Chapter

5

ENERGY AUDIT

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5.1 INTRODUCTION

An energy audit is an inspection, survey and analysis of energy flows in a building, process or system with the objective of understanding the energy dynamics of the system under study. Typically an energy audit is conducted to seek opportunities to reduce the amount of energy input into the system without negatively affecting the output(s). When the object of study is an occupied building then reducing energy consumption while maintaining or improving human comfort, health and safety are of primary concern. Beyond simply identifying the sources of energy use, an energy audit seeks to prioritize the energy uses according to the greatest to least cost effective opportunities for energy savings.

An energy audit of a home may involve recording various characteristics of the building envelope including the walls, ceilings, floors, doors, windows and skylights. For each of these components the area and resistance to heat flow (R-value) is measured or estimated. The leakage rate or infiltration of air through the building envelope is of concern which are strongly affected by window construction and quality of door seals such as weather-stripping. The goal of this exercise is to quantify the building's overall thermal performance. The audit may also assess the efficiency, physical condition and programming of mechanical systems such as the heating, ventilation, air conditioning equipment and thermostat.

A home energy audit may include a written report estimating energy use given local climate criteria, thermostat settings, roof overhang and solar orientation. This could show energy use for a given time period, say a year and the impact of any suggested improvements per year. The accuracy of energy estimates are greatly improved when the homeowner's billing history is available showing the quantities of electricity, natural gas, fuel oil, or other energy sources consumed over a one or two-year period.

Increasingly in the last several decades, industrial and agricultural energy audits have exploded as the demand to lower increasingly expensive energy costs and move towards a sustainable future have made energy audit great.

Energy-audit is the basic tool by which a rational energy management programme can be developed in any sector using energy. Until an assessment has been carried out on how the energy flows within an establishment, areas where wastage occurs cannot be highlighted and the scope for improvements identified.

Energy audit is similar to the financial audit. It involves brief on site survey and analysis of the systems concerned. It can be defined as the technique for assessing the energy conservation potential. Energy audit is the key to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial energy audit is an effective tool in defining and pursuing comprehensive energy managment programme.

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

History of Energy Audit

Energy audits initially became popular in response to the energy crisis of 1973 and later years. Interest in energy audits has recently increased as a result of growing understanding of human impact upon global warming and climate change.

5.1.1 Need for Energy Audit

In any industry, the three top operating expenses are often found to be energy (both electrical and thermal), labour and materials. If one were to relate to the manageability of the cost or potential cost savings in each of the above components, energy would invariably emerge as a top ranker and thus energy management function constitutes a strategic area for cost reduction. Energy audit will help to understand more about the ways energy and fuel are used in any industry and help in identifying the areas where waste can occur and where scope for improvement exists.

The energy audit would give a positive orientation to the energy cost reduction, preventive maintenance and quality control programmes which are vital for production and utility activities. Such an audit programme will help to keep focus on variations which occur in the energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment, etc.

In general, energy audit is the translation of conservation ideas into realities by lending technically feasible solutions with economic and other organizational considerations within a specified time frame.

The primary objective of energy audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy audit provides a "bench-mark" (reference point) for managing energy in the organization and also provides the basis for planning a more effective use of energy throughout the organization.

Energy audit study helps an industry to undetstand and analyse its energy utilisation and identify areas of energy wastage, decide how to budget its energy use, plan and practice feasible energy conservation methods that will enhance their energy efficiency, curtail energy wastage and substantially reduce energy costs.

The energy audit serves to identify all the energy streams in a facility, qualify energy usage with its discrete functions, in an attempt to balance the total energy input with its use. Energy audit is thus the key to a systematic approach for decision-making in the area of energy management. As a result, the energy audit study becomes an effective tool in defining and pursuing comprehensive Energy Management Programme (EMP).

Energy audit of a group of similar type of industries will help generate vital information on different energy utilisation patterns and practices followed and single out best practices in particular industrial sector. Group energy audit will generate greater awareness energy efficiency and help small industries to operate more profitably.

5.1.2 Energy Audit Study should be Directed Towards

- Identifying cost-effective measures to improve the efficiency of energy use,
- Estimates of potential energy saving, implementation costs and payback periods for each recommended action, and
- Documenting results and vital information generated through these activities.

5.1.3 An Energy Audit Study Includes

- Auditing of energy consumption (including any heat and power generated).
- General examination of work place (including physical condition of organisation, its processes, occupancy time and variations in ambient temperature and energy consumption pattern, etc.).
- Measurement of all energy flows, (including testing of boiler or steam raising, heating equipment, refrigeration, etc.).
- Analysis and appraisal of energy usage (*e.g.*, specific fuel consumption, energy-product interrelationship).
- Energy management procedures and methodology.

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- Analysis and appraisal of energy usage (*e.g.*, specific fuel consumption, energy-product interrelationship).
- Energy management procedures and methodology.

- Identification of energy improvement opportunities and recommendations for energy efficiency measures and quantification of implementation costs and paybacks.
- Identification of possible usage of co-generation, renewable sources of energy and recommendations for implementation, wherever possible, with cost benefit analysis.

5.2 TYPES OF ENERGY AUDIT

The term energy audit is commonly used to describe a broad spectrum of energy studies ranging from a quick walk-through of a facility to identify major problem areas to a comprehensive analysis of the implications of alternative energy efficiency measures sufficient to satisfy the financial criteria of sophisticated investors.

The type of energy audit to be performed depends on:

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

Thus energy audit can be classified into the following types:

(i) Preliminary audit
(ii) Mini audit or general audit
(iii) Detailed audit or comprehensive audit/investment grade audit.

5.2.1 Preliminary Audit

The preliminary audit (alternatively called a simple audit, screening audit or walk-through audit) is the simplest and quickest type of audit. It involves minimal interviews with site-operating personnel, a brief review of facility utility bills and other operating data and a walk-through of the facility to become familiar with the building operation and to identify any glaring areas of energy waste or inefficiency.

Typically, only major problem areas will be uncovered during this type of audit. Corrective measures are briefly described and quick estimates of implementation cost; potential operating cost savings and simple payback periods are provided. The level of detail, while not sufficient for reaching a final decision on implementing a proposed measures, is adequate to prioritize energy-efficiency projects and to determine the need for a more detailed audit.

5.2.2 General Audit or Mini Audit

The general audit (alternatively called a mini-audit, site energy audit or complete site energy audit) expands on the preliminary audit described above by collecting more detailed information about facility operation and by performing a more detailed evaluation of energy conservation measures. Utility bills are collected for a 12 to 36 month period to allow the auditor to evaluate the facility's energy/demand rate structures and energy usage profiles. If interval meter data is available, the detailed energy profiles that such data makes possible will typically be analysed for signs of energy waste. Additional metering of specific energy-consuming systems is often performed to supplement utility data. In -depth interviews with facility operating personnel are conducted to provide a better understanding of major energy consuming systems and to gain insight into short and longer term energy consumption patterns.

This type of audit will be able to identify all energy-conservation measures appropriate for the facility, given its operating parameters. A detailed financial analysis is performed for each measure based on detailed implementation cost estimates, site-specific operating cost savings and the customer's investment criteria. Sufficient detail is provided to justify project iinplementation.

5.2.3 Investment-Grade Audit/Comprehensive Audit

In most corporate settings, upgrades to a facility's energy infrastructure must compete for capital funding with non-energy-related investments. Both energy and non-energy investments are rated on a single set of financial criteria that generally stress the expected return on investment (ROI). The projected operating savings from the implementation of energy projects must be developed such that they provide a high level of confidence. In fact, investors often demand guaranteed savings.

The investment-grade audit (alternatively called a comprehensive audit, detailed audit, maxi audit or technical analysis audit) expands on the general audit described above by providing a dynamic model of energy-use characteristics of both the existing facility and all energy conservation measures identified. The building model is calibrated against actual utility data to provide a realistic baseline against which to compute operating savings for proposed measures. Extensive attention is given to understanding not only the operating characteristics of all energy consuming systems, but also situations that cause load profile variations on short and longer term bases (*e.g.*, daily, weekly, monthly, annual).

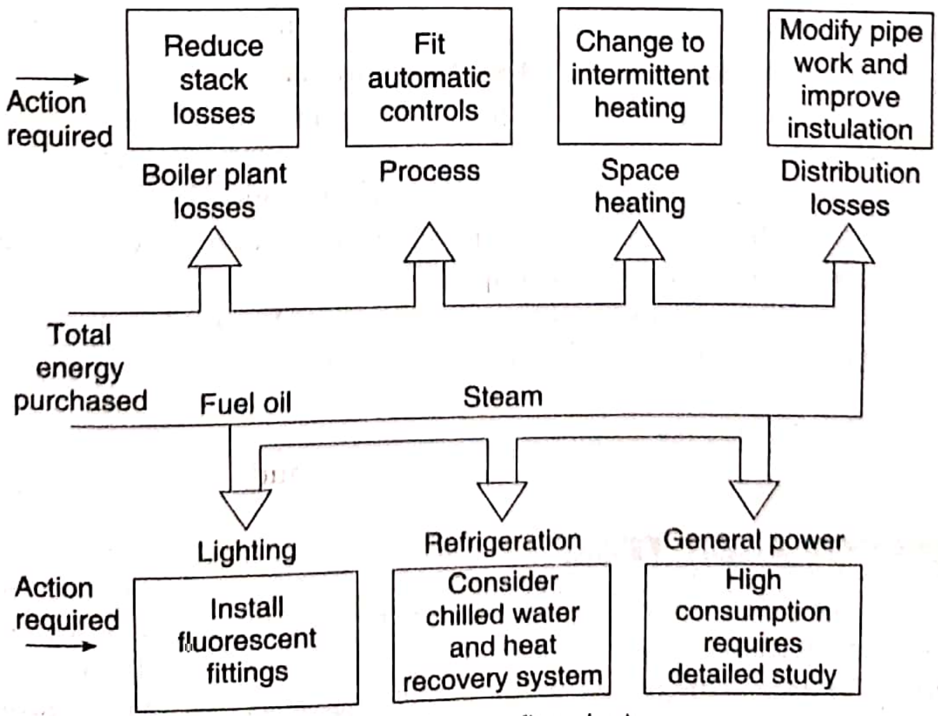


Fig. 5.1 Energy-flow chart.

Existing utility data is supplemented with sub-metering of major energy consuming systems and monitoring of system operating characteristics.

It involves preparation of total energy balance sheet, drawing energy-flow charts etc. as shown in Fig. 5.1.

5.3 MAJOR ENERGY CONSUMING EQUIPMENT AND SYSTEM

The energy consuming equipment and systems found in most of the establishments are as under:

- Application of large drives
- Ventilation, and air conditioning, heating and cooling
- Lighting
- Vertical transportation
- Pumps and exhausts
- Combustion equipment
- Compressors
- Heat treatment plants
- Water treatment plants etc.

