UNIT – I

ENERGY AUDITING

INTRODUCTION

The manufacturing industry in India, accounts for over 50% of total commercial energy used in the country. Across the world, industry consumes about 1/3 of all natural energy sources (Murphy & McKay, Energy Management, Butterworth Heinemann, London, 1982). The high levels of energy used in Indian Industry compared to similar industries in advanced countries, the increasing problems of availability of energy sources and their ever escalating costs, strongly point to the immediate need for effective control on the use of energy.

It is believed and often proved by actual studies that a reduction in energy consumption by as much as 10-30% is a realizable goal in a large number of industries, by better and effective energy management at unit level. And these savings can generally be achieved with little or no additional investment.

Any savings that can be achieved in energy costs, directly add to the profit figures. While this is also true, in respect of other direct costs as well, i.e. labour and material costs, it is much harder and more difficult to achieve reduction in their costs.

Another area by which profitability of an enterprise can be improved is by increasing production and market share; but these obviously require additional investments on expansion of manufacturing facilities and man-power and involve added management and marketing effort; and a small portion of increased sales volume contributes to profits.

While the situation from industry to industry may vary, it may be pertinent to state that energy cost savings to the extent of 15-20% is definitely feasible, at least in those industries (besides commercial buildings) where serious study has not yet been attempted. One can visualize the improvement in profitability besides improvement in the competitiveness of Indian manufactured goods in world market, which reduction in energy costs could result in, without any major investment.

Definition & Objectives of Energy Management

The fundamental goal of energy management is to produce goods and provide services with the least cost and least environmental effect. The term energy management means many things to many people. One definition of energy management is:

"The judicious and effective use of energy to maximize profits (minimize costs) and enhance competitive positions"

(Cape Hart, Turner and Kennedy, Guide to Energy Management Fairmont press inc. 1997)

Another comprehensive definition is

"The strategy of adjusting and optimizing energy, using systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total costs of producing the output from these systems"

The *objective* of Energy Management is to achieve and maintain optimum energy procurement and utilization, throughout the organization and:

- To minimize energy costs / waste without affecting production & quality
- To minimize environmental effects.

Common Units and Measurements

SI (System International de‘ units) is followed throughout this course. However, the students are expected to be familiar with other systems of units and their conversion from one system to the other. SI is an absolute system of units.

Fundamental units of SI system

Eight fundamental units have been defined by SI system of units and all other units are derived from these 8 fundamental units. These are tabulated below:

S. No.	Fundamental unit	Unit / Dimension of Measurement
1	Length	Meter, m(L)
2	Mass	Kilogram, kg (M)
3	Time	Second, s(T)
4	Electric Current	Ampere, A(A)
5	Temperature	Kelvin, K
6	Luminous intensity	Candela, Cd
Supplementary units		
7	plane angle	Radian, rad
8	supplementary angle	Steradian, Sr

Decimal fractions and multiples

S. No.	Prefix	Fraction	Symbol
1	Milli	10^{-3}	m
2	Micro	10^{-6}	u
3	Nano	10^{-9}	n
4	Pico	10^{-12}	p
5	Femto	10^{-15}	f
6	Atto	10^{-18}	a
7	Kilo	10^{3}	K
8	Mega	10^{6}	M
9	Giga	10^{9}	G
10	Tera	10^{12}	T

1 Micron: 10^{-6}m or 10^{-3} mm

Let us convert some of these units into other systems, which are still in use (in India and abroad).

1 inch	: 1‖	: 2.54 mm (exactly)
1 foot	: 1‘	: 30.48 cm (exactly) or 0.3048 m
1 yard	: 3‘	: 0.9144 m
1 lb mass	: 453.6 gm	: 0.4536 kg

Definitions

Velocity is defined as rate of change of displacement. In SI units, velocity is represented by m/s.

Acceleration is defined as rate of change of velocity and is represented by $m/s^{2.}$ Acceleration due to gravity is expressed by g and is generally taken as 9.81 m/s^2.

Force is defined by Newton‘s second law of motion and is denoted by _Newton‘. 1 Newton is the force that is required to bring 1 unit of acceleration (1 m/s^2) in a unit mass (1 kg).

F : ma ($kg*m/s^2$) : measure in Newton

Work is defined as force acting over a distance.

W : F*s ($kg.m/s^2$)*m : Newton-m : $kg.m^2/s^2$

Energy and *Work* have the same units, i.e. Newton-m, which is also called joule. 1 erg is the unit of energy in CGS system of units.

1 erg : 10^{-5}

Power is defined as rate of work done and is expressed in watts.

P : W/T ($kg.m/s^2.s$) : Newton – m/s^2 or joule/s or watt (W)

According to First law of thermodynamics, work and heat are mutually convertible.

ENERGY AUDIT

The main purpose energy audit is to increase energy efficiency, and reduce energy related costs. Energy audit is not an exact science. *It involves collection of detailed data and its analyses*. More often sophisticated instruments are used to collect data, but its analyses and interpretation requires technical knowledge, experience, and sound judgment.

Energy audit is a fundamental part of an Energy Management Programme (EMP) in controlling energy costs. It will identify areas of wasteful and inefficient use of energy.

As per the *Energy Conservation Act, 2001*, Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption".

DEFINITIONS AND CONCEPTS

The successful implementation of individual energy conservation programme depends on a proper organizational framework and baseline data for identifying and evaluating energy conservation opportunities. The determination of the baseline data requires a comprehensive and detailed survey of energy uses, material-energy balances, and energy loss. This survey is generally referred to as the Energy Audit.

To save energy, it is necessary to know where, how and how much energy is being consumed. The objective of energy audits is to characterize and quantify the use of energy within the plant at various levels in departments, sections, major processes, and major equipment. The plant energy study provides a comprehensive and detailed picture not only of the type and quantity of energy being used but also how efficiently it is being utilized, and where it is wasted or lost.

The energy audit process include description of energy inputs and product outputs by major departments or by major processing functions, and will evaluate the energy; efficiency of each step of the manufacturing process. Means of improving these will be listed, and a preliminary assessment of the cost of these improvements will be made to indicate the expected payback on any capital investment needed.

The aims of energy audit are as follows:

1. To identify the main energy users and quantify their annual energy consumption.
2. To ascertain the optimized energy data
3. To determine the availability or energy/production data
4. To investigate the distribution systems for the site services and note any existing metering
5. To prepare energy and process flow diagrams for the site

The Energy Audits are normally carried out in two phases, i.e., Preliminary Energy Audit (PEA) and Detailed Energy Audit (DEA).

TYPES OF PLANT ENERGY STUDIES

The type of Energy Audit to be performed depends on:

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

There are mainly two types of energy audit, viz.

