UNIT 3 CLASSIFICATION OF ENERGY CONSERVATION MEASURES

Structure

3.1 INTRODUCTION

Based on the energy audit of a unit, different kinds of energy conservation measures emerge. These may be classified under three categories, namely short-term measures, medium-term measures and long-term measures. The technical feasibility of energy conservation measures should address the following issues:

- Availability of technology,
- The impact of energy conservation measure on production, and
- The maintenance requirements and availability of spares.

The economic analysis of energy conservation measures can be conducted by using a variety of methods (see Block 5, Unit 3 of this course for details). The techniques used are : Simple payback method, Internal Rate of Return method, Net Present Value method, etc.

Objectives

After studying this unit, you will be able to

- understand different types of energy conservation measures,

- classify energy conservation measures of any unit into short-term measures, medium-term measures and long-term measures, and
- develop the techno-economics for each category.

3.2 CLASSIFICATION OF ENERGY CONSERVATION MEASURES

As stated above, the energy conservation measures could be classified into three broad categories discussed below.

3.2.1 Short Term : Low Investment

The short term measures include the following :

- Operational Improvement like tuning of a boiler,
- Use of energy saving devices,
- Good Housekeeping, and
- Payback Period: few days or few months.

For carrying out the economic analysis of low investment short duration measures, the simple payback method is usually sufficient. The following procedure may be adopted :

Step 1 : Name the energy conservation measure.

Step 2 : Determine the likely investment in equipments, civil works, instrumentation and auxiliaries.

Step 3: Determine annual operating costs. This includes cost of capital, maintenance, manpower, energy, depreciation, etc.

Step 4 : Determine annual savings in thermal energy, electrical energy, raw material, waste disposal, etc.

Step 5 : Determine net savings :

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

Step 6 : Determine the simple payback period :

Simple payback period in months = (Investment/net savings/year) × 12

The above steps may be repeated for all the energy conservation measures and summarized as shown in the Table 3.1.

Table 3.1 : Summary of Recommended Energy Conservation Measures

Sl. No.	Recommended Energy Saving	Annual Energy (Fuel and Electricity) Savings (KWh/Kl/MT)	Annual Savings (Rs.)	Capital Investment (Rs.)	Simple Payback Period
1					
2					
3					
4					
Total					

3.2.2 Medium Term : Less Investment

The medium term measures include the following :

- Use of Controls,
- Equipment Modification,
- Process Change,
- Energy Efficient Technologies, and
- Payback Period: few months to about a year or so.

3.2.3 Long Term : High Investment

The long term measures include the following :

- Energy Efficient Devices,
- Product Modification,
- Technology Change, and
- Payback Period : few years.

We have given several energy conservation measures with payback periods in subsequent Blocks. We will now demonstrate one energy conservation measure with payback period. Table 3.2 below shows the format of reporting energy conservation measures.

Table 3.2 : Energy Management and Audit Reporting Format for Energy Conservation Recommendations

A : Energy Audit of Existing System	
There are 3 motors in the unit	Source of Data
Motor 1 • Motor Rated HP = 40 • Rated Full Load (Ampere) = 53 • Actual load (Ampere) = 28 • Loading (%) = 28 × 100/53 = 52.8	 Name plate data Name plate data Measured data Calculated data
Motor 2 • Motor Rated HP = 40 • Rated Full Load (Ampere) = 53 • Actual load (Ampere) = 29 • Loading (%) = 29 × 100/29 = 54.7	 Name plate data Name plate data Measured data Calculated data
Motor 2 • Motor Rated HP = 40 • Rated Full Load (Ampere) = 53 • Actual load (Ampere) = 32 • Loading (%) = 32 × 100/53 = 60.3	 Name plate data Name plate data Measured data Calculated data

B : Recommended Energy Conservation Measures
Replacement of existing motors by energy efficient motors
The motors are designed to be efficient at full rated load. The motor efficiency reduces drastically when the load factor on the motor is less than 50-60% of rated load. The proper selection of a motor for a particular condition depends primarily on the following factors : ➢ Running Characteristics ➢ Losses ➢ Power Factor ➢ Starting Characteristics and Operation under variable loads