There could be other energy consuming office equipment, such as typewriters, computers, ovens, heaters, printers, tea and coffee-makers, etc.

The technical members of the audit team must have the basic understanding of the use of energy in equipment and systems under study. The team must concern themselves on what factors affect the equipment/ system's energy use.

These equipment/systems are installed to satisfy a demand and consequently utilise energy. Outcome of an energy-audit exercise should answer the following querries:

- What is the demand?
- How is this demand satisfied by the equipment/system?
- What are the equipment/system operating conditions to satisfy the demand?
- What is the equipment/system energy consumption at these conditions?
- What modifications in the operating conditions are necessary to reduce/control energy consumption?
- What are the expected energy savings from these modifications?
- What are the costs in undertaking these energy conservation opportunities (ECOs)?
- What is the pay-back time?

5.4 ENERGY AUDIT TEAM

In any establishment, in order for an energy audit to be successful, a multi-disciplinary team is required covering all technical, safety, accountancy and management aspects. This is best accomplished by involving site personnel of suitable rank specialising in these aspects. An essential part of energy auditing is to establish a sound working relationship with site personnel.

The audit team normally consists of (i) technical manpower, (ii) floor manager/supervisor, (iii) audit personnel along with a person called energy-manager as team leader. The team leader should necessarily have general technical knowledge with-lot of managerial skill. The technical manpower may consists of electrical, mechanical, electronics, instrumentation and civil engineers. The floor manager/supervisor may also have a draftsman in their team. The energy-audit-team may be shown diagrammatically as depicted in Fig. 5.2.

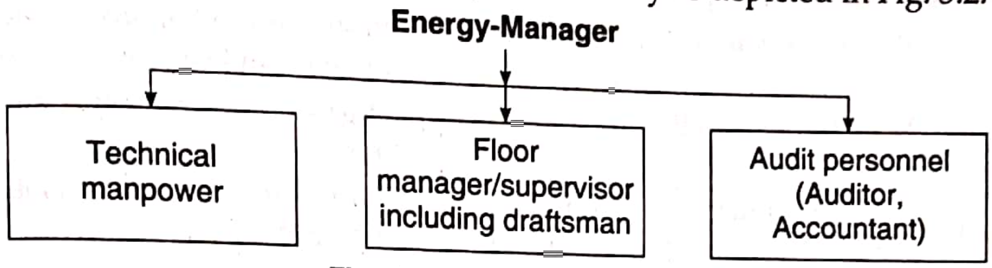


Fig. 5.2 Energy-audit-team.

5.5 ENERGY AUDIT METHODOLOGY

Energy audit methodology includes the various phases and steps involved in carrying out energy audit.

5.5.1 Preliminary Energy Audit Methodology

Preliminary energy audit is a relatively quick exercise to :

- Establish energy consumption in the organisation.
- 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.

5.5.2 Detailed Energy Audit Methodology

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

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

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

Detailed energy auditing is carried out in three phases:

Phase I - Pre-audit phase

Phase II - Audit phase

Phase III - Post-audit phase

Industry-to-industry, the methodology of energy audits needs to be flexible.

A comprehensive ten-step methodology for conduct of energy audit at field level is presented below. Energy manager and energy auditor may follow these steps to start with and add/change as per their needs and industry types.

Table 5.1 : Ten Steps Methodology for Deailed Energy Audit

Step No.	Plan of Action	Purpose/Results
Step 1	Phase I - Pre-audit phase	
	– Plan and organise	– Resource planning, establish/organise and energy audit team
	– Walk through audit	– Organise instruments and time frame
	– Informal interview with energy manager, production/plant manager	– Macro data collection (suitable to type of industry)
		– Familiarisation of process/plant activities
		– First hand observation and assessment of current level operation and practices.
Step 2	– Conduct of brief meeting/awareness programme with all divisional heads and persons concerned (2-3 hrs.)	– Building up cooperation
		– Issue questionnaire for each department
		– Orientation, awareness creation
	Phase II - Audit phase	
Step 3	– Primary data gathering, process flow diagram and 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 and steam distribution)
		– Design, operating data and schedule of operation
		– Annual energy bill and energy consumption pattern (Refer manual, log sheet, name plate, interview)
Step 4	– Conduct survey and monitoring	– Measurements: Motor survey, insulation, and lighting survey with portable instruments for collection of more and accurate data. Confirm and compare operating data with design data.

Step 5	– Conduct of detailed trials/experiments for selected energy guzzlers	– Trials/experiments: - 24 hours power monitoring (MD, PF, kWh etc.). - Load variations trends in pumps, fan compressors etc. - Boiler/Efficiency trials for (4-8 hours) - Furnace efficiency trials equipments performance experiments etc.
Step 6	– Analysis of energy use	– Energy and material balance and energy loss/waste analysis
Step 7	– Identification and development of energy conservation (ENCON) opportunities	Identification and Consolidation ENCON measures – Conceive, develop and refine ideas – Review the previous ideas suggested by unit personal – Review the previous ideas suggested by energy audit if any – Use brainstorming and value analysis techniques – Contact vendors for new/efficient technology
Step 8	– Cost benefit analysis	– Assess technical feasibility, economic viability and prioritization of ENCON options for implementation – Select the most promising projects – Prioritise by low, medium, long term measures
Step 9	– Reporting and 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 detail of activities of various phases of audit is as follows :

Phase I : Pre Audit Phase Activities

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

Initial site visit and preparation required for detailed auditing: An initial site visit may take one day and gives the energy auditor/engineer an opportunity to meet the personnel concerned, to familiarise him with the site and to assess the procedures necessary to carry out the energy audit.

During the initial site visit the energy auditor/engineer should carry out the following actions :

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

The main aims of this visit are:

- To finalise energy audit team.
- To identify the main energy consuming areas/plant items to be surveyed during the audit.
- To identify any existing instrumentation/additional metering required.
- To decide whether any meters will have to be installed prior to the audit, *e.g.*, kWh, steam, oil or gas meters.
- To identify the instrumentation required for carrying out the audit.
- To plan with time frame.
- To collect macro data on plant energy resources, major energy consuming centers.
- To create awareness through meetings/programme.

Phase II : Detailed Energy Audit Activities

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

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

The information to be collected during the detailed audit includes:

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

2. Material balance data (raw materials, intermediate and final products, recycled materials, use of scrap or waste products, production of by-products for re-use in other industries, etc.)
3. Energy cost and tariff data.
4. Process and material flow diagrams.
5. Generation and distribution of site services (*e.g.*, compressed air, steam).
6. Sources of energy supply (*e.g.*, electricity from the grid or self-generation).
7. Potential of fuel substitution, process modifications and the use of co-generation systems (combined heat and power generation).
8. Energy management procedures and energy awareness training programmes within the establishment.

Existing baseline information and reports are useful to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs. The audit team should collect the following baseline data:

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

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

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

5.6 PROCESS FLOW DIAGRAM

Draw process flow diagram and list process steps; identify waste streams and obvious energy wastage: An overview of unit operations, important process steps, areas of material and energy use and sources of waste generation should be gathered and should be represented in a flowchart as shown in the Fig. 5.3 below. Existing drawings, records and shop floor walk through will help in making this flowchart. Simultaneously the team should identify the various inputs and outputs streams at each process step.

Example: A flowchart of Penicillin-G manufacturing is given in the Fig. 5.3 below. Note that waste stream (Mycelium) and obvious energy wastes such as condensate drained and steam leakages have been identified in this flowchart.

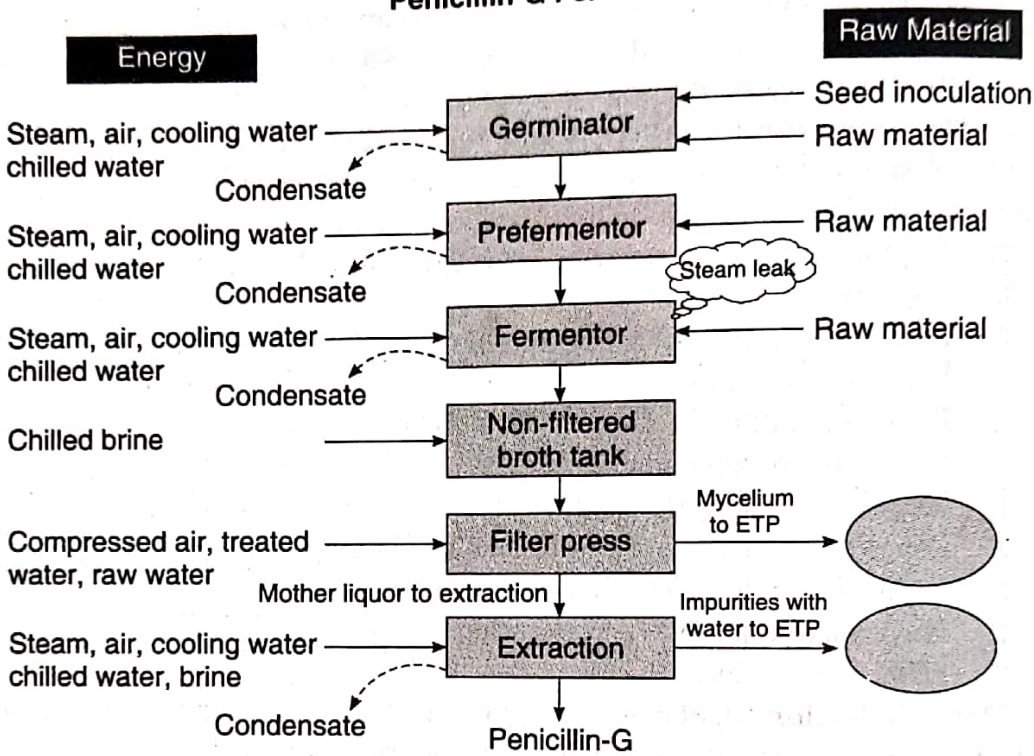


Fig. 5.3

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

5.7 IDENTIFICATION OF ENERGY CONSERVATION OPPORTUNITIES

- **Fuel substitution :** Identifying the appropriate fuel for efficient energy conversion.
- **Energy generation:** Identifying efficiency opportunities in energy conversion equipment/utility such as captive power generation, steam generation in boilers, thermic fluid heating, optimal loading of DG sets, minimum excess air combustion with boilers/thermic fluid heating, optimising existing efficiencies, efficient energy conversion equipment, biomass gasifiers, cogeneration, high efficiency DG sets, etc.