1) Preliminary Energy Audit (PEA)
2) Detailed Energy Audit (DEA)

Preliminary Energy Audit (PEA) / House Keeping Practices

Considerable savings are possible through small improvements in the ―house keeping‖ practices, and the cumulative effect of many such small efficiency improvements could be quite significant. These can identify by a short survey, observation and measurements. Many energy conscious industries have already achieved considerable progress in this area.

Approach to Preliminary Energy Audit (PEA)

This essentially involves preliminary data collection and analyses. The PEA is based on collection of available data, analysis, observation, and inference based on experience and judgment is carried out within a short time.

The PEA is the first step in implementing an energy conservation programme, and consists of essentially collecting and analyzing data without the use of sophisticated instruments. The ability and experience on the part of Energy Auditor will influence the degree of its success.

Normally the results of the audit would depend on :-

Experience of the auditor	Availability and completeness of data
Physical size of the facility	Depth of analysis of available data
Complexity of operations within the facility	Awareness of energy matters within the facility

Broadly, the audit is carried out in six steps:-

1. **Organize resources**
   - Manpower / time frame
   - Instrumentation
2. **Identify data requirements**
   - Data forms
3. **Collect data**
   a. Conduct informal interviews
      - Senior management
      - Energy manager/coordinator
      - Plant engineer
      - Operators and production management and personnel
      - Administrative personnel
      - Financial manager

   b. Conduct plant walkthrough/visual inspection
      - Material/energy flow through plant
      - Major functional departments
      - Any installed instrumentation, including utility meters

- Energy report procedures
- Production and operational reporting procedures
- Conservation opportunities

4. Analyze data

a. Develop data base

- Historical data for all energy suppliers
- Time frame basis
- Other related data
- Process flow sheets
- Energy consuming equipment inventory

b. Evaluate data

- Energy use consumption, cost, and schedules
- Energy consumption indices
- Plant operations
- Energy savings potential
- Plant energy management program
- Preliminary energy audit

5. Develop action plan

- Conservation opportunities for immediate implementation
- Projects for further study
- Resources for detailed energy audit
  - Systems for test
  - Instrumentation; portable and fixed
  - Manpower requirements
  - Time frame
- Refinement of corporate energy management programme

6. Implementation

- Implement identified low cost/no cost projects
- Perform detailed audit

The preliminary energy audit is essentially, as the name implies a preliminary data collection and its analysis process. Readily available data on the plants energy systems and energy-using processes or equipment are obtained and studied. The operation and condition of equipment are observed by going around the plant. These provide basis to develop recommendations for immediate short term measures and to provide quick and rough estimates of savings that are possible and achievable.

A preliminary study usually identifies and assesses obvious areas for energy savings such as stream leaks, compressed air leaks, poor or missing insulation, condensate recovery, idling equipment, deterioration and deficiencies in combustion and heat transfer equipment etc. and serves to identify specific areas for the detailed plant energy study.

2.3.1.1. Preliminary Energy Audit Methodology

Preliminary energy audit is a relatively quick exercise to:

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

Detailed Energy Audit (DEA)

This would be a comprehensive energy efficiency study using *portable energy monitoring instruments.* The essential part of this audit is carrying out various measurements and analyses covering individually every significant energy consuming plant item/processes, to determine their efficiencies and loss of energy at that point, and potential energy savings are explored and crystallized, and every recommendation for investment is supported by criteria such as pay-back analysis.

The detailed plant energy study is a comprehensive analyses evaluation of all aspects of energy generation, distribution and utilization within the plant. At the plant level, the analyses require time series data on a daily, monthly, or yearly basis, on the quantities of all forms of primary energy flowing into the plant, e.g. coal, fuel oil, electricity, etc. and production figures of major products, by-products and waste products, at the department or section level. Information is required on the quantity of energy forms consumed, and the production figures of intermediate products. At the equipment level, in addition to the quantities of energy forms and material products, process parameters such as temperature, pressure, flow rate, etc. are also required.

Data generation and collection is an essential and critical element of a detailed energy audit study. Difficulties in getting data required generally arise due to unavailability of historical records. The acquisition of actual operating data through existing or new permanently installed instruments or portable test instruments cannot be overemphasized in this context.

Ten steps methodology for DEA

STEP No	PLAN OF ACTION	PURPOSE / RESULTS
Step-1	*Phase-I: Pre Phase Audit* ✓ Plan and Organize ✓ Walk through Audit ✓ Informal Interview with Energy Manager, Production / Plant Manager	• Resource planning, Establish/organize a Energy audit team. • Organize Instruments & time frame • Macro Data collection (suitable to type of industry.) • Familiarization of process/plant activities • First hand observation & Assessment of current level operation and practices.
Step-2	✓ Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.)	• Building up cooperation • Issue questionnaire for each department • Orientation, awareness creation.
Step-3	*Phase-II: Audit Phase* ✓ Primary data gathering, Process Flow Diagram, & Energy Utility Diagram	• Historic data analysis, Baseline data collection • Prepare process flow charts • All service utilities system diagram (Example: Single line power distribution diagram, water, compressed air & steam distribution. • Design, operating data and schedule of operation • Annual Energy Bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step-4	✓ Conduct survey and monitoring	• Measurements: Motor survey, Insulation, and Lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.
Step-5	✓ Conduct of detailed trials / experiments for selected energy guzzlers	• Trials/Experiments: ○ 24hours power monitoring (MD, PF, kWh etc.). ○ Load variations trends in pumps, fan compressors etc. ○ Boiler/Efficiency trials for (4-8 hours) ○ Furnace Efficiency trials Equipments Performance experiments etc.,
Step-6	✓ Analysis of energy use	• Energy and Material balance & energy loss/waste analysis.
Step-7	✓ Identification and development of Energy Conservation (ENCON) opportunities.	• Identification & Consolidation ENCON measures. • Conceive, develop, and refine ideas • Review the previous ideas suggested by unit

		personal • Review the previous ideas suggested by energy audit if any • Use brainstorming and value analysis techniques • Contact vendors for new/efficient technology.
Step-8	✓ Cost benefit analysis	• Assess technical feasibility, economic viability and prioritization of ENCON (Energy Conservation) options for implementation.
Step-9	✓ Reporting & Presentation to the Top Management	• Documentation, Report Presentation to the top Management.
Step-10	*Phase-III: Post Audit Phase* ✓ Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance • Action plan, Schedule for implementation • Follow-up and periodic review

The duration of DEA studies depends on *plant size and complexity*. Whereas the preliminary energy study can be carried out in a few days, the detailed study would require anywhere from few weeks to months to years of effort.

Plant energy studies can be carried out in house if adequate resources and expertise exist for doing so. Alternatively or additionally, external assistance may be sought from energy consultants, equipment suppliers, and engineering and design firms, in either case, intense interaction between plant personnel and the study team is essential for a proper understanding and a meaningful analysis of the plants energy options. Too often, the plant energy study is considered to be the consultants problem, resulting in minimal inputs and involvement from plant personnel. This attitude is counter-productive. Without the active participation of all levels, full benefits cannot be expected to be accomplished.

