

= 321930/1000 = 321.93 kWh

As stated earlier, there will be on an average 25% reduction with electronic fan regulator as against the conventional fan regulator.

So annual energy saved will be 0.25 × 321.93 KWh.

Cost of energy saved = 0.25 × 321.93 × 2.5 = Rs. 201

Payback period = Cost of electronic fan regulator/Cost of energy saved

= 200/ 201 = about a year

Points to Remember

1. Electronic fan regulators should be used to control the speed of the fans.
2. As far as possible, only energy efficient fans should be used.
3. Windows should be kept open to allow natural air circulation. This will help not only to reduce fan usage but also to operate the fan at reduced speed.
4. A fan running with full speed in a closed room will heat up the room. Thus warm air should be allowed to circulate back to the environment.

4.4 HOUSEHOLD APPLIANCES

There are different types of fuels used in cooking. The heat value and fuel requirement in a single day for a family of five persons is given in Table 4.6 which also includes the conversion efficiencies.

Table 4.6 : Cooking Fuel Required per Day for a Family of 5 Members

Fuel	Heat Value (KCal/Kg)	Requirement (per Day)	Conversion Efficiency (%)
Soft Coke	6050	1.6 Kg	20-30
Charcoal	6500	1.5 Kg	23-30
Wood	4750	6.1 Kg	10-30
Cow dung	2145	12.3 Kg	8-12
Kerosene	5222	0.7 Ltrs	37-52
Electricity	-	3.3 KWh	45-50
LPG	11,812	0.375 Kg	60-65

4.4.1 Advantage of Adopting Pressure Cookers

In a pressure cooker the boiling point of water (100°C) rises because of higher pressure and therefore cooking is done faster, saving about 75% of the fuel and time. A comparison of cooking time in open pot and pressure cooker is given in Table 4.7.

Table 4.7 : Cooking Time in Open Pot and Pressure Cooker

Food	Cooking Time (Minutes)	
	Open Pot	Pressure Cooker
Potatoes	25	8
Dal	45	11
Rice	35	8
Chana	90	25
Mutton	60	18

4.4.2 Cooking Utensils

The fuel consumption and cooking time strongly depends on the kind of stove and the material of the utensil. Table 4.8 gives the time required and fuel consumed for cooking 1 Kg of rice.

Table 4.8 : Energy use in Firewood Stoves, Kerosene Stoves and LPG Burners

Utensil Used	Fuel Wood Stove		Kerosene Stove		LPG Burner	
	Time (min)	Fuel Cons. (gm.)	Time (min)	Fuel Cons. (cc)	Time (min)	Fuel Cons. (gm)
Stainless Steel	45	900	40	93.7	35	231
Aluminium	40	700	35	87.5	30	198
Mud Pot	50	1200	45	100	40	264

4.4.3 Air-conditioning Unit

Air-conditioners have become a common household item in most of the towns and cities. Hence, it is important to know about them before deciding on the size and model of air-conditioner to be purchased. Some broad guidelines are :

- Install the most energy efficient unit even if it is little more expensive.
- Avoid direct sunshine on the outdoor heat exchanger of an air conditioner to improve its work efficiency by about 10%.
- Remove regularly, obstructions from front of air conditioners or their grills and registers, to affect energy savings of the order of 5-15%.
- Clear air filter on room units and grills and registers of central unit, every 2-3 weeks. It can save energy up to 5-10%.
- Check for air leaks; this can lead to energy savings of the order of 5-20%.
- Clean and calibrate thermostats; this saves energy of the order of 5-20%.

- %.
- Follow the manufacturer's suggested maintenance. Properly maintained air conditioning unit consume 5-10% less energy.
- Replace old unit with more efficient unit.

Some of the useful points for air conditioners are given in Table 4.9.

Table 4.9 : Some Useful Points for using Air-Conditioner Efficiently

Conservation Measure	Frequency	Savings Potential (%)
Remove obstruction from front of air conditioner or their grills and registers	Regularly	5-15
Clean air filter on room units and grills and registers of central units	Every 2-3 weeks	5-10
Check for air leaks	Yearly	5-20
Balance the system	Yearly or as needed	5-10
Clean and calibrate thermostats	Yearly	5
Follow manufacturer's suggested maintenance	Regularly	5-10
Replace old unit with more efficient unit	-	Varies

4.4.4 Desert Coolers

The desert coolers are of two types (a) for inside room and (b) for installation in the window. Preferably the desert coolers should be installed in the windows. The following points should be carefully looked into from energy conservation point of view :

- Desert coolers should be as per BIS specifications. If not, one should try to obtain details of the energy consumption and power factor of the unit.
- The power factor for the desert coolers lies in the range 0.85 to 0.90. This can be improved to 0.95 by application of shunt capacitors. This will result in substantial savings of electrical energy.
- Wherever feasible, one should prefer desert cooler to air-conditioner, because for the same capacity of air-conditioner, the average power consumption in these coolers is found to be 4 to 5 times lower.

4.5 ADOPTING RENEWABLE ENERGY SYSTEMS

Renewable energy systems are devised to harness renewable energy such as solar, wind, bioenergy, etc., for their useful application in energy processes, thereby effecting the conservation of conventional energy.

As the renewable energy is clean and non-polluting, it's use helps preserve the environment and ecology thereby improving the quality of life. These systems are more suited to human environment as they are free from all types of pollution including noise pollution.