- **Energy distribution:** Identifying efficiency opportunities network such as transformers, cables, switchgears and power factor improvement in electrical systems and chilled water, cooling water, hot water, compressed air, etc.
- **Energy usage by processes:** This is where the major opportunity for improvement and many of them are hidden. Process analysis is useful tool for process integration measures.

Technical and economic feasibility: The technical feasibility should address the following issues:

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

The economic viability often becomes the key parameter for the management acceptance. The economic analysis can be conducted by using a variety of methods. Example: Pay back method, internal rate of return method, net present value method, etc. For low investment short duration measures, which have attractive economic viability, simplest of the methods, payback is usually sufficient. A sample worksheet for assessing economic feasibility is provided below:

Sample worksheet for economic feasibility

Name of energy efficiency measure

1. Investment	**2. Annual operating costs**	**3. Annual savings**
– Equipments	– Cost of capital	– Thermal energy
– Civil works	– Maintenance	– Electrical energy
– Instrumentation	– Manpower	– Raw material
– Auxiliaries	– Energy	– Waste disposal
	– Depreciation	

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

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

5.8 CLASSIFICATION OF ENERGY CONSERVATION MEASURES

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

1. Low cost : high return;
2. Medium cost : medium return;
3. High cost : high return.

Normally the low cost : high return projects receive priority. Other projects have to be analysed, engineered and budgeted for implementation in a phased manner. Projects relating to energy cascading and process changes almost always involve high costs coupled with high returns and may require careful scrutiny before funds can be committed. These projects are generally complex and may require long lead times before they can be implemented. Refer Table 5.2 for project priority guidelines.

Table 5.2 : Project Priority Guideline

Priority	Economical Feasibility	Technical Feasibility	Risk/Feasibility
A - Good	Well defined and attractive	Existing technology adequate	No risk highly feasible
B - May be	Well defined and only marginally acceptable	Existing technology may be updated, lack of confirmation	Minor operating risk /may be feasible
C - Held	Poorly defined and marginally unacceptable	Existing technology is inadequate	Doubtful
D - No	Clearly not attractive	Need major break through	Not feasible

5.9 ENERGY AUDIT REPORTING FORMAT

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

Report on

Detailed Energy Audit

Table of Contents

3.2.3 Water
3.2.4 Compressed air
3.2.5 Chilled water
3.2.6 Cooling water

The following worksheets (refer Table 5.3 and Table 5.4) can be used as guidance for energy audit assessment and reporting.

Table 5.3 : Summary of Energy Saving Recommendations

S. No.	Energy saving recommendations	Annual energy (fuel and electricity) savings (kWh/MT or kl/MT)	Annual savings (Rs. Lakhs)	Capital investment (Rs. Lakhs)	Simple payback period
1.					
2.					
3.					
4.					
Total					

Table 5.4 : Types and Priority of Energy Saving Measures

Type of energy saving options	Annual electricity/ Fuel savings	Annual savings	Priority
	kWh/MT (or) kl/MT	(Rs. Lakhs)	
(A) No investment (immediate) – Operational improvement – Housekeeping (B) Low investment (Short to medium term) – Controls – Equipment modification – Process change (C) High investment (Long term) – Energy efficient devices – Product modification – Technology change			

Reporting Format for Energy Conservation Recommendations

(A) Title of recommendation: Combine DG set cooling tower with main cooling tower. (say; example)

(B) Description of existing system and its operation: Main cooling tower is operating with 30% of its capacity. The rated cooling water flow is 5000 m^3/hr. Two cooling water pumps are in operation continuously with 50% of its rated capacity. A separate cooling tower is also operating for DG set operation continuously.

(C) Description of proposed system and its operation: The DG set cooling water flow is only 240 m^3/h. By adding this flow into the main cooling tower will eliminate the need for a separate cooling tower operation for DG set, besides improving the % loading of main cooling tower. It is suggested to stop the DG set cooling tower operation.

(D) Energy saving calculations:

Capacity of main cooling tower	= 5000 m^3/hr
Temp. across cooling tower (design)	= 8°C
Present capacity	= 3000 m^3/hr
Temp. across cooling tower (operating)	= 4°C
% loading of main cooling tower	= $(3000 \times 4)/(5000 \times 8) - 30\%$
Capacity of DG set cooling tower	= 240 m^3/hr
Temp. acros. the tower	= 5°C
Heat load $(240 \times 1000 \times 1 \times 5)$	= 1200000 K.Cal/hr

Power drawn by the DG set cooling tower:

No of pumps and its rating	= 2 nos × 7.5 kW
No of fans and its rating	= 2 nos × 22 kW
Power consumption @ 80% load	= $(22 \times 2 + 7.5 \times 2) \times .80 - 47$ kW
Additional power required for main cooling tower for additional water flow of 240 m^3/h (66.67 l/s) with 6 kg/cm^2	= $(66.67 \times 6)/(102 \times 0.55) - 7$ kW
Net energy savings	= 47 – 7 = 40 kW

(E) Cost benefits:

Annual energy saving potential	= 40 kW × 8400 hr
	= 3,36,000 units/year
Annual cost savings	= 3,36,000 × Rs. 4.00
(Assuming Rs. 4/kWh as cost)	= Rs. 13.41 Lakh per year
Investment (Only cost of piping)	= Rs. 1.5 Lakhs
Simple Pay back period	= Less than 2 months

5.10 RELEVANCE OF ENERGY COSTS

Understanding energy cost is vital factor for awareness creation and saving calculation. In many industries sufficient meters may not be available to measure all the energy used. In such cases, invoices for fuels and electricity will be useful. The annual company balance sheet is the other sources where fuel cost and power are given with production related information.

Energy invoices can be used for the following purposes:

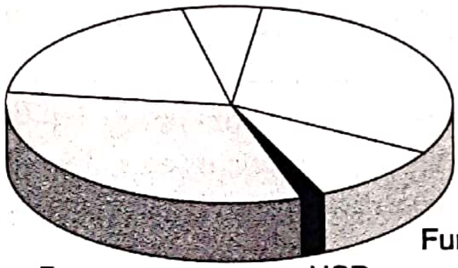
- They provide a record of energy purchased in a given year, which gives a base-line for future reference.
- Energy invoices may indicate the potential for savings when related to production requirements or to air-conditioning requirements/space heating, etc.
- When electricity is purchased on the basis of maximum demand tariff.
- They can suggest where savings are most likely to be made.

- In later years invoices can be used to quantify the energy and cost savings made through energy conservation measures.

5.10.1 Fuel Costs

A wide variety of fuels are available for thermal energy supply. Few are listed below:

- Fuel oil
- Low Sulphur Heavy Stock (LSHS)
- Light Diesel Oil (LDO)
- Liquefied Petroleum Gas (LPG)
- Coal
- Lignite
- Wood etc.



Assumed sample of total energy bill - Rs. 6 crores annum (say; example)

Fig. 5.4 Annual energy bill.

Understanding fuel cost is fairly simple and it is purchased in tons or kiloliters. Availability, cost and quality are the main three factors that should be considered while purchasing. The following factors should be taken into account during procurement of fuels for energy efficiency and economics.

- Price at source, transport charge, type of transport.
- Quality of fuel (contaminations, moisture etc.)
- Energy content (calorific value).

5.10.2 Power Costs

Electricity price in India not only varies from state to state, but also city to city and consumer to consumer though it does the same work everywhere. Many factors are involved in deciding final cost of purchased electricity such as:

- Maximum demand charges, kVA
  (*i.e.*, **How fast** the electricity is used?)
- Energy charges, kWh
  (*i.e.*, **How much** electricity is consumed?)
- TOD charges, peak/non-peak period
  (*i.e.*, **When** electricity is utilised?)
- Power factor charge, P.F.
  (*i.e.*, **Real power use versus apparent power use factor**)
- Other incentives and penalties applied from time to time.

- High tension tariff and low tension tariff rate changes.
- Slab rate cost and its variation.
- Type of tariff clause and rate for various categories such as commercial, residential, industrial, government, agricultural, etc.
- Tariff rate for developed and underdeveloped area/states.
- Tax holiday for new projects.

Example: Purchased Energy Bill

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

Table 5.5

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

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

Electricity (1 kWh) = 860 kCal/kWh (0.0036 GJ)

Heavy fuel oil (Gross calorific value, GCV)

= 10000 kCal/litre (0.0411 GJ/litre)

Coal (Gross calorific value, GCV)

= 4000 kCal/kg (28 GJ/ton)

5.11 BENCHMARKING AND ENERGY PERFORMANCE

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

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

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

Benchmarking energy performance permits:

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

The benchmark parameters can be :

- Gross production related
  - *e.g.* kWh/MT clinder or cement produced (cement plant)
  - *e.g.* kWh/kg yarn produced (Textile unit)
  - *e.g.* kWh/MT, kCal/kg, paper produced (Paper plant)
  - *e.g.* kCal/kWh power produced (Heat rate of a power plant)
  - *e.g.* Million kilocals/MT urea or ammonia (Fertiliser plant)
  - *e.g.* kWh/MT of liquid metal output (in a foundry)
- Equipment/utility related
  - *e.g.* kW/ton of refrigeration (on air conditioning plant)
  - *e.g.* % thermal efficiency of a boiler plant
  - *e.g.* % cooling tower effectiveness in a cooling tower
  - *e.g.* kWh/NM^3 of compressed air generated
  - *e.g.* kWh/litre in a diesel power generation plant.

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

- For a cement plant: type of cement, blaine number (fineness), *i.e.*, Portland and process used (wet/dry) are to be reported alongside kWh/MT figure.
- For a textile unit: average count, type of yarn, *i.e.*, polyester/cotton, is to be reported along side kWh/square meter.
- For a paper plant: paper type, raw material (recycling extent), GSM quality is some important factors to be reported along with kWh/MT, kCal/Kg figures.
- For a power plant/cogeneration plant: plant % loading, condenser vacuum, inlet cooling water temperature, would be important factors to be mentioned alongside heat rate (kCal/kWh).
- For a fertiliser plant: capacity utilisation (%) and on-stream factor are two inputs worth comparing while mentioning specific energy consumption.
- For a foundry unit: melt-output, furnace type, composition (mild steel, high carbon steel/cast iron etc.) raw material mix, number or power trips could be some useful operating parameters to be reported while mentioning specific energy consumption data.
- For an Air conditioning (A/C) plant: Chilled water temperature level and refrigeration load (TR) are crucial for comparing kW/TR.

- For a boiler plant: fuel quality, type, steam pressure, temperature, flow are useful comparators alongside thermal efficiency and more importantly, whether thermal efficiency is on gross calorific value basis or net calorific value basis or whether the computation is by direct method or indirect heat loss method, may mean a lot in benchmarking exercise for meaningful comparison.
- Cooling tower effectiveness: ambient air wet/dry bulb temperature, relative humidity, air and circulating water flows are required to be reported to make meaningful sense.
- Compressed air specific power consumption: is to be compared at similar inlet air temperature and pressure of generation.
- Diesel power plant performance: is to be compared at similar loading %, steady run condition, etc.