C : Techno economics of Recommended Energy Conservation Measures

There are two costs involved :

(1) Capital cost

(2) Operational (Running) cost

In the present scenario of energy crisis (higher price and limited availability) the running cost assumes greater significance. The running cost of a motor depends upon its efficiency which is defined as following :

$$Efficiency = \frac{Power\ Loss}{Power\ Input} = \frac{Mechanical\ Energy\ Out}{Electrical\ Energy\ In}$$

The cost of annual energy conserved with the recommended energy efficient motors may be calculated as follows :

$$Annual\ Savings\ =$$

$$Power\ Output\ in\ KW * \left[\frac{1}{\eta_o} - \frac{1}{\eta_n}\right] * 100 * No\ of\ Working\ Hr\ in\ a\ Year * Tariff$$

where, η_o = efficiency of old motor and η_n = efficiency of new motor

While considering the tariff in the above example, following observations should be kept in mind.

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

- Maximum demand charges, KVA : How fast is the electricity used?
- Energy charges, KWh : How much electricity is consumed?
- Peak/Non-peak period: When is electricity utilized?
- Power Factor Charge, P.F : Real power use versus.
- Apparent power use factor.
- Other incentives and penalties applied from time to time.

3.3 SHORT TERM : LOW COST MEASURES

We will discuss energy conservation measures emerged in the audit of printing press discussed in the earlier units.

3.3.1 Tuning of a Boiler

The boilers used in any industry need careful attention during its operation. The tuning of boilers simply means improving the performance of boilers by changing the air and fuel flow rate.

In the boiler used in printing press, the following observations were made :

- In the operation of the boiler no attention was paid to the control of combustion air. There seemed to be no organized practice of controlling excess air through analysis of the flue gases.
- Some of the flue-gas parameters changed over a wide range as the amount for air supplied to the furnace was varied from a dangerously low to a wastefully high level. These were unburned hydrocarbons, O_2, CO, CO_2, NO_x, SO_2. Several of these parameters can be used to determine the optimum level of air for safe and efficient boiler operation.
- The major cause of boiler losses, both avoidable and unavoidable is the boiler draft : 79 % of the air that is blown into the furnace is nitrogen, and this must be heated along with the products of combustion and sent up the stack. If the level of excess air is higher than necessary, excess oxygen, in addition to even more nitrogen, carries still more heat up the stack.
- All boilers need some excess air to ensure proper combustion of the fuel. With appropriate control of air for combustion, based on daily testing as stated above, it may be safely said that the working efficiency of the boiler may be increased by at least 10%. The payback period of such measures is few months.

SAQ 1

What is meant by tuning of a boiler?

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3.3.2 Use of Energy Saver

As discussed earlier in the context of lighting in the printing press, the electricity consumption in lighting constitutes a significant portion. An energy conserving device like a P-20 BEBLEC device can cut down lighting load by about 20% without affecting lighting level. P-20 introduces an inductive impedance across the lighting circuit and thus reduces the current drawn by the load. P-20 is largely available in 1.5, 3.0, 4.5, 6.0 and 7.5 KVA rating. This device is more useful in installations where lights are on for 24 hours, as is in the case of printing press. Let us see how much electricity can be saved using such a device.

The 12,000 fluorescent tube lights of 40 W each consume effectively 54 W due to loss of 14 W in conventional ballasts.

Hence, total consumption due to these tube lights will be

$$= 12{,}000 \times 54/1000 = 648 \text{ KW}$$

For an average Power Factor of 0.9, the connected load = 648/0.9 = 720 KVA

Present energy consumption = 648 KW × 300 Days/year × 24 Hrs/Day

= 4665600 KWh/year

Energy saving by Beblec unit (20%) = 0.2 × 4665600

= 933120 KWh/year

Cost of saving @ 2.0 Rs./KWh = Rs. 1866240/- per year.

Recommended model of P-20 (18 KVA, 40 nos.)

Total cost per unit = Rs. 30000/-

Total cost of 40 units = Rs. 30000 × 40 = Rs. 1200000/-

Simple payback period = (1200000/933120) × 12 = 8 Months

If the costs of the electricity get increased, the payback period will get reduced.