ENERGY CONSUMPTION MONITORING

Energy Consumption is to monitor, assess by a company/industry and compared with a specific products manufactured by the industry can be done by two parameters as follows.

They are,

1. Energy Index
2. Cost Index

Energy index

Energy index is a useful parameter to ―monitor and compare energy consumption of specific products manufactured by the industry‖.

Energy index is the figure obtained by dividing energy consumption by production output, and the index may be calculated weekly, monthly or annually. Although the total energy indices are sufficient for monitoring purposes, a record of the individual energy indices should be maintained. In the event of an increase or decrease (due to perhaps a conservation measure) in energy index, the particular source can be investigated immediately.

$$\text{Energy Index (EI)} = \frac{\text{total energy consumption}}{\text{total production output}} \text{ (based on weekly, monthly \& annually)}$$

Energy may be purchased in various units, for example, coal in tons; gas in ft^3,m^3, therms; oil in gallons, litres, tons, barrels etc. the relevant conversion units from one system to the other are given below:

To determine the heat available from the fuel, it is necessary to know the calorific value per unit quantity of energy form and this data is also given in the following example. Further, when estimating the total energy used by a company that consumes several energy forms, it is convenient to rationalize the heat units to common basis.

Example 1:

An office block uses $40*10^3$ gallons of fuel oil per year for heating purposes. The calorific value is $175*10^3$ Btu/gal. The fuel consumption may be expressed in litres or m^3.

Sol:

$40*10^3*4.545$ litres = $182*10^3$ litres = 182 m^3

The calorific value may be quoted as 10^3 J/litres

$175*10^3$ Btu/gal = $175*10^3*0.2321*10^3$ J/l = $40600*10^3$ J/l = $40.6*10^6$ J/l

The total theoretical heat available becomes:

i. $40*10^3$ gal $*175*10^3$ Btu/gal = $7.00*10^9$ Btu/year
ii. $182*10^3$ I * 40600 $*10^3$ Btu/gal = $7.39*10^9$ J/year
iii. 182 m^3 $*40.6*10^6$ Btu/gal = $7.39*10^9$ J/year

Example 2:

Consider a company using three energy forms – oil, gas and electricity. The annual energy consumption is shown below in various energy units. Each of these energy types may be represented as a percentage of the total energy used and tabulated as an energy balance.

Energy type	Consumption	Energy	Energy (J)	Energy (Wh)
Oil	$10*10^3$ gal	$1.775*10^9$ Btu	$1.872*10^{12}$	$0.520*10^9$
Gas	$5*10^3$ therms	$5*10^3$ therms	$0.526*10^{12}$	$0.146*10^9$
Electricity	99510^3 kWh	99510^3 kWh	$0.358*10^{12}$	$0.995*10^9$
		Total	$2.754*10^{12}$	$1.661*10^9$

Note: Calorific value of oil: 18.3*10 Btu/lb; Density of fuel: 9.7 lb/gal

Percentage Energy Balance

Energy form	Percentage
Oil	67.9
Gas	19.1
Electricity	13.0
Total	100.0

Example 3:

If the company in Example 2 produces $100*10^3$ tons of a particular product, calculate the energy indices.

Sol:

Oil energy index : $0.520*10^9$ Wh/$100*10^9$ = $5.20*10^3$ Wh/ton of product

Gas energy index : $0.146*10^9$ Wh/$100*10^9$ = $1.46*10^3$ Wh/ton of product

Electricity energy index : $0.995*10^9$ Wh/$100*10^9$ = $9.95\ 10^3$ Wh/ton of product

Total energy index : $1.661*10^9$ Wh/$100*10^9$ = $16.61*10^3$ Wh/ton of product

Cost Index

The *cost index* is another parameter which can be used to –monitor and assess energy consumption by a company‖. The cost index is defined as the cost of energy divided by the production output. An individual cost index can be determined for each energy form and for the total energy consumption by the company.

$$\text{Cost Index (CI)} = \frac{\text{total cost of energy}}{\text{total production output}}$$

Example 4:

Table below shows energy costs for a company using coke, gas and electricity. This company produces $15*10^3$ tons per year. Calculate cost indices.

Energy type	Consumption	Costs (Rs.)
Coke	$1.5*10^3$ (tons)	$108.0*10^3$
Gas	$18*10^3$ (therms)	$3.6*10^3$
Electricity	$1*10^9$ (Wh)	$22.5*10^3$
	Total	$134*10^3$

Sol:

Coke cost index = $108.0*10^3$ / $15*10^3$ (tons) = Rs. 7.2/ton

Gas cost index = $3.6*10^3$ / $15*10^3$ (tons) = Rs. 0.2/ton

Electricity cost index = $22.5*10^3 / 15*10^3$ (tons) = Rs. 1.5/ton

Total cost index = $134.1*10^3 / 15*10^3$ (tons) = Rs. 8.9/ton

REPRESENTATION OF CONSUMPTION

Several methods of representing energy flows and energy consumption are available and these may be graphical or tabular. Most among them are the *"pie chart and the sankey diagram"*.

Pie chart

Energy usage is plotted on a circular chart where the quantity of a particular type is represented as a segment of a circle. The size of the segment will be proportional to the energy consumption using a particular fuel (energy form or source) relative to total energy use. The energy units must be rationalized to the same units.

Example 5:

A company uses on an hourly basis $11.72*10^3$ therms of gas, $500*10^3$ W electricity and $4.32*10^9$ J oil. Represent these energy consumptions in a pie chart.

Sol:

The results may all be expressed in watts as follows:

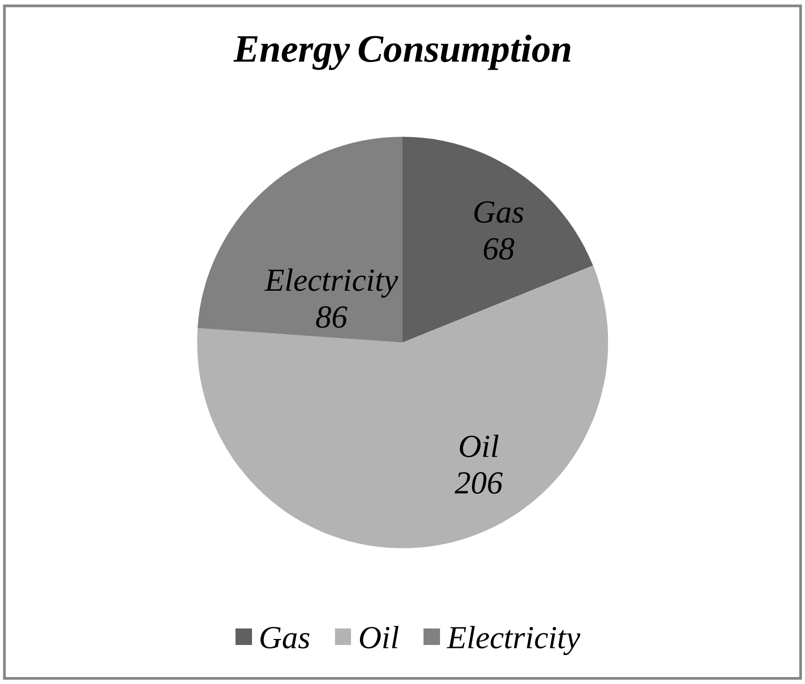
Gas = $11.72*10^3 / 29.31*10^{-3}$ = $400*10^3$ W