5.11.1 Plant Energy Performance

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

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

5.11.2 Production Factor

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

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

5.11.3 Reference Year Equivalent Energy Use

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

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

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

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

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

5.11.4 Monthly Energy Performance

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

5.12 MATCHING ENERGY USAGE TO REQUIREMENT

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

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

5.13 MAXIMISING SYSTEM EFFICIENCY

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

- Eliminate steam leakages by trap improvements.
- Maximise condensate recovery.
- Adopt combustion controls for maximising combustion efficiency.

- Replace pumps, fans, air compressors, refrigeration compressors, boilers, furnaces, heaters and other energy consuming equipment, wherever significant energy efficiency margins exist.

Optimising the Input Energy Requirements

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

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

5.14 FUEL AND ENERGY SUBSTITUTION

Fuel substitution: Substituting existing fossil fuel with more efficient and less cost/less polluting fuel such as natural gas, biogas and locally available agro-residues.

Energy is an important input in the production. There are two ways to reduce energy dependency; energy conservation and substitution.

Fuel substitution has taken place in all the major sectors of the Indian economy. Kerosene and Liquefied Petroleum Gas (LPG) have substituted soft coke in residential use.

Few examples of fuel substitution:

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

Few examples of energy substitution:

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

Case Study: Example on Fuel Substitution

A textile process industry replaced old fuel oil fired thermic fluid heater with agro fuel fired heater. The economics of the project are given below :

(A) Title of recommendation : Use of agro fuel (coconut chips) in place of furnace oil in a boiler.

(B) Description of existing system and its operation : A thermic fluid heater with furnace oil currently. In the same plant a coconut chip fired boiler is operating continuously with good performance.

(C) Description of proposed system and its operation : It was suggested to replace the oil fired thermic fluid heater with coconut chip fired boiler as the company has the facilities for handling coconut chip fired system.

(D) Energy saving calculations:

Old System

Type of fuel firing	**: Furnace oil fired heater**
GCV	: 10,200 kCal/kg
Average thermal efficiency	: 82%
Heat duty	: 15 lakh kCal/hour
Operating hours	: 25 days × 12 month × 24 hours = 7,200 hrs
Annual fuel cost	: Rs. 130 lakh (7200 × 1800 Rs./hr.)

Modified System

Type of fuel saving	**= Coconut chips fired heater**
GCV	= 4200 kCal/kg
Average thermal efficiency	= 72%
Heat duty	= 15 lakh kCal/hour
Annual operating cost	= 7200 × 700 Rs./hr = 50 lakh
Annual savings	= 130 – 250 = Rs. 80 lakh
Additional auxiliary power + Manpower cost	= Rs. 10 lakh
Net annual saving	= Rs. 70 lakh
Investment for new coconut fired heater	= Rs. 35 lakh
Simple pay back period	**= 6 months**

5.15 ENERGY AUDIT INSTRUMENTS

The requirement for an energy audit such as identification and quantification of energy necessitates measurements; these measurements require the use of instruments. These instruments must be portable, durable, easy to operate and relatively inexpensive. The parameters generally monitored during energy audit may include the following :

Basic electrical parameters in AC and DC systems : Voltage (V), Current (I), Power factor, Active power (kW), apparent power (demand) (kVA), Reactive power (kVAr), Energy consumption (kWh), Frequency (Hz), Harmonics, etc.

Parameters of importance other than electrical such as temperature and heat flow, radiation, air and gas flow, liquid flow, revolutions per minute (RPM), air velocity, noise and vibration, dust concentration, Total Dissolved Solids (TDS), pH, moisture content, relative humidity, flue gas analysis – CO_2, O_2, CO, SO_x, NO_x, combustion efficiency, etc.

Key instruments for energy audit are listed below :

The operating instructions for all instruments must be understood and staff should familiarise themselves with the instruments and their operation prior to actual audit use.

Audit Meters and Instruments

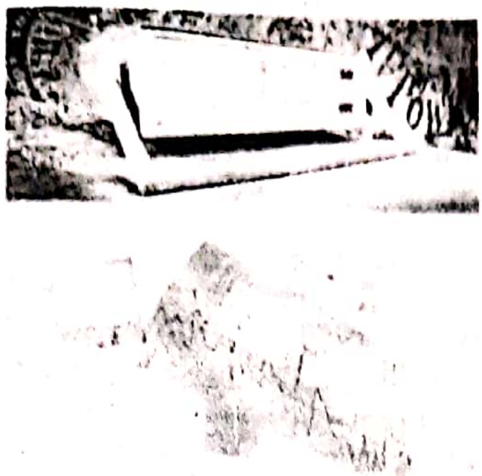
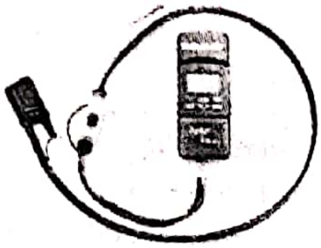
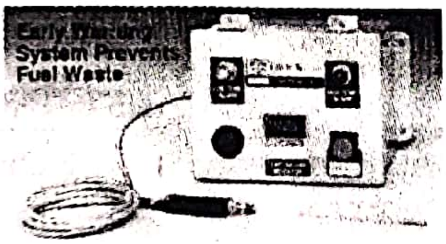
The following is a suggested list of meters and instruments for undertaking energy-audit.

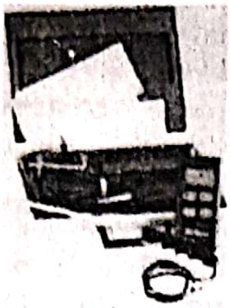
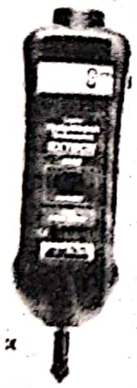
S. No.	Name
1.	Digital temperature indicator
2.	Infrared pyrometer
3.	Digital humidity meter
4.	pH meter kit
5.	Combustion analyzer
6.	Combustion test kit
7.	Velometer and probes
8.	Pitot tubes : (i) 24 inch (ii) 60 inch
9.	Micromanometer
10.	Differential pressure gauge
11.	TDS meter
12.	Clip-on power meter (1000 A)
13.	Clip-on power meter (200 A)
14.	3-phase adaptor
15.	Strobe tachometer
16.	Ultrasonic leak detector
17.	Ultrasonic flow meter
18.	Signal recorder
19.	Multimeter (digital)
20.	Light meter (Luxmeter)
21.	Hygro/thermograph
22.	Whirling hygrometer
23.	Vane anemometer
24.	U tube manometer
25.	Thermocouple probes – High range
26.	Thermocouple probes – Low range
27.	Industrial stethoscope
28.	Computer with CVT and Printer
29.	Drawing Kit

Most of these instruments can be used in conducting an energy audit.

These instruments and audit tools should be supplemented with the performance charts/tables of energy consuming equipment operating in the establishment. If not available on site, copies should be requested from its original suppliers or from its manufacturers.

The brief description of some of these instrument is as follows :

	**Electrical measuring instruments:** These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts. In addition some of these instruments also measure harmonics. These instruments are applied on-line, *i.e.* on running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals.
	**Combustion analyzer:** This instrument has in-built chemical cells which measure various gases such as O_2, CO, NO_x and SO_x.
	**Fuel efficiency monitor:** This measures oxygen and temperature of the fuel gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency.
	**Fyrite:** A hand bellow pump draws the fuel gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. A separate fyrite can be used for O_2 and CO_2 measurement.
	**Contact thermometer:** These are thermocouples which measures for example fuel gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature, leaf type probe is used with the same instrument.

	**Infrared thermometer:** This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures, etc.
	**Pitot tube and manometer:** Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows.
	**Water flow meter:** This non-contact flow measuring device using doppler effect/ Ultrasonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter.
 	**Speed measurements:** In any audit exercise speed measurements are critical as they may change with frequency, belt slip and loading. A simple tachometer is a contact type instrument which can be used where direct access is possible. More sophisticated and safer ones are non-contact instruments such as stroboscopes.
	**Leak detectors:** Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities.
	**Lux meters:** Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.

5.16 ENERGY EFFICIENCY

Energy efficiency may refer to:

- Efficient energy use
- Energy conversion efficiency, the ratio between the output and input of an energy conversion machine
- Energy conservation, efforts made to reduce energy consumption.

Efficient Energy Use

Efficient energy use, sometimes simply called energy efficiency, is using less energy to provide the same level of energy service. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Another example would be installing fluorescent lights and or skylights instead of incandescent lights to attain the same level of illumination. Compact fluorescent lights use two-thirds less energy and may last 6 to 10 times longer than incandescent light bulbs. Efficient energy use is achieved primarily by means of a more efficient technology or processes rather than by changes in individual behaviour.

Energy efficient buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third and help controlling global emissions of greenhouse gases, according to the International Energy Agency.

Energy efficiency and renewable energy are said to be the twin pillars of sustainable energy policy.

Making homes, vehicles and businesses more energy efficient is seen as a largely untapped solution to addressing the problems of pollution, global warming, energy security and fossil fuel depletion. Many of these ideas have been discussed for years, since the 1973 oil crisis brought energy issues to the forefront.

Energy efficiency has proved to be a cost-effective strategy for building economics without necessarily growing energy consumption.

Energy Conversion Efficiency

Energy conversion efficiency is the ratio between the useful output of an energy conversion machine and the input, in energy terms. The useful output may be electric power, mechanical work or heat. Output energy is always lower than input energy.

Energy conversion efficiency is not defined uniquely, but instead depends on the usefulness of the output. All or part of the heat produced from burning a fuel may become rejected waste heat if, for example, work is the desired output from a thermodynamic cycle.

Even though the definition includes the notion of usefulness, efficiency is considered a technical or physical term. Goal or mission oriented terms include effectiveness and efficacy.

Generally, energy conversion efficiency is a dimensionless number between 0 and 1.0 or 0 to 100%. Efficiencies may not exceed 100%, *e.g.*, for a perpetual motion machine. However, other effectiveness measures that can exceed 1.0 are used for heat pumps and other devices that move heat rather than convert it.

The examples of energy conversion efficiency of various equipment are already discussed in chapter 2.

One of the purpose of the energy audit is to check the energy conversion efficiency of equipment in the system.

5.17 ENERGY AUDIT FOR BUILDINGS

The energy audit in a building is a feasibility study. For it not only serves to identify energy use among the various services and to identify opportunities for energy conservation, but it is also a crucial first step in establishing an energy management programme. The audit will produce the data on which such a programme is based. The study should reveal to the owner, manager or management team of the building the options available for reducing energy waste, the costs involved and the benefits achievable from implementing those energy-conserving opportunities (ECOs).