3.3.3 Replacement of 40 W Tubes with 36 W Tubes

There are about 12000 fluorescent tubes of 40 W each operating 24 hrs per day. The tubes are fitted with conventional chokes which consume about 14 W of power. Thus for 300 operational days in a year, the annual consumption is given by :

$$Annual\ Consumption\ E1 = \frac{1200 * 54 * 300 * 24}{1000} KWh / year$$

= 46,65,600 KWh/year

These tubes can be replaced by fluorescent lamps of 36 W in periodical replacement. The 36 W tubes will consume 50 W (36 W + 14 W in conventional choke). The annual consumption after replacing all the tubes will be:

$$Annual\ Consumption\ E2 = \frac{1200 * 50 * 300 * 24}{1000} KWh / year$$

= 43,20,000 KWh/year

The saving in electricity consumption = E1 − E2

= 3,45,600 KWh/year

Cost of electricity saved @ Rs. 2.0/KWh

= Rs. 6,91,200/-

The cost of 36 W tube is Rs.30, the total investment for replacing 12,000 tubes will be Rs. 3,60,000.

The payback period will be as follows :

Payback period = (360000/69200) × 12 = 6 months.

3.3.4 Replacement of Conventional Chokes with Electronic Chokes

In fluorescent lighting ballast (choke) and a starter are essential for starting and running the fluorescent lamp. Approximately one fourth of power is lost in ballast. Electronic ballast overcomes this problem with better quality of fluorescent lighting.

If the conventional chokes are replaced by electronic chokes (they need to be replaced every year anyway) there would be no additional investment as described in the Table 3.3. Suppose 500 fixtures are replaced with electronic choke per year, the cost details are given below.

Cost of each choke = Rs. 125

Cost of starter = Rs. 10

Cost of electronic choke = Rs. 250

Table 3.3 : Cost Analysis of Replacing Conventional Chokes by Electronic Chokes

Parameter	Conventional Choke (Rs.)	Electronic Choke (Rs.)
Investment/year (Rs.)	125 × 500 = 62500	500 × 250 = 125000
Cost of starters (Rs.)	10 × 500 = 5000	-
Net Investment Rs.)	125000 – (62500 + 5000) = 57500	
Power Rating (W)	(40 + 14) × 500 = 27000	(40 + 3) × 500 = 21500
Annual Energy consumption (KWh)	27000 × 24 × 300/1000 =194400	21500 × 24 × 300/1000 = 154800
Cost of energy @ Rs. 2.0/KWh; (Rs.)	388800	309600
Net amount of annual savings (Rs.)	79200	
Simple Payback Period	57500 * 12/79200 = 8.7 months	

3.4 MEDIUM TERM MEDIUM COST MEASURES

3.4.1 Recovery of Waste Heat from Flue Gases

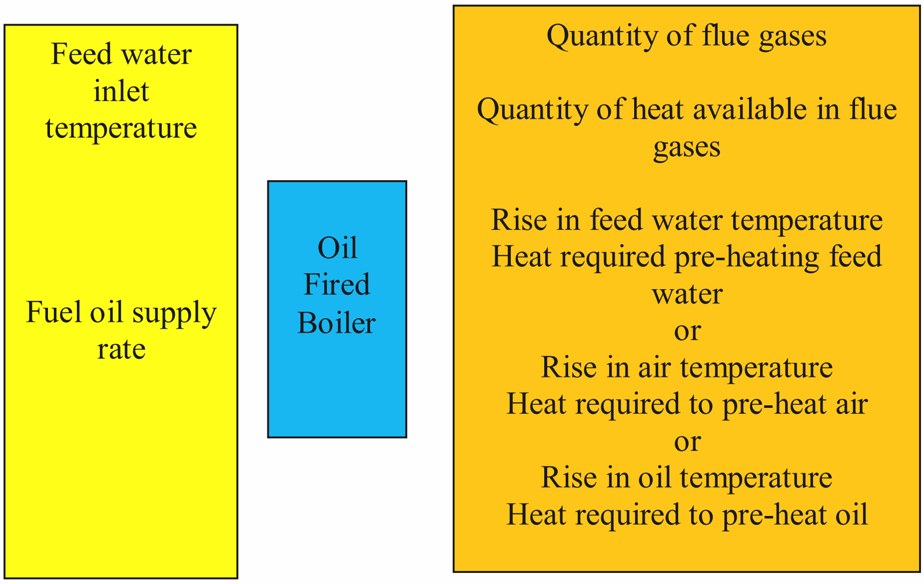
Use of heat recovery devices based on exploitation of the heat contained in the flue gases is an attractive option. The waste heat in flue gases could be recovered by any one of the following measures :

(1) By pre-heating the oil.