The available renewable energy systems can be classified into following categories depending upon the source of energy :

(i) Solar Energy Systems : Solar water heaters, solar cookers, solar photovoltaic (PV) converters, solar (PV) pumps, solar (PV) lamps, solar (PV) for television.

(ii) Wind energy Systems : Wind energy converters, wind pumps.

(iii) Bioenergy Systems : Biogas energy converters, cooking stoves, lamps.

4.6 ENERGY EFFICIENT MOTORS

Given below are a number of examples showing how energy efficient motors contribute to energy conservation. While carrying out energy audit of large number of induction motors, it was observed that majority of the motors were under loaded varying from 50% to 78%. The motor efficiency reduces drastically when the load factor on the motor is less than 50 to 60 % of the rated load.

The advantages of energy efficient motors are :

- Energy efficient motors result in low operating costs, and
- Long life.

The annual energy saved by the energy efficient motor may be calculated as follows :

$$Annual\ Energy\ Saved$$
$$= Power\ output\ in\ KW * \left(\frac{1}{\eta_O} - \frac{1}{\eta_N}\right) * \frac{No\ of\ working\ hours}{Year} * 100$$

where η_O is the efficiency of the old motor and η_N is the efficiency of the new motor.

The cost of the annual energy saved may be easily calculated by multiplying annual energy saved by the tariff. Once we know the cost of the annual energy saved, the simple payback period may be determined by dividing the cost of new motor by the cost of annual energy saved.

$$Cost\ of\ Annual\ Energy\ Saved = Annal\ Energy\ Saved * Tariff$$

$$Simple\ payback\ period = \frac{Cost\ of\ new\ motor}{\cos t\ of\ annual\ energy\ saved}$$

Few examples are discussed below.

Example 1

A 10 HP motor was found to be working with 31.25% load. What could be the right size of energy efficient motor, energy saved and payback period if the motor is working 20 Hrs/day and 300 days/year. The cost of electricity is Rs. 5/ kWh.

Solution

Motor = 10 HP

Efficiency of 10 HP motor at 31.25% loading = 65%.

HP delivered = 10 × 31.25/100 = 3.125 HP

Now say 5 HP energy efficient motor is selected.

Loading of 5 HP motor = 3.125/5 = 0.62 = 62%

Efficiency of energy efficient motor = 90%

Cost of annual energy saved

= (10 × 0.746 × 31.25/100) × (90-65)/(90 × 65) × 100 × 20 × 300 × Rs. 5

= Rs. 29887

Cost of 5HP energy efficient motor = Rs. 10000

Payback Period = 10000 × 12/29887 = 4 months

Example 2

A 12.5 HP motor was found to be working with 50% load. What could be the right size of energy efficient motor, energy saved and payback period if the motor is working 20 Hrs/day and 300 days/year. The cost of electricity is Rs. 5/ kWh.

Solution

Motor = 12.5 HP

Efficiency of 12.5 HP motor at 50% loading = 80%.

HP delivered = 12.5 × 50/100 = 6.25 HP

Now say 7.5 HP energy efficient motor is selected.

Loading of 7.5 HP motor = 6.25/7.5 = 0.83 = 83%

Efficiency of energy efficient motor = 92%

Cost of annual energy saved = Rs. 22805

Cost of 7.5 HP energy efficient motor = Rs. 15000

Payback Period = 15000 × 12/22805 = 8 months.

Example 3

A 10 HP motor was found to be working with 50% load. What could be the right size of energy efficient motor, energy saved and payback period if the motor is working 20 Hrs/day and 300 days/year. The cost of electricity is Rs. 5/kWh.

Solution

Motor = 10 HP

Efficiency of 10 HP motor at 50% lading = 80%.

HP delivered = 10 × 50/100 = 5 HP

Now say 7.5 HP energy efficient motor is selected.

Loading of 7.5 HP motor = 5/7.5 = 0.66 = 66%

Efficiency of 7.5 HP energy efficient motor = 92%

Cost of annual energy saved

= (10 × 0.746 × 50/100) × (92 – 80)/(92 × 80) × 100 × 20 × 300 × Rs. 5

= Rs. 18244.

Cost of 7.5HP energy efficient motor = Rs. 15000

Payback Period = 15000 × 12/18244 = 10 months.

Example 4

A 3 HP motor was found to be working with 56% load. What could be the right size of energy efficient motor, energy saved and payback period if the motor is working 10 Hrs/day and 300 days/year. The cost of electricity is Rs. 5/kWh.

Solution

Motor = 3 HP

Efficiency of 3 HP motor at 56% lading = 82%.

HP delivered = 3 × 56/100 = 1.68 HP

Now say 2.2 HP energy efficient motor is selected.

Loading of 2.2 HP motor = 1.68/2.2 = 0.76 = 76%

Efficiency of 2.2 HP energy efficient motor = 92%

Cost of annual energy saved

= (3 × 0.746 × 56/100) × (92 – 82)/(92 × 82) × 100 × 10 × 300 × Rs. 5

= Rs. 2491

Cost of 2.2 HP energy efficient motor = Rs. 8000.

Payback Period = 8000/2491 = 3.2 Years.

Since this motor is running 10 hrs daily and the payback period of the suggested motor is more than 3 years, this motor may be allowed to continue.

4.7 LET US SUM UP

In this Unit the advantages of using energy-efficient devices like CFLs, electronic ballasts, voltage reducers, LEDs, electronic regulators etc have been discussed. The energy conservation potential of other household devices like pressure cookers and other renewal energy systems has also been presented.