Electricity = $500*10^3$ W

Oil = $4.32*10^9*0.278*10^{-3}$ = $1200*10^3$ W

Total hourly energy consumption = $2100*10^3$ W

The pie chart can be represented as follows



Consequently, the angles occupied by the segment are:

Gas $= (400*10^3/2100*10^3)*360 = 68^0$

Oil $= (1200*10^3/2100*10^3)*360= 206^0$

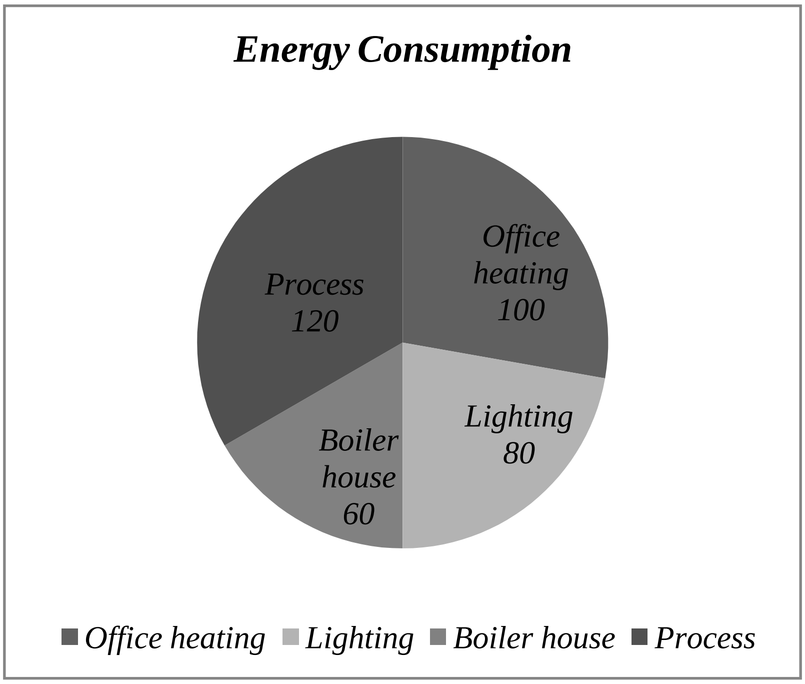
Gas $= (500*10^3/2100*10^3)*360 = 86^0$

Example 6:

The use of pie charts may be extended to show the consumption of a particular type of energy through a company. Consider electricity usage by a company as:

Office heating	$150x10^3W$	(100^0)
Lighting	$120x10^3W$	(80^0)
Boiler house	$90x10^3W$	(60^0)
Process	$180x10^3W$	(120^0)
Total	$540 x10^3W$	(360^0)

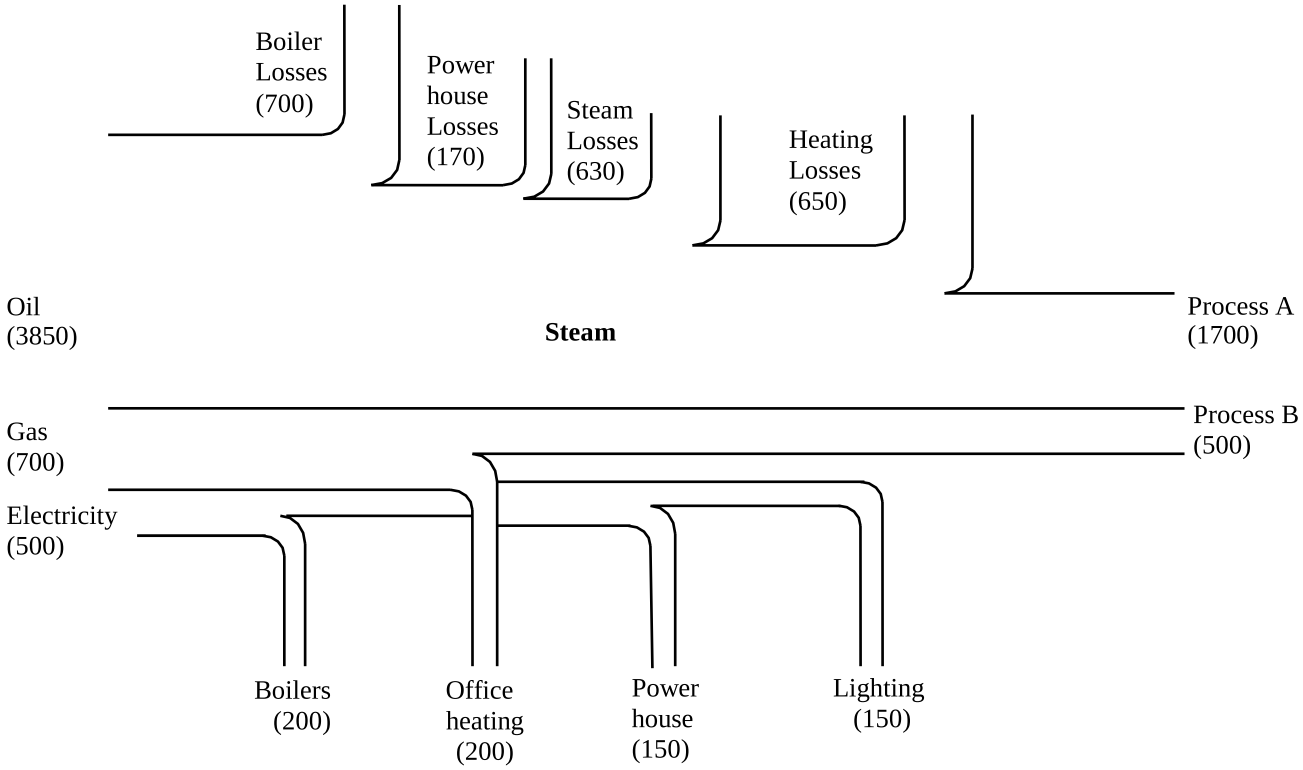
The pie chart can be plotted as follows



Sankey diagram

Following Figure shows a Sankey diagram which represents all the primary energy flows into a factory. The widths of the bands are directly proportional to energy production (source), utilization and losses. The primary energy sources are gas, electricity and coal/oil *(say, for steam generation)* and represent energy inputs at the left-hand side of the Sankey diagram.