(2) By pre-heating boiler feed water; the device is known as economizer.

(3) By pre-heating the excess air needed for the combustion; the device is known as air pre-heater.

You need the input and output data as follows :



Oil Pre-heating

The proposed heat recovery system recommended for the printing press was in the form of oil pre-heater and air pre-heater as shown in Figure 3.1. The costs may be worked as follows :

The flue gas temperature was 330ºC. It was proposed to preheat oil first so that the temperature of flue gases reduced to 324ºC.

Energy content, Q, in flue gases at 330ºC.

Q = Mass flux of flue gases × specific heat of flue gases × temperature difference

Mass flux of the gas = 963.9 Kg./hr

Specific heat of the flue gas = 0.28 KCal/Kg.ºC

Temperature difference = 330 – 324 = 6ºC

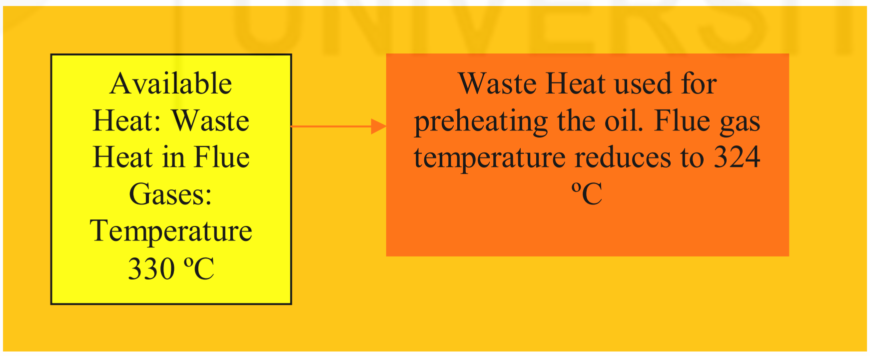


Figure 3.1 : Schematic Diagram of Waste Heat Recovery from Flue Gases

$$Q = 963.9 \times 0.28 \times 6 = 1619.4 \text{ KCal/hr}$$

Specific heat of oil = 0.510 KCal/Kg ºC

Mass flow rate of oil = 51 Kg/ hour

Let T be the Temperature up to which oil can be heated.

Initial temperature of oil = 30ºC.

Thus, $51 \times 0.510 \times (T - 30) = 1619.4$

Giving $T = 92.3$ºC

Calorific value of oil = 10000 Kcal/Kg.

Savings in terms of fuel oil = 1619.4 Kcal/Kg/10000 Kcal/Kg

= 0.16194 Kg/hr

Running operating hours = 300 days × 24 hrs/day = 7200 hrs

Annual savings of fuel oil = 0.16194 Kg/hr × 7200 hr = 1166 Kg.

Annual cost of oil saved = 1166 Kg. × Rs. 20/Kg = Rs. 23320

We can work out the cost of heat exchanger required. The detailed calculations are not given here. The cost of pre-heater comes out to Rs. 6000 and the simple payback period is just about 3 months.

> It has been shown that the existing electric oil heater can be replaced by a small heat exchanger heating the oil to the desired temperature by flue gases. It emerges as a highly cost effective device giving payback period of just a week.
>
> Since this does not require much heat the flue gases continue to be a potential heat source for another heat recovery in the form of air pre-heater. This is also very cost effective, leading to payback period of less than a year.

3.4.2 Installation of Solar Water Heating Systems

We have observed that the boiler consumes oil at the rate of 80 Kg per hour during the period of the year when there is no sunshine. Water is circulated through the boiler at the rate of 304 liters per minute. For this consumption the rise in the water temperature in the boiler works out to be = 27ºC. A detailed analysis is given below.