The energy management programme is a systematic on-going strategy for controlling a building's energy consumption pattern. It is to reduce waste to energy and money to the minimum permitted by the climate the building is located, its functions, occupancy schedules and other factors. It establishes and maintains an efficienc balance between a building's annual functional energy requirements and its annual actual energy consumption.

5.17.1 Stages in Energy Programme for Buildings

The energy audit may range from a simple walk-through survey at one extreme to one that may span several phases. These phases include a simple walk-through survey, followed by monitoring of energy use in the building services and then model analysis using computer simulation of building operation. The complexity of the audit is therefore directly related to the stages or degree of sophistication of the energy management programme and the cost of the audit exercise.

The first stage is to reduce energy use in areas where energy is wasted and reductions will not cause disruptions to the various functions. The level of service must not be compromised by the reduction in energy consumed. It begins with a detailed, step-by-step analysis of the building's energy use factors and costs, such as insulation values, occupancy schedules, chiller efficiencies, lighting levels and records of utility and fuel expenditures. It includes the identification of specific ECOs, along with the cost-effective benefits of each one. The completed study would provide the building owner with a thorough and detailed basis for deciding which ECOs to implement, the magnitude of savings to be expected and the energy conservation goals to be established and achieved in the energy management programme. However, the ECOs may yield modest gains.

The second stage is to improve efficiency of energy conversion equipment and to reduce energy use by proper operations and maintenance. For this reason, it is necessary to reduce the number of operating machines and operating hours according to the demands of the load and fully optimise equipment operations. Hence the ECOs would include the following:

- Building equipment operation,
- Building envelope,
- Air-conditioning and mechanical ventilation equipment and systems,
- Lighting systems,
- Power systems, and
- Miscellaneous services.

The first two stages can be implemented without remodelling buildings and existing facilities.

The third stage would require changes to the underlying functions of buildings by remodelling rebuilding or introducing further control upgrades to the building. This requires some invesiment.

The last stage is to carry out large-scale energy reducing measures when existing facilities have past their useful life or require extensive repairs or replacement because of obsolescence. In this case higher energy savings may be achieved. For these last two stages, the audit may be more extensive in order to identify more ECOs for evaluation, but at an increased need for heavier capital expenditure to realise these opportunities.

5.17.2 Surveying the Building

A walk-through survey of a building may reveal several ECOs to the experienced eye of the auditor. The survey could be divided into three parts.

Preliminary Survey

Prior to the walk-through survey, the auditor may need to know the building and the way it is used. The information can be obtained from:

- architectural blueprints,
- air-conditioning blueprints,
- electrical lighting and power blueprints,
- utility bills and operation logs for the year preceding the audit,
- air-conditioning manuals and system data, and
- building and plant operation schedules.

Walk-through

Thus having familiarised with the building, the walk-through process could be relatively straightforward, if the blueprints and other preliminary information available describes the building and its operation accurately. The process could begin with a walk around the building to study the building envelope Building features such as building wall colour, external sun-shading devices, window screens and tint and so on are noted as possible ECOs.

If a model analysis is included in the study, the building must be divided into zones of analysis. The survey inside the building would include confirmed that the air-conditioning system is as indicated on plans. Additions and alterations would be noted. The type and condition of the windows, effectiveness of window seals, typical lighting and power requirements, occupancy and space usage are noted. This information could be compared against the recommendations inthe relevant codes of practices.

System and plant data could be obtained by a visit to the mechanical rooms and plant room. Nameplate data could be compared against those in the building's documents and spot readings of the current indicating panels for pumps and chillers recorded for estimating the load on the system.

Operator's Input

The auditor may discuss with the building maintenance staff further on the operating schedules and seek clarification on any unusual pattern in the trend of the utility bills. Unusual patterns such as sudden increase or decrease in utility bills could be caused by changes in occupancy in the building or change in use by existing tenants. It is not uncommon for tenants to expand their computing operations that may increase the energy use significantly.

Report

At this stage, ECOs could be found in measures such as:

- Reduce system operating hours,
- Adjust space temperature and humidity,
- Reduce building envelope gain,
- Adjust space ventilation rates and building exfiltration,
- Review system air and water distribution,
- Adjust chiller water temperatures, and
- Review chiller operations.

The benefit from adopting each ECO should be compared against cost of implementation. Caution should be exercised in the cost-benefit analysis given the wider range of certainty of the projections made. However, a survey at this level may be sufficient for small buildings.

5.17.3 Measurements

The capability of the energy auditor and the scope of an audit could be extended by the use of in place instrumentation and temporary monitoring equipment. In-place instrumentation refers to existing utility metering, air-conditioning control instrumentation and energy management systems (EMS).

The use of in-place utility metering and temporary monitoring equipment in energy auditing can yield valuable information about the building systems such as:

- Energy signature and end-use consumption analysis,
- Discovery and identification of ECOs,
- Quantification of energy use and misuse,
- Establishing bounds for potential energy reduction, and
- Data acquisition for further calculation and analysis.

Existing Information

Existing instrumentation such as utility meter readings and energy billings could be used to establish energy consumption patterns for the building. The regularity of consumption pattern is an indicator that no significant change in consumption occurred prior to the audit. This can also be used to check the validity of projections based on extrapolated short-term monitored data. Utility data could be used to establish useful indices such as kWh/m^2/year to compare relative energy performance of buildings.

Air-conditioning control instrumentation such as chilled water temperature probes, water flow meters could be used to estimate cooling load demand and plant operation. For example, chilled water temperature outside the designed range may indicate that cooling coils may be operating under offdesign conditions.

Short Term Monitoring

The building may not be equipped for monitoring energy consumption and it may be necessary to install temporary measurement devices such as instantaneous recorders (strip chart, data loggers etc.) and totalizing recorders (kWh meters) to obtain data over the period of a week for the study. Monitored data is also useful for completing the energy model of a building for use in some building energy simulation software. For example the total building energy consumption would include energy used in the vertical transportation system and potable water pumps which are not modelled in the software.

An estimate for annual consumption is extrapolated from the typical week consumption profile. Regularity of the weekly consumption profile means that the annual consumption could be estimated with confidence and the value used to cross check with the annual energy bills.

5.17.4 Model Analysis

Building energy consumption in simplest terms is just the product of rate of consumption of a system and the period of operation. In lighting systems, its energy consumption could be determined manually with precision as it does not interact with other consumption variables. Energy consumption of cooling systems, however, is many times more complicated as it is affected by the internal heat again within a building as well as weather variables, which varies in a complex manner over time.

Building model analysis using computers offers several improvements over manual calculations. These include :

- Precise schedule of building parameters,
- Precise determination of weather impact,
- Specification of part load performance of plant and equipment, and
- Consideration of parameter interactions such as lighting load on air-conditioning consumption.

Software

Some software permit hour-by-hour calculations of building consumption for the entire 8760 hours of the year, but require thorough knowledge of the software to carry out accurate and meaningful analysis. Simplified software based on consumption analysis on characteristic days may also be considered. However, the improvements in computational power of the desktop PC has introduced several powerful features and user-friendly graphical interface possible in more recent versions of such software making it more accessible to the practicing engineer.

Analysis

The general procedure for an analysis would be to establish a model giving an annual consumption within 10% of the measured data. This establishes the base model. The impact of ECOs on energy consumption would be compared against the base model. ECOs could be considered singly or in combinations to determine the interactions between them. The results of the energy savings in each analysis should not be taken as absolute but rather taken to be relative to the base run so as to give an indication of the order of magnitude of savings. Thus those ECOs which shows significant gains would be implemented.

The objective of energy audit is to identify the end use of energy in building and its ECOs and as a feasibility study leading to implementation of an energy management programme. The audit procedures can be expanded as needed in the various phases of the energy programme with the application of each succeeding phase yielding more information on energy use and more opportunities for raising energy efficiency.

5.18 ENERGY AUDIT FORM FOR COMMERCIAL BUILDINGS SUCH AS HOTELS

Short Audit Form

Hotel

Name : ______________________________

Address : ______________________________

Owner of the building

Contractor : ☐ Other : ☐

Contact person for energy systems : ______________________________

Telephone number : ______________________________

Main Characteristics

This short audit form is used to identify the hotel characteristics and electrical, heating, cooling and domestic hot water systems installed.

Known future changes in installations and/or energy use, etc. can be noted separately.

Type (related to guests)

Business : ☐ Tourism : ☐

Occupation

Occupation rate, % ________________

Class(related to quality)

Highest(5*) ☐ High(4*) ☐ Average(3*) ☐

Size

Number of rooms : __________ Average room size, m^2 : ________

Total covered area, m^2 : ________________

Public general service and service area, m^2 : ________________

Special service

Climate cooling : Total size of climatized areas : ________________

Swimming pool : Area, m^2 : ________ Period of use : ________

Restaurant : Places : ________ Use of non guests : ________

Average meals/month: ________________

Laundry: Yes ☐ No ☐

Energy sources, primary energy bought (used) per year, MWh

Energy	Energy per year, MWh
Electricity	
District heating	
Light oil	
Natural gas	
Other :	

Use of water, per year

Use of water, total m^3 : ________________

There of, for domestic hot water, m^3 : ________________

Climate according to geographical location, just for internal use

Heating degree-days : ______________________

Outside average temperature in summer : ______________________

Energy Data

Electricity: The following information can usually be found on your electricity bills.

Installed electrical power, kW : ______________________

Electrical demand (max demand), kW: ______________________

Electricity consumption :

Month	Demand kW	Consumption kWh
Jan.		
Feb.		
Mar.		
Apr.		
May		
Jun.		
Jul.		
Aug.		
Sep.		
Oct.		
Nov.		
Dec.		
Total		

Installed systems within the hotel, electrical power by end-use/equipment. (HVAC; Swimming pool heater; Domestic hot water; Climate cooling, refrigerator, etc.)

Unit No.	Heating-, cooling-, water- and electrical system	Power, kWe	Installed year	Used for :	Meters installed Yes/No
1					
2					
3					
4					
5					
6					
7					
8					

9					
10					
11					

Thermal energy consumption for the year
Installed thermal power (total), kW
Installed power by end-use/equipment, kW:
(HVAC; Swimming pool heater, Domestic hot water, etc.)

1st Thermal energy source:
Energy source : ________________ Unit : ________________
Produced energy used for : ________________________________

Month consumption, MWh:

Jan.	Feb.	Mar.	Apr.	May	Jun.
Jul.	Aug.	Sep.	Oct.	Nov.	Dec.