Sankey diagrams are quite difficult to construct as measurements must be made for all energy flows and this will involve considerable metering and instrumentation. However, the picture can be gradually built up starting from gas and electricity before going on to steam. The construction of a Sankey diagram is an excellent exercise in energy management and its value is in highlighting



Energy Inputs: Oil, Gas, Electricity are represented in left side

Sankey diagram representing energy usage (10^6 Joule per hour) by a company

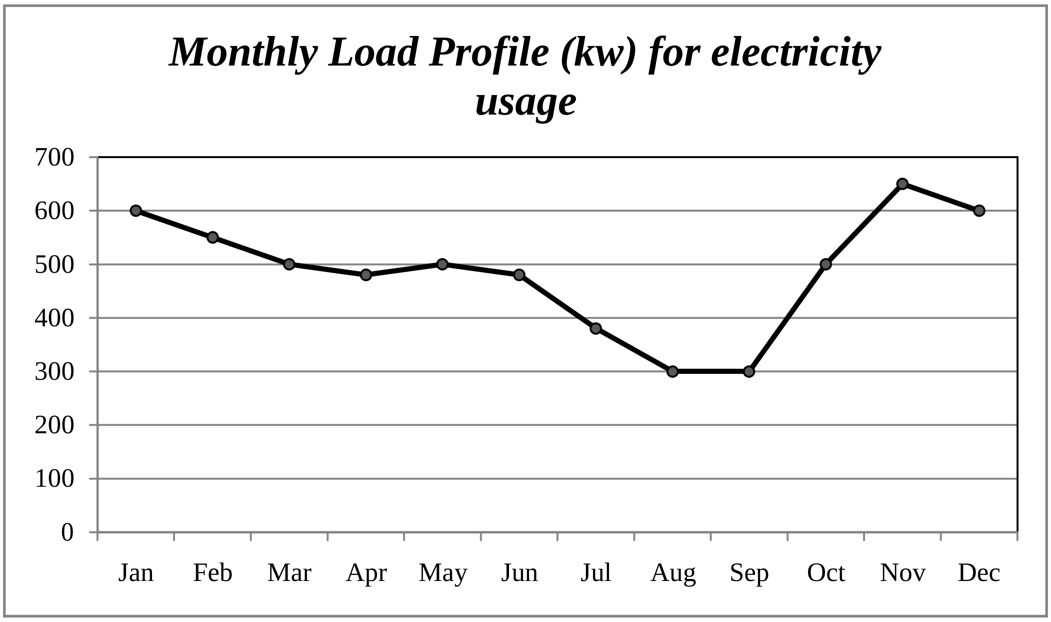
losses which one never knew existed.

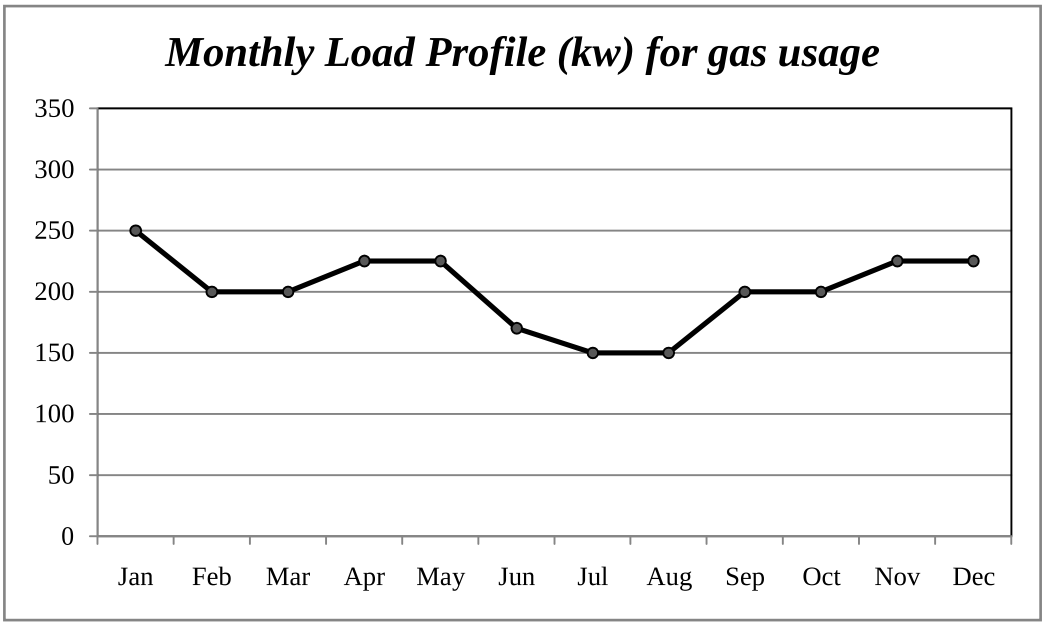
For the purpose of *monitoring and checking energy consumption* and usage on a weekly or monthly basis, pie charts and Sankey diagram are relatively difficult. An alternative method of monitoring energy consumption on a time-dependent basis is to use load profiles.

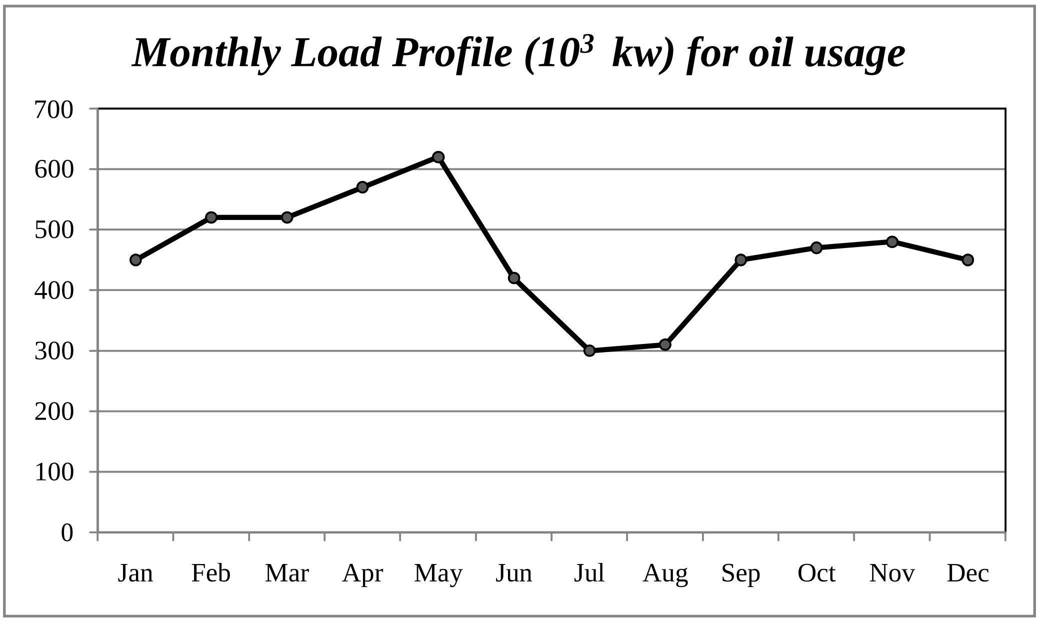
LOAD PROFILES (HISTOGRAM)