It has been observed that the oil consumption during the sunny months of the year is 51 Kg/hour. If we want to do away with this consumption by the installation of more solar water heaters, we need to know the cost of solar water heater and other associated costs.

The total heat released by the boiler

= 51 Kg./hr × 9000 KCal/Kg. × 0.73 (efficiency of boiler)

= 335070 KCal

A standard 2 m^2 solar water heater is needed for heating water from ambient 30ºC to 80ºC at the rate of 100 litres per day. Assuming 6 hours of sunshine in a day, the number N of collectors required to provide heat at the above rate may be calculated by using the following relation :

$$N \times 100 \times (80 - 30)/6 = 335070$$

Giving $N = 402$

The cost analysis based on approximate market prices is as follows :

1. Cost of Solar collector system including cost of civil work, Piping, insulation, etc. = Rs. 13,000/-
2. Subsidy on each collector = Rs. 2,000/-
3. Subsidy by state Government @ 20% = Rs. 2,200/-
4. Total investment by Printing Press = 402 × (13000 − 2000 − 2200)

   = Rs. 3.53×10^6
5. Annual saving of oil, assuming 275 sunny days in a year

   = 275 × 6 × 51 = 84150 Kg = 93500 Litres

6. Saving per year @ 6.0 Rs. /litre = 93500 × 6.0 = Rs 0.56 × 10^6

7. Payback period = 6.3 years.

The payback period based on the current prices will be about 5 years.

3.4.3 Energy from Ink and Paper Wastage

The ink waste available in the Printing Press could be mixed up with waste paper and could be used in gasifier for power generation. The process involves the making of small brickets of ink waste and paper and then burning them in gasifier. The ink waste available was found out to be 30000 1/day and waste paper 5.5 Ton/day. When these two are mixed to make brickets, the annual availability may be 5000 tons.

Cost of Gasifier system = Rs. 65,000/-

Calorific value of the waste ink = 190.9 KCal/Kg

Burning rate of biomass = 3 Kg/KWh

Operating hours = 6000 hr/year

Total electricity produced = 5 × 6000 = 30000 KWh/year

Total biomass required = 3 × 30,000 = 90000 Kg = 90 Tonnes

Cost of electricity produced @ Rs. 2.0 per KWh

= 30000 × 2

= 60000 Rs./ year

Total system cost = Rs. 65000/-

Simple payback period = (65000/60000) × 12 = 13 months

When a single unit is tested fully, multiple units can be installed.

3.5 LONG TERM : HIGH COST MEASURES

3.5.1 Solar PV Panels for Street Lighting

Continuing with the example of the printing press, it was noted that there were 400 numbers of poles and there were two 40-watt tubes on each pole. These tubes operated for 12 hours/day. The existing street lights could be replaced by solar PV system.

$$\text{Annual electricity consumption} = \frac{400 \times 2 \times 40 \times 12 \times 365}{1000}$$

= 140160 KWh

One pole of solar PV system consists of two numbers 11 W fixture. By replacing all poles by solar PV system, the saving of electricity would be :

Saving in electricity by PV system = 140160 KWh

Cost of one pole with fixture = Rs. 25000/-

Government Subsidy on one pole = Rs. 18000/-

Investment required = 7000 × 400 = Rs. 2800000

The cost of electricity saved @ Rs. 3/KWh

= 140160 KWh × Rs. 3/KWh = Rs. 420480

The payback period = (2800000/420480) = 6.7 years

3.5.2 Replacement of Existing Motors by Energy Efficient Motors

A large number of electric motors of different horse power ranges are employed in the press to carry out a variety of functions involving varying loads and duty cycles. With so many applications of the motors it is difficult to lay down a comprehensive set of guidelines for all applications.

During the energy audit, measurements of actual currents being drawn by some large sized motors were made and are given in Table 3.4. It was found that some of them were running up to 65% below the rated current. An induction motor should always be loaded to its maximum efficiency (Figure 3.2). These motors are designed to be efficient at full rated load. The motor efficiency get reduced drastically when the load factor on the motor is less than 50-60% of rated load. Hence, the practice of periodic measurement of currents of motors when these are running should be followed regularly. This data should be well documented over a period of time so as to cover all likely loads.