Total consumption, MWh : ________________

2nd Thermal energy source:
Energy source : ________________ Unit : ________________
Produced energy used for : ________________________________

Month consumption, MWh:

Jan.	Feb.	Mar.	Apr.	May	Jun.
Jul.	Aug.	Sep.	Oct.	Nov.	Dec.

Total consumption, MWh : ________________

3rd Thermal energy source:
Energy source : ________________ Unit : ________________
Energy used for : ________________________________

Month consumption, MWh:

Jan.	Feb.	Mar.	Apr.	May	Jun.
Jul.	Aug.	Sep.	Oct.	Nov.	Dec.

Total consumption, MWh : ________________

Principal schemes and manuals to be enclosed for the individual systems: Schemes of installation, regulation equipment, flow scheme and a copy of the manual if possible.

5.19 CHECKLIST FOR ENERGY SAVING MEASURES IN HOTELS

Energy Management

Is there a good management of the energy consumption? (operating hours, split areas etc.) ☐ Yes ☐ Partly ☐ No

Heating/Hot Water

Is the in-door temperature controlled? ☐ Yes ☐ Partly ☐ No

Is the insulation in good condition? ☐ Yes ☐ Partly ☐ No

Is the domestic water temperature controlled? ☐ Yes ☐ Partly ☐ No

Lightning

Is the use of electric lightning optimised? ☐ Yes ☐ Partly ☐ No
(use of daylight, motion detectors, room-key automatic switch etc.)

Ventilation

Is the ventilation system optimised? ☐ Yes ☐ Partly ☐ No

Air Conditioning

Is the AC system optimised and co-ordinated with the heating?
☐ Yes ☐ Partly ☐ No

Are other energy consumer in the hotel optimised?

Catering ☐ Yes ☐ Partly ☐ No

Laundry ☐ Yes ☐ Partly ☐ No

Pool ☐ Yes ☐ Partly ☐ No

Staff knowledge and Behaviour

Is there defined responsibilities and instruction for energy efficient behaviour? ☐ Yes ☐ Partly ☐ No

Is the staff educated in energy savings and aware about relevant instructions? ☐ Yes ☐ Partly ☐ No

Comments : ____

____

■ REVIEW QUESTIONS

1. Define energy audit.
2. What activities are needed to be carried out while doing Home Energy Audit?
3. Give the definition of energy audit as per energy conservation act (India), 2001.
4. What is the need of energy audit?
5. Mention the activities included in energy audit study.
6. Give the classification (types) of energy audit.
7. What is preliminary audit?
8. Explain the various activities involved in general audit or mini audit.
9. Explain investment grade or comprehensive or detailed audit.
10. How does detailed audit differ from preliminary audit?
11. Draw an energy flow chart and explain it.
12. List down the various energy consuming equipment and systems.
13. Elaborate about energy audit team.
14. Explain the preliminary energy audit methodology.
15. Explain various steps involved in detailed energy audit methodology.
16. Discuss pre-audit phase activities.
17. What activities are involved in phase-II of detailed energy audit?
18. What information need to be collected during the detailed audit.
19. Draw the process flow diagram of any process.
20. What kind of energy conservation opportunities are identified after carrying out the energy audit.
21. Give the classification of energy conservation measures.
22. Elaborate about the energy audit reporting format.
23. Discuss about the reporting format for energy conservation recommendation.
24. Discuss about the relevance of energy costs.
25. Explain the term benchmarking of energy performance.
26. Define the term plant energy performance.
27. Define the term production factor.
28. Define reference year equivalent energy use.
29. How system efficiency can be maximised?
30. Discuss about fuel and energy substitution.
31. List down the important energy audit instruments used in energy audit. Also explain briefly about their function.
32. Define the term energy efficiency.
33. What are the advantages of improving energy efficiency?
34. How energy efficiency can be improved in appliances?

35. What steps are necessary in designing a new building to improve energy efficiency?
36. How energy efficiency can be improved in industrial process?
37. How energy efficiency can be improved in vehicles.
38. Elaborate how energy conservation and energy efficiency are co-related to each other.
39. Define the term energy conversion efficiency.
40. Write a detailed note on energy audit for buildings.
41. What are the main elements involved in short audit form used for preliminary audit of hotels.
42. What are the various points needed to be checked as per the checklist for energy saving measures which must be taken in commercial buildings such as hotels?
43. Give a case study of an energy audit carried out by you for any building or industrial process. Elaborate about the process and mention each points and energy saving measures taken and their effects on energy consumption.

❑❑❑

ENERGY MANAGEMENT

BME-56(III Sem)

CHEMICAL ENGINEERING)

by

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Assistant Professor

Mechanical Engineering Department

- **Meaning of Energy Audit:**

Energy audit is an official scientific study of energy consumption of an organization/process/plant/equipment aimed at reduction of energy consumption and energy costs without affecting productivity and comforts and suggesting the methods for energy saving and reduction in energy cost. Energy audit is carried out in planned, official manner by every energy intensive organization/plant management.

i. Familarisation with the energy inlets and outlets, of energy.

ii. Data acquisition, measurements.

iii. Study of advanced, modern processes and plants for similar activities under audit.

iv. Formulating energy equations and software.

v. Economic evaluation of energy consumption in the sector/organisation/plant under audit.

vi. Analysis of energy consuming sub-processes.

vii. Suggest energy conservation processes along with alternatives, necessary investments, payback periods, economic benefits etc.

viii. Suggest steps to be taken for reducing energy consumption without sacrificing productivity.

The energy audit identifies the cost of energy and where and how it is used. It will identify the amount of energy expended in a process with the help of mass and energy balance for each proc

The energy flow diagram is then prepared showing the quantity, form, source and quality (i.e., temperature) of the energy required for various processes. Next step is to make a critical analysis for energy used and energy wasted. This is followed by identification of potential areas for energy saving.

Objectives of Energy Audit:

The main purpose of energy audit is to establish quickly and reliably, the basic relative costs of the various forms of energy purchased their main use and to identify mam locations where losses, wastages or inefficiency occurs.

In simple language we can say that, energy audit helps to understand more about the ways different energy sources are used in the industry and helps to identify areas where waste can occur and where scope for improvement may be possible. Thus, energy audit is one of the concepts used in the energy management and it involves methodological examination and comprehensive review of energy use in industries

Types of Energy Audit:

The energy audit can be of following two types:

1. Preliminary audit.

2. Detailed audit.

Preliminary audit:

Preliminary audit is carried out in the limited time say within 10 days and it highlights the energy cost and wastages in the major equipment's and processes. It also gives the major energy supplies and demanding accounting. The questionnaire containing the industrial details of energy consumption process carried out, energy need to unit product; load data etc. must be completed before the pre-audit visit.

The pre-audit visit is done, by the audit team/audit consultant, in the plant area with the attention focused on the energy inputs, spots of wastage and available energy conservation opportunities. The items for waste recycling opportunities are identified. The data regarding energy inputs and outputs are collected for use during preliminary audit.

During the visit, discussions with line supervisors and line technicians and joint brainstorming may be necessary to acquire creative ideas

and to know the practical difficulties in carrying out the proposed energy conservation measures (ECMs).

After the pre-audit visit, the work of energy audit is undertaken. In the preliminary audit, low tech recommendations are preferred. High tech solutions are given under detailed energy audit. Some of the low cost recommendations may be: Switching off lights when not required, replace incandescent lamps by the fluorescent lamps, automatic thermostat control, use of solar water heating panels etc.

The preliminary audit spots energy waste spots and recommend short, intermediate and long term solutions. It should adopt step by step and cautious approach for improvements and new techniques of energy management and control system.

Detailed (Comprehensive) Energy Audit:

Detailed energy audit, also known as comprehensive energy audit includes engineering recommendations and well defined projects with priorities. It account for the total energy utilised in plants. It involves detailed engineering for options to reduce energy consumption and also reduce cost. The duration of such studies is generally from 1 to 10 weeks. The action plan in divided into short term, medium term and long term actions.

The short term action plan requires no capital investment or least investment to avoid energy wastages and minimising non-essential energy uses and improving the system efficiency through improved maintenance programme.

The medium term action plan requires a little investment to achieve efficiency improvement through modifications of existing equipment's and other operations.

Detailed Energy analysis

The long term action plan is aimed to achieve economy through latest energy saving techniques and innovations. The capital investments are required to be studied thoroughly while finalising the long term action-plan.

The comprehensive (detailed) energy audit is a thorough and extensive energy audit that analyses and quantifies the amount of energy consumption in each sub system of the plant and compares the same with the target energy consumption. Target per unit energy consumption is the optimum energy consumption per unit product.

The comprehensive audit is quite exhaustive, and it is convenient to split it into following sub parts:

1. Overall system audit:

This accounts for energy leakage/loss through the total system to the atmosphere. The energy conservation measures to eliminate such leakages/loss are recommended.

2. Functional audit:

It identifies the energy conservation measures in operation and maintenance of each main plant and its subsystems and suggests ECOs is operation and maintenance.

3. Utility Audit:

It identifies yearly/monthly/daily consumption of commercial secondary energy (electricity/petroleum products/fuel etc.) and suggests ECOs.

4. Modernization audit:

It recommends major changes in the process requiring retrofitting.

What is an energy audit?

According to the definition in the ISO 50002 standard, an energy audit is a systematic analysis of energy use and energy consumption within a defined energy audit scope, in order to identify, quantify and report on the opportunities for improved energy performance

Therefore, an energy audit is an energy assessment. This evaluation analyses energy flows in a building, process or system to reduce the amount of energy input into the system whilst maintaining or improving human comfort, health and safety. The level of detail of this evaluation determines the type of audit.

Report of Energy Audit:

The comprehensive energy audit report generally converts the following:

(i) Energy conservation opportunities (ECOs)

(ii) Energy conservation measures (ECMs)

(iii) Projected investments for ECMs.

(iv) Projected annual savings of ECMs and pay-back period.

(v) Feasibility studies for retrofitting/modification work.

Types of energy audit

Basically there are three types of energy audit:

Walk-Through Audit (WTA): as the name suggests, this audit consists of a walk-through inspection of a facility to identify maintenance, operational or deficient equipment issues and also to identify areas that need further evaluation.

The results of a Walk-Through Audit include an identification of energy saving opportunities, a qualitative analysis of the implementation of energy saving measures and an estimation of its potential energy saving. The final audit report is usually accompanied by basic comments on a project's feasibility.

Energy Diagnosis: this audit includes performing economic calculations and may include using some metering devices to identify actual energy consumption and losses. The results of an Energy Diagnosis include an energy balance (energy uses breakdown) and a list of energy efficiency measures derived from performance or building facility. The results also include financial analysis for each of the identified measures in order to categorize and prioritize the implementation of these measures.