The usages of oil, gas and electricity in a plant can be plotted on a graph as shown in following Figure. The results illustrate seasonal variations and perhaps variations in production schedules. This technique has the major advantage that after a period of time, energy consumption patterns emerge and it is possible to tell at a glance if an area is exceeding its predicted value. An overall load profile equivalent to several pie charts and sankey diagrams can be obtained by plotting the previous profiles can be also drawn.

Load factor — The ratio of the average load over the peak load. Peak load is normally the maximum demand but may be the instantaneous peak. The load factor is between zero and one. A load factor close to 1.0 indicates that the load runs almost constantly. A low load factor indicates a more widely varying load. From the utility point of view, it is better to have high load-factor loads. Load factor is normally found from the total energy used kilowatt-hours.


Monthly Load Profile (kw) for electricity usage
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Monthly Load Profile (kw) for gas usage
350
300
250
200
150
100
50
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Monthly Load Profile (10^3 kw) for oil usage
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

ENERGY CONSERVATION SCHEMES

Development of an energy conservation programme can provide savings by reduced energy use. However, it is economical to implement an energy conservation program only when savings can offset implementation cost over a period of time. Potential areas of conserving energy and a logical analysis of the methods or techniques of conservation would provide a systematic and disciplined approach to the entire conservation strategy as a sequel to the energy audit. Some established conservation trends are replacement, retrofit, process innovation, fuel conversion and co-generation.

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

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

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

Short-term energy conservation schemes

Items in this group can be considered as a tightening of operational control and improved housekeeping.

a. *Furnace efficiencies*: greater emphasis should be placed on minimum excess combustion air. Oxygen levels of flue gases should be continually monitored and compared with target values. Oil burners must be cleaned and maintained regularly.
b. *Heat exchangers*: in the case of heat exchangers where useful heat is transferred form product streams to feed streams, careful monitoring of performance should be carried out to determine optimum cleaning cycles. Frequency of cleaning will generally increase as a result, with consequent improved heat recovery.
c. *Good housekeeping*: doors and windows should be kept closed as much as possible during the heating season. Wear natural light is sufficient, do not use artificial light. Avoid excessive ventilation during the heating season. Encourage staff to wear clothing appropriate to the temperature of the working areas.

d. *Use of steam*: major steam leaks should be repaired as soon as possible after they occur: often a firm specializing in _on stream' maintenance can be used. One crude distillation columns where live steam is used for stripping purposes, the amount required should be optimized and carefully controlled.

e. *Electrical power*: in industries where all the electrical power is _imported', conservation measures can reduce the annual electricity costs by 10-15%. Steam driven turbines may prove more economical as prime movers. Natural air cooling may be sufficient and therefore induced-draught fans may be taken out of commission. Pumping costs can sometimes be saved by utilizing gravity to move products from one tank to another. Where possible, use off-peak electricity.

Medium-term energy conservation schemes

Significant savings in energy consumption are often available for quite modest outlays of capital based on a pay-back period of less than two years.

a. *Insulation*: Improving insulation to prevent cold air leaking into the building and also, improving insulation of the steam distribution system. Many optimum insulation thicknesses were determined at a time when fuel oil was £6 per tone and, consequently, at present fuel oil prices, optimum thicknesses have increased appreciable. In addition, in older plants lagging may have deteriorated to varying degrees.

   In one company, additional insulation was added to four boiler casing after calculation had showed the structures could accept the increase in temperature. For an outlay of £25000, savings of £60000 per annum were achieved.

   In an oil refinery the lagging on the process steam system was up rated to new optimum thicknesses and the £20000 invested in the project was recouped within a year.

b. *Heating systems*: Improving the time and temperature control of the heating systems in buildings should result in substantial energy savings.

c. Replacing air compressors

d. *Instrumentation*: to measure and control the energy conservation parameters, adequate instrumentation must be provided or operators will soon lose interest in maintaining efficiencies if they are working with inadequate and unreliable instruments.

e. *Process modifications*: Many of these schemes will depend on the nature of the industry concerned, however, one general scheme will be considered. Steam condensate, if uncontaminated, may be used as boiler feed water. Improved condensate return systems can increase the amount recovered. The effect will be to increase the heat recovered in the condensate and at the same time reduce raw water and treatment costs.

   In one instance 10000 kg h^{-1} of condensate was recovered for an investment of £10000; the pay-back time was less than six months.

f. *Burners*: the control and amount of atomizing steam is important and often in furnaces and boilers the amount of atomizing steam is far in excess of design.

   In a hospital two fuel oil-fired boilers were examined and in some instances it was found that 1 kg steam/kg fuel oil was being utilized. The oil burners were replaced and the atomizing steam requirements are now 0.1 kg steam/kg fuel oil. The pay-back for an outlay of £12000 was ten months.

g. *Electrical Power Savings*: considerable savings may be made by adjusting the electrical power factor correction.

   Capacitors were installed in one particular company at a cost of £10000. The power factor was increased from 0.84 to 0.97 reducing the maximum demand level by over 14 per cent. The pay-back time was nine months.

To increase plant capacity two feed pumps may be run in parallel to achieve the required feed rate. When replacement, for mechanical reasons, becomes necessary it is more economical to replace the pumps by a single pump having a higher capacity.

Long-term energy conservation schemes

To obtain further economics in energy consumption required the spending of significant amounts of capital, although, in many cases, the return on capital for the long-term investment may not be as good as that of the medium term. Full financial evaluation is needed, using the appraisal techniques discussed in unit-V, to ensure that investment is economically viable.

a. *Heater modifications*: the installation of heating tubes and air pre-heaters to extract more heat from furnace flue gases.
b. *Improved Insulation*: Additional lagging of heated storage tanks. This type of project often comes within the medium-term group.
c. *Heat recovery*: Improved heat recovery in the processing areas by additional heat exchange schemes.

Many of the energy projects that have been outlined may be adopted by a wide variety of companies. However, some are more specific in their application and it is necessary to consider the contribution of energy costs to companies and energy usage by different industries.