The proper selection of a motor for a particular condition depends primarily on the following factors :

1. Running Characteristics
   (a) Losses, (b) Power Factor
2. Starting characteristics and operation under variable loads
3. Speed Control
4. Braking

Table 3.4 : Loading Pattern of Selected A.C. Motors

Sl. No.	Selection	Motor H.P.	Rated Full Load (Ampere)	Actual Load (Ampere)	Loading %
Air conditioning Room					
1.	Condenser	50	96	56	58.3
	Pump	50	96	66	68.8
2.	Chilled water				
	Pump				
i)	Primary	40	53	28	52.8
		40	53	29	54.7
		40	53	32	60.3
		40	53	-	-
ii)	Secondary	50	96	52	54.1
		50	96	68	70.8
		100	128	98	76.5
		100	128	68	53.5
		15	20	17.5	87.5
		15	20	-	-
		7.5	10.5	7.0	66.6
		7.5	10.5	7.5	71.4
		7.5	10.5	-	-
		7.5	10.5	9.0	85.7
3.	Boiler Room	20	-	28	-
		20	-	-	-

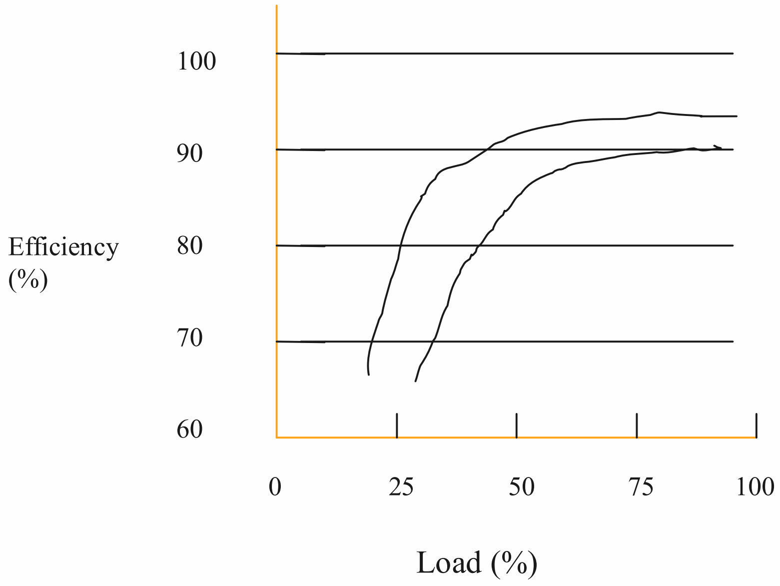


Figure 3.2 : Variation of Motor Efficiency with Load

3.6 LET US SUM UP

In this Unit, we have discussed short term, medium term and long term energy conservation measures.

Short-term energy conservation measures like tuning of boilers, use of energy savers, and replacement of conventional chokes with electronic chokes require very small investment which can be covered in a very short period.

Medium-term measures like heat recovery from flue gases, installation of solar water heating systems, using ink and paper wastage in gasifiers to generate energy, etc. require relatively small investment which can be recovered in a year or so.

Long-term measures like using solar PV panels for street lighting require large investment. However, the cost can be recovered a few years' time.

Energy conservation measures, whether short-term or long-term, are a desirable option, as they not only help us save energy, but are also beneficial from monetary point of view.

3.7 KEY WORDS

Ballast

A device that gives starting voltage and limits the current during normal operation in electrical discharge lamps (such as fluorescent lamps)

Efficiency

Efficiency is the ratio of power loss to the power input

Energy Saver

A device to save electricity

Long Term High Investment

The energy conservation measures with high expenditure such that payback period is more than a year or so.

Medium Term: Low Investment

The energy conservation measures with expenditure such that payback period is about a year or so.

Short Term: Small Investment

The energy conservation measures requiring small investment and having very small payback period ranging from a few weeks to a few months.

Payback Period

The time taken by an energy saving device to recover the cost of the device through cost of energy saved.

3.8 ANSWERS TO SAQs

SAQ 1

Tuning of a boiler means improving the efficiency of the boiler by optimizing the air and fuel flow rate.