Investment Grade Audit (IGA): this audit is a detailed account of energy use, including a quantitative study of the implementation with detailed investments and operational and maintenance costs and an analysis of the investment model. The results of an Investment Grade Audit include the real energy demand and an energy balance. Likewise, the audit suggests a number of energy saving measures, including the calculation of energy savings and the investment needed to carry them out.This audit proposes bundled measures, with a financing plan as well as implementation and savings verification plans.

How do I know which energy audit is right for me?

It depends on the purpose of the energy audit. If you want to identify potential savings in order to prioritize further studies, you need a Walk-Through Audit.

If you intend to invest a large amount of money in energy efficiency measures, you need an Investment Grade Audit.

An excellent option is the Energy Diagnosis, because you can obtain enough information about your facility to start working on energy efficiency, with a very good quality-to-price ratio.

So, depending on the funding available for the audit, the cost and potential of the energy management opportunity and the required accuracy for the audit information, you can choose the most suitable type of energy audit for your needs.

Laws of Thermodynamics

- First Law of Thermodynamics
- Second Law of Thermodynamics

  (a). Kelvin Plank statement

  (b). Clausius statement

First Law of thermodynamics

- CLOSED SYSTEM

  (a).System follows a cycle

  (b). System follows a process

- OPEN SYSTEM

  Steady flow Energy Equation

Second law of therodynamics

- Kelvin-Plank statement of second law
- Clausius statement of Second law

- Mass balance or Continuity equation
- Availability

UNIT-II

- Energy audit concepts, Energy audit based on 1st law and 2nd law of thermodynamics, Mass and Energy balances, Availability analysis, Evaluation of energy conserving Opportunities, Economic analysis and life cycle costing. Energy conservation areas, Energy transmission and storage, Plant wide energy optimization Models, Data base for energy management

ENERGY CONSERVING OPPORTUNITIES

ENERGY CONSERVATION AREAS

DIFFERENT PARAMETERS INVOLVED

ENERGY AUDIT INSTRUMENTS

Energy Conservation Opportunities

Energy Conservation

- Energy conservation refers to the reducing of energy consumption through using less of an energy service.
- Energy conservation differs from efficient energy use, which mean using less energy for a constant service
- Even though energy conservation reduces energy services, it can result in increased environmental quality, national security, personal financial security and higher savings.

Energy tax

- Some countries employ energy or carbon taxes to motivate energy users to reduce their consumption.
- Carbon taxes can allow consumption to shift to nuclear power and other alternatives that carry a different set of environmental side effects and limitations.
- Meanwhile, taxes on all energy consumption stand to reduce energy use across the board, while reducing a broader array of environmental consequences arising from energy production.

Energy conservation Opportunities

- One of the primary ways to improve energy conservation is to use an energy audit.
- An **energy audit** is an inspection and analysis of energy use and flows for energy conservation in a building, process or system to reduce the amount of energy input into the system without negatively affecting the output.
- This is normally accomplished by **trained professionals** and can be part of some of the national programs discussed above.
- In addition, recent development of **smar tphone apps** enable homeowners to complete relatively sophisticated energy audits themselves

Energy Consuming Sector

- Industries (All types of industries)
- Household (Lightening and Comfort purpose)
- Transportation (Moving of goods and Public transport etc)

Energy conservation Areas

- Buildings
- Transportation
- Consumer product
- Thermal utilities
- Electrical utilities

Energy Resources

- Non- renewable resources: oil, coal, natural gas, and nuclear power, etc.
- Renewable resources: hydraulic, geothermal and wind power, solar energy, and biomass, etc.

Current Situation of Energy Conservation

Overview of International Energy Conservation

- The amount of energy consumption in the entire world has been increased, accompanied by economic development of each country. It is expected that such amounts will continue to increase by 30% from 1997 to 2030.
- The increase of energy consumption is remarkable particularly in developing countries centered on Asian countries and the Asian region excluding Japan, which will accounts for almost half of future increase of the world's energy consumption.
- A reserve-production ratio that has been currently confirmed by exploration, as of 2004 would be approximately 40 years for oil, 61 years for natural gas, and 204 years for coal.

Current Situation……

- Although this ratio fluctuates due to excavation of new oil fields, oil and natural gas as basic resources would be exhausted within about 60 years in calculation.
- Additionally, as a result of mass consumption of fossil fuels, global warming caused by an increasing amount of CO_2 emissions in the air has been occurring at rapid speed, which is one of the most crucial global issues.
- According to the report by the "Intergovernmental Panel on Climate Change (IPCC)" announced in 2001, the global average temperature has increased by 0.6℃ over the 100 years of the 20th century. It is forecasted that increase in the global average temperature of 5.8℃ at maximum and the rising water level of 88 cm will occur by 2100.

Current Situation

- In addition, if the rising water level in Japan goes over 30 cm, it is estimated that 60% of sandy beaches would be lost.
- Moreover, based on previous statistics, it is clear that elasticity of GDP to energy demand becomes “1” on a long-term basis. This value means the amount of energy consumption will increase at the same percentage as that of economic growth in the long run.
- That is to say, unless countries achieve reduction of the amount of energy consumption (energy conservation) at the same percentage as that of economic growth every year, it will be impossible to even maintain the current situation.

Measures and policies concerning the Industrial Sector

- ENEGY MANAGER system based on the Energy Conservation Law.
- Voluntary Action Plan on Environment protection
- Subsidy system for adoption and dissemination of technologies and facilities that contributes to energy conservation.
- Subsidy system for ESCO in the industrial sector (low interest loans, preferential tax treatments, and subsidy systems).
- Activities for promotion, awareness, and dissemination of energy conservation

Measures and policies in Household

- Improvement of efficiency of equipment through the Top Runner approach.
- Improvement of performance concerning energy conservation of housings and buildings in accordance with the Energy Conservation Law.
- Subsidy system for adoption and dissemination of technologies.
- Radical reform of lifestyle of citizens
- Activities for promotion, awareness, and dissemination of energy conservation

Transportation sector

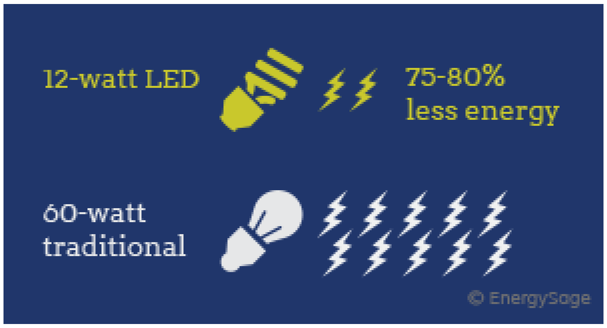
- Improvement of gas mileage for vehicles through the Top Runner approach based on the Energy Conservation Law.
- Energy conservation by stopping “idling“ of vehicles
- Promotion of dissemination of clean energy vehicles
- Improvement of energy consumption of individual transportation equipment
- Technical development by the government
- Enhancement of efficiency in logistics and transportation
- Promotion of telework.

Energy Conservation Projects

- Waste heat recovery
- Increasing overall efficiency of the thermal equipment.
- Avoiding heat losses.
- Conversion of electrical heating in to Thermal heating.
- Use of low cost fuel for same application.
- F.O. Emulsification for reducing consumption.
- Use of Fuel saving Devices.
- Heat repellant coating for furnaces ovens.
- Insulating hot surfaces.
- Tuning of Burners for their highest combustion efficiency.

Energy conservation: 10 ways to save energy

Last updated 8/26/2020



There are many different ways to reduce your household's energy use, ranging from simple behavioral adjustments to extensive home improvements. The two major motives for conserving energy are to save on utility bills and protect the environment. Here are the ten most common ways to conserve energy and save electricity in your home, listed from the simplest to the most intensive methods.

Top 10 ways to conserve energy

1. Adjust your day-to-day behaviors

To reduce energy consumption in your home, you do not necessarily need to go out and purchase energy efficient products. Energy conservation can be as simple as turning off lights or appliances when you do not need them. You can also use energy-intensive appliances less by performing household tasks manually, such as hang-drying your clothes instead of putting them in the dryer, or washing dishes by hand.

The behavior adjustments that have the highest potential for utility savings are turning down the heat on your thermostat in the winter and using your air conditioner less in the summer. Heating and cooling costs constitute nearly half of an average home's utility bills, so these reductions in the intensity and frequency of heating and cooling offer the greatest savings.

There are tools you can use to figure out where most of your electricity is going in your home and which appliances are using the most electricity on a day-to-day basis.

2. Replace your light bulbs

Traditional incandescent light bulbs consume an excessive amount of electricity and must be replaced more often than their energy efficient alternatives. Halogen incandescent bulbs, compact fluorescent lights (CFLs), and light-emitting diode bulbs (LEDs) use anywhere from 25-80 percent less electricity and last 3 to 25 times longer than traditional bulbs.

Although energy efficient bulbs are more expensive off the shelf, their efficient energy use and longer lifetimes mean that they cost less in the long run.

3. Use smart power strips

“Phantom loads,” or the electricity used by electronics when they are turned off or in standby mode, are a major source of energy waste. In fact, it is estimated that 75% of the energy used to power household electronics is consumed when they are switched off, which can cost you up to $200 per year. Smart power strips, also known as advanced power strips, eliminate the problem of phantom loads by shutting off the power to electronics when they are not in use. Smart power strips can be set to turn off at an assigned time, during a period of inactivity, through remote switches, or based on the status of a “master” device.

4. Install a programmable or smart thermostat

A programmable thermostat can be set to automatically turn off or reduce heating and cooling during the times when you are asleep or away. When you install a programmable thermostat, you eliminate wasteful energy use from heating and cooling without upgrading your HVAC system.

On average, a programmable thermostat can save you $180 per year. Programmable thermostats come in different models that can be set to fit your weekly schedule. Additional features of programmable thermostats can include indicators for when to replace air filters or HVAC system problems, which also improve the efficiency of your heating and cooling system.

5. Purchase energy efficient appliances

On average, appliances are responsible for roughly 13% of total household energy use. When purchasing an appliance, you should pay attention to two numbers: the initial purchase price and the annual operating cost. Although energy efficient appliances might have higher upfront purchase prices, their operating costs are often 9-25% lower than conventional models.

When purchasing an energy efficient appliance, you should look for appliances with the ENERGY STAR label, which is a federal guarantee that the appliance will consume less energy during use and when on standby than standard models. Energy savings differ based on the specific appliance. For example, ENERGY STAR certified clothes washers consume 25% less energy and 45% less water than conventional ones, whereas ENERGY STAR refrigerators use only 9% less energy.

6. Reduce your water heating expenses

Water heating is a major contributor to your total energy consumption. Other than purchasing an energy efficient water heater, there are three methods of reducing your water heating expenses:

you can simply use less hot water, turn down the thermostat on your water heater, or insulate your water heater and the first six feet of hot and cold water pipes.