Industrial Energy Audit:

Energy audits assist industrial companies or facilities in understanding how they use energy and help to identify the areas where waste occurs and where opportunities for improvement exist. This guidebook provides step-by-step guidelines that can be easily followed even by those who have not previously conducted energy audits. These guidelines are developed in a manner that can be used by both in-house auditors who are auditing their own plant and outside consultants who are hired to do an energy audit.

The Canadian Industry Program for Energy Conservation (CIPEC) has published a guidebook titled Energy Efficiency Planning and Management Guide (CIPEC 2002) which presents a comprehensive discussion of the procedures for conducting an industrial energy audit. CIPEC also has a more recent guidebook specifically for energy auditing called the Energy Savings Toolbox – an Energy Audit Manual and Tool (CIPEC 2009).

Also, American Society of Mechanical Engineers (ASME) has published energy assessment standards that cover the assessment of pumping, compressed air, steam, and process heating systems. In these standards the step-by-step procedure for measurement and assessment of these systems are presented which are key component of any energy audit practice and are highly recommended to energy auditors and mangers.

An energy audit is a key to assessing the energy performance of an industrial plant and for developing an energy management program. The typical steps of an energy audit are: • preparation and planning • data collection and review • plant surveys and system measurements • observation and review of operating practices • data documentation and analysis • reporting of the results and recommendations.

Overview of energy audit procedures:

An overview of the procedure for a detailed industrial energy audit is shown in Figure 1. A preliminary audit (walk-through audit) contains some of the same steps of the procedure shown, but the depth of the data collection and analysis might be different depending on the scope and objectives of the audit. Overall, there are three main steps (excluding the post-audit activities) each of which has several sub-steps. These three main steps are energy audit preparation, execution, and reporting.

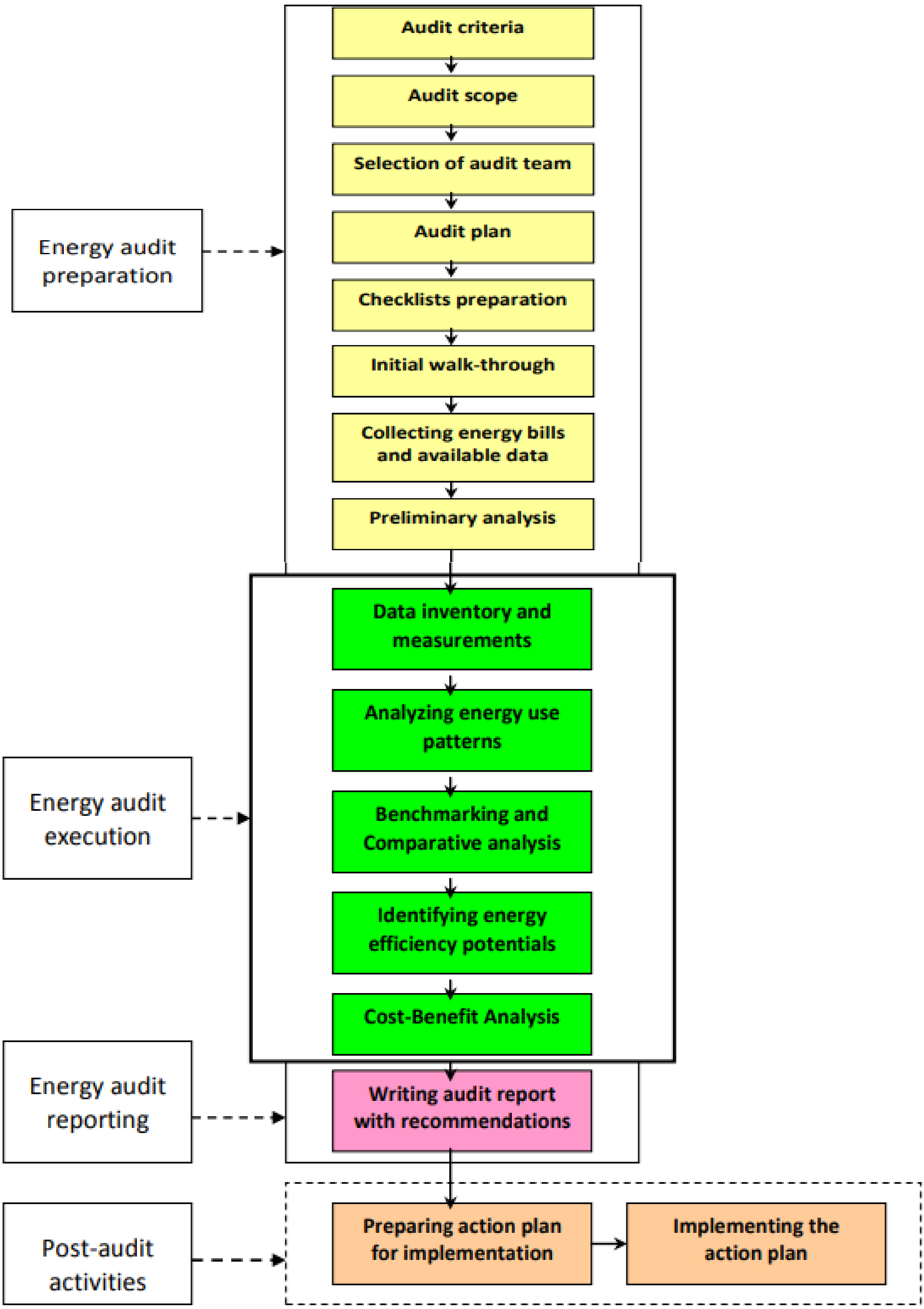


Figure 1. Overview of an industrial energy audit

Energy Savings Potential:

As a first step, we obtain the energy savings potential for each of the seven selected industries. Methodologically such an exercise involves use of efficiency benchmark of some of the best performing units within the concerned industry. Energy efficiency benchmarking for an industry is a process by which energy performance of an individual plant within the industry or a sector comprising of similar plants is compared against a common accepted best performance standard. The latter is decided by analysing the variation of performance metric across plants and their reasons leading to a criterion of best performance standard and value under the working condition of the plant or industry. As benchmarking is used as a tool for comparison it should have an important characteristic that the metric used should be independent of unit size. In the present study the metric used for benchmark analysis is energy intensity.

For the manufacturing sector in India the only available data source for carrying out such analysis is the unit level ASI data. We use the data for the latest year available i.e., 2007-08. There are, however, certain limitations of ASI data which delimit the scope of application of benchmark analysis discussed above. As the ASI data does not reveal the identity of different firms within an industry, it cannot be used for analysing the performance of different units over time. However, one can compare performance of different units within an industry vis-à-vis certain benchmark value.