If you are considering replacing your water heater with an efficient model, you should keep in mind two factors: the type of water heater that meets your needs and the type of fuel it will use. For example, tankless water heaters are energy efficient, but they are also a poor choice for large families as they cannot handle multiple and simultaneous uses of hot water. Efficient water heaters can be anywhere between 8% and 300% more energy efficient than a conventional storage water heater.

7. Install energy efficient windows

Windows are significant source of energy waste - they can add up to 10-25% of your total heating bill. To prevent heat loss through your windows, you can replace single-pane windows with double-pane products instead.

For homes in colder regions, gas-filled windows with "low-e" coatings can significantly reduce your heating expenses. In addition, interior or exterior storm windows can reduce unnecessary heat loss by 10 to 20 percent. You should especially consider storm windows if your region experiences frequent extreme weather events.

In warmer climates, heat gain through windows may be a problem. In addition to minimizing heat loss, low-e coatings on windows can reduce heat gain by reflecting more light and lowering the amount of thermal energy that enters your home. Depending on where you live, ENERGY STAR windows can save you $20-$95 each year on your utility bills. Window shades, shutters, screens, and awnings can also provide an extra layer of insulation between your home and outside temperatures.

8. Upgrade your HVAC system

An HVAC system is composed of heating, ventilation, and air conditioning equipment. Heating alone is responsible for more than 40% of home energy use. Because homes in Northern regions are exposed to much colder temperatures during the year, ENERGY STAR gas furnaces have different specifications in the northern and southern halves of the United States.

Upgrading to a "U.S. South" ENERGY STAR certification can save you up to 12% on your heating bill, or an average of $36 per year. ENERGY STAR furnaces in the northern half of the U.S. are labeled with the standard ENERGY STAR logo and are up to 16% more energy efficient than baseline models. This translates to average savings of $94 per year on your heating bill in the Northern U.S.

Air conditioning, by comparison, isn't a significant contributor to energy bills – on average, it only makes up six percent of the total energy use of your home. ENERGY STAR central air conditioning units are eight percent more efficient than conventional models. Air conditioning systems are usually integrated with heating systems, which means that you should purchase your new furnace and air conditioner at the same time in order to ensure that the air conditioner performs at its maximum rated energy efficiency.

Upgrades to the third component of an HVAC system – ventilation – can also improve your energy efficiency. A ventilation system is composed of a network of ducts, which distributes hot and cold air throughout your home. If these ducts are not properly sealed or insulated, the resulting energy waste can add hundreds of dollars to your annual heating and cooling expenses. Proper insulation and maintenance on your ventilation system can reduce your heating and cooling expenses by up to 20%.

9. Weatherize your home

Weatherizing, or sealing air leaks around your home, is a great way to reduce your heating and cooling expenses. The most common sources of air leaks into your home are vents, windows, and doors. To prevent these leaks, you should ensure that there are no cracks or openings between the wall and vent, window, or doorframe.

To seal air leaks between stationary objects, such as the wall and window frame, you can apply caulk. For cracks between moving objects, such as operable windows and doors, you can apply weather stripping. Weather stripping and caulking are simple air sealing techniques that typically offer a return on investment in less than a year. Air leaks can also occur through openings in the wall, floor, and ceiling from plumbing, ducting, or electrical wiring.

Air leaking out of your home is most often from the home interior into your attic through small openings. Whether it is through ducts, light fixtures, or the attic hatch, hot air will rise and escape through small openings. As the natural flow of heat is from warmer to cooler areas, these small openings can make your heating bill even higher if your attic is not sufficiently insulated. To reap the full amount of savings from weatherization, you should consider fully insulating your home.

10. Insulate your home

Insulation plays a key role in lowering your utility bills through retaining heat during the winter and keeping heat out of your home during the summer. The recommended level of heat resistance, or "R-value," for your insulation depends on where you live. In warmer climates, the recommended R-value is much lower than for buildings located in colder regions like the Northeast.

The level of insulation you should install depends on the area of your house. Your attic, walls, floors, basement, and crawlspace are the five main areas where you should consider adding insulation. Use the Home Energy Saver tool for recommendations based on the specifications of your home, or find general regional recommendations on the Department of Energy's webpage on insulation.

Energy Management Database

Concept

- Green Aware developed their Energy Management Database so companies could manage their energy programmes more effectively and monitor their progress and gain valuable feedback from the staff.
- The database has a wide variety of uses, allowing companies to manage their energy meetings, maintain their facilities and give their staff a platform to raise energy ideas.

Benefits of Green Aware Energy Management Database (EMD)

- It cannot be over stated how much a well planned energy programme requires the backing from senior management to the staff on the floor.
- EMD enables companies to monitor/track and drive their energy programme.
- Giving energy managers the ability to manage their energy team meetings creates a close loop process. Meaning no task is missed and all meeting minutes are recorded at the touch of a button.
- By giving staff the opportunity to raise energy ideas, a company will see its energy programme grow from strength to strength as staff feel part of the company energy programme.
- By empowering staff to raise energy ideas they will continue to raise more ideas, as staff will see a result for their efforts.
- Making energy awareness instinctive in a company.
- EMD is a WEB based system, which means it is accessible to all either in the "home" or at "work"

How does it work?

- Access to our Energy Management Database is via our website.
- Organisations must nominate a manager who will have full control over the system.
- The manager will have permissions to provide access to employees (per licence agreement).
- Managers have the ability to create meetings (agenda, minutes and tasks).

- Employees have the ability to view meetings and raise energy ideas against the manager.

Applications Areas

- There are many areas the Green Aware Energy Management Database can be applied.
    - Energy Meetings
    - Energy Ideas
    - Facilities Management
- Most company's energy programmes vary and the system can be tailored to suit individual criteria.

Unique System Application

- We believe that the best available practices are sometimes overlooked by companies.
- Organisations using our Energy Management Database will be able to learn from other organisations across different spectrums of businesses/organisation

Reporting applications

- Company energy managers will have the ability to export their company ideas & meeting tasks into excel at a click of a button.

DATA BASE MANAGEMENT SYSTEM

Database Management System or **DBMS** in short refers to the technology of storing and retrieving users' **data** with utmost efficiency along with appropriate security measures. **DBMS** allows its users to create their own **databases** as per their requirement. These **databases** are highly configurable and offer a bunch of options.

A **database** is an organized collection of **data**, generally stored and accessed electronically from a computer **system**. ... The **database management system** (**DBMS**) is the software that interacts with end users, applications, and the **database** itself to capture and analyze the **data**.

Four Types of DBMS systems are:

- Hierarchical database.
- Network database.
- **Relational database**.
- **Object-Oriented database**.

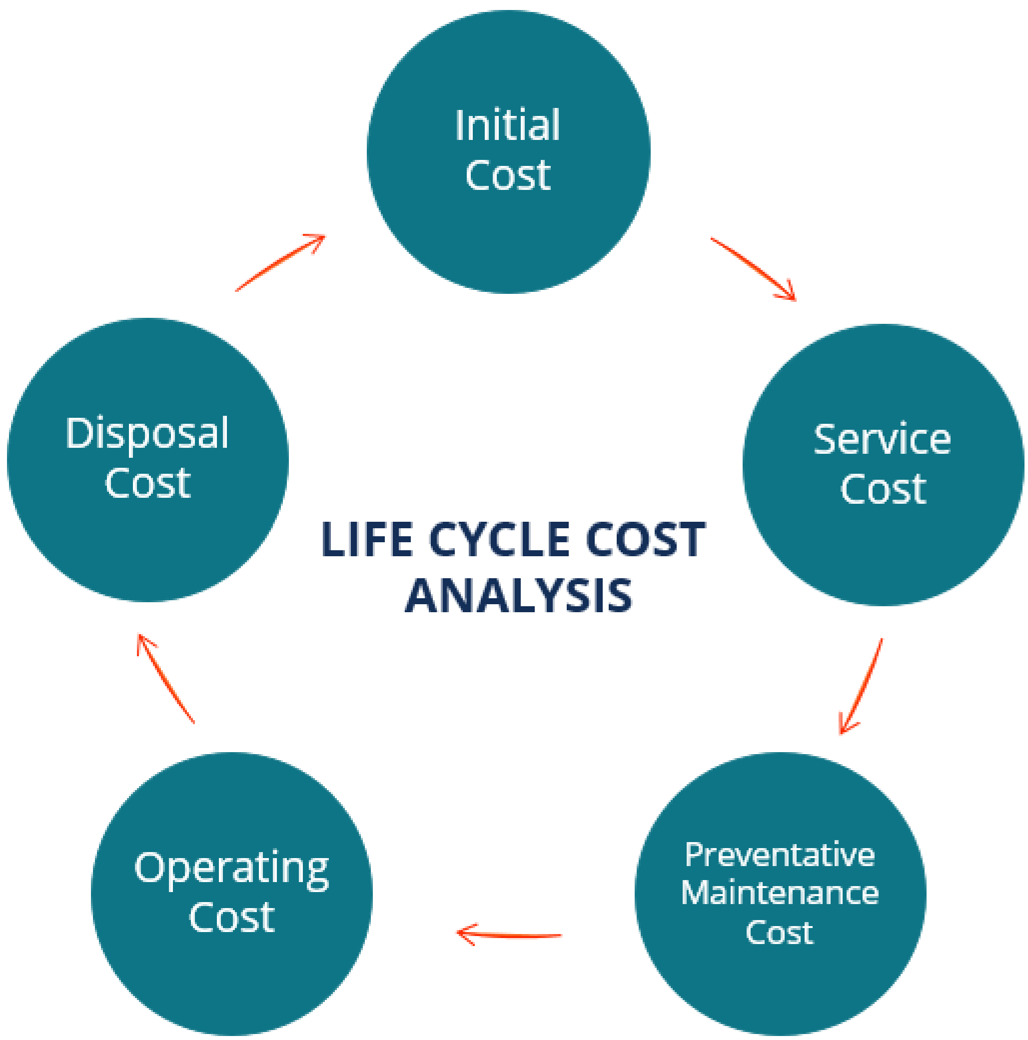
The ten functions in the DBMS are: data dictionary management, data storage management, data transformation and presentation, **security management**, **multiuser access control**, backup and recovery management, data integrity management, database access languages and application programming interfaces, database communication .

A **Database Management** Software (DBMS) is used for storing, manipulating, and managing data, such as format, names of fields, and record and file structures in a **database**. Users can construct their own **databases** using a DBMS to satisfy their business requirements.

What is Life Cycle Cost Analysis?

Life Cycle Costing (LCC) is an important **economic analysis** used in the selection of alternatives that impact both pending and future costs. It compares initial investment options and identifies the least **cost** alternatives for