There are a large number of units/firms of varying sizes within an industry. Comparing energy intensity of a small unit with that of large unit may not be meaningful because of the scale of operation. In order to overcome the problem of comparing dissimilar units, we have classified the units within an industry into different groups on the basis of a) share in final energy consumption (measured in kgoe); b) share in electricity consumption (measured in Kwh); and c) total output (measured in rupees), so that units within a group are similar in nature. We then calculate the energy savings potential for each group within the industry assuming technology to be related with any of these three measures of scale.

Having classified the units within an industry into different groups, units within a group are ranked in order of their energy intensities. Energy intensity of a unit is defined as total final energy consumed for generating one unit of output. Since the output is measured in monetary units, energy intensity is defined as energy consumed for generating Re. 1 worth of output. Two measures of energy intensity have been used depending on the way in which the units are grouped. These are

	Unit of energy intensity		Definition of Energy Intensity
1	**Classification based on Share of total energy consumption**		
	a)	Kgoe/Re	$\frac{energy\ consumption\ (in\ oil\ equivalent\ units)}{total\ output\ (in\ Rupees)}$
2	**Classification based on Share of total electricity consumption**		
	b)	Kwh/Re	$\frac{electricity\ consumption\ (Kwh)}{total\ output\ (in\ Rupees)}$
3	**Classification based on Value of Output**		
	a)	Kgoe/Re	$\frac{energy\ consumption\ (in\ oil\ equivalent\ units)}{total\ output\ (in\ Rupees)}$
	b)	Kwh/Re	$\frac{electricity\ consumption\ (Kwh)}{total\ output\ (in\ Rupees)}$

After having arranged the units within a group in order of their energy intensities, 10 per cent units that have the lowest energy intensity are selected and average energy intensity of these units is calculated. This average energy intensity of the top 10 per cent energy efficient units (i.e., the mean of the first decile of the energy intensity distribution within a group) is taken as the benchmark to which all the units within the group having energy intensity higher than the average were to achieve within a given period. Units which have energy intensity lower than the average continue to operate at their existing energy intensities. Energy consumption of all units having intensity higher than the benchmark is worked out using the benchmark energy intensity. However, for units which have energy intensity lower than the benchmark, their current energy consumption is considered. By adding the energy consumption of the two, modified overall energy consumption of the group is obtained. For a group the difference between its actual energy consumption and modified energy consumption worked out as discussed above is obtained. The ratio of this difference in energy consumption and the actual energy consumption of a group gives its energy savings potential. Energy savings potential of different groups within the industry is calculated in a similar manner. Aggregating the energy savings potential of different groups within an industry we get the overall energy savings potential for the concerned industry.

Similar exercise is carried out i) by taking the lowest 25 per cent units as per energy intensity criteria within a group and taking their average intensity (i.e., the mean of the first quartile of the energy intensity distribution) as the benchmark and ii) by taking the average intensity of units having energy intensity lower than the median energy intensity of the group (i.e., mean of the median of the energy intensity distribution) as the benchmark. Energy savings potential for each group is calculated and aggregating it across all groups gives the savings potential for the concerned industry.

Table 1: Energy Savings Potential in Select Industries in India– 2007-08

Classification Based on	Unit of energy intensity	least energy intensive 10% units	least energy intensive 25% units	median energy intensive units
1. Textile Industry				
a) Share in total energy consumption	Kgoe/Re	70.675	58.526	45.592
b) Share in total electricity consumption	Kwh/Re	72.482	58.288	45.825
c) Value of Total Output	Kgoe/Re	86.876	72.885	53.253
d) Value of Total Output	Kwh/Re	88.233	73.764	53.629
2. Paper & Pulp Industry				
a) Share in total energy consumption	Kgoe/Re	79.141	71.777	62.516
b) Share in total electricity consumption	Kwh/Re	68.429	55.417	42.655
c) Value of Total Output	Kgoe/Re	93.666	83.584	68.963
d) Value of Total Output	Kwh/Re	92.444	84.541	65.275
3. Iron & Steel Industry				
a) Share in total energy consumption	Kgoe/Re	66.463	59.624	50.653
b) Share in total electricity consumption	Kwh/Re	72.944	66.813	52.073
c) Value of Total Output	Kgoe/Re	91.199	83.927	63.363
d) Value of Total Output	Kwh/Re	91.706	85.874	73.446
4. Fertiliser Industry				
a) Share in total energy consumption	Kgoe/Re	59.200	48.920	38.769
b) Share in total electricity consumption	Kwh/Re	37.696	32.786	26.128
c) Value of Total Output	Kgoe/Re	93.648	88.787	77.016
d) Value of Total Output	Kwh/Re	89.497	84.726	78.137
5. Chlor-Alkali Industry				
a) Share in total energy consumption	Kgoe/Re	55.751	44.992	36.906
b) Share in total electricity consumption	Kwh/Re	49.117	47.798	39.529
c) Value of Total Output	Kgoe/Re	88.318	84.155	66.119
d) Value of Total Output	Kwh/Re	95.119	93.868	87.153
6. Cement Industry				
a) Share in total energy consumption	Kgoe/Re	49.995	38.033	30.16

b) Share in total electricity consumption	Kwh/Re	40.029	30.129	22.672
c) Value of Total Output	Kgoe/Re	83.851	74.769	59.374
d) Value of Total Output	Kwh/Re	73.59	65.786	39.981
7. Aluminium Industry				
a) Share in total energy consumption	Kgoe/Re	53.853	52.181	40.276
b) Share in total electricity consumption	Kwh/Re	10.492	9.512	8.59
c) Value of Total Output	Kgoe/Re	58.517	55.321	43.432
d) Value of Total Output	Kwh/Re	11.141	10.698	8.684

Source: Authors calculation
Note: Kgoe: kilograms of oil equivalent; Kwh: kilowatt hours; Re: Rupee

Table 1 shows the energy savings potential for each of the seven industries for 2007-08.1 One can see that there exists considerable potential for energy savings in each of these industries. However, what is important is the extent to which the derived energy savings potential can be achieved in reality. Attaining the benchmark level of intensity may not be technologically feasible or economically viable for all units within an industry as this may involve considerable investments thereby raising the unit costs at the given current prices and interest rates. Nonetheless, efforts must be made to improve energy intensity of all units within the industry so that improvement in overall energy intensity of the industry can be achieved. It is essential to look into the cost as well as gains from energy savings by adopting more energy-efficient technologies. Will the gains from improving energy efficiency outweigh the costs of steps taken for improvement in energy intensity? What fiscal and monetary measures need to be adopted that would incentivise the industry to improve its energy efficiency both in the short and long run. These are some of the issues that need to be addressed in order to find out the level of energy savings which can be attained in reality. We analyse in the following section the behavior of energy savings in non-energy sector in response to changes in factor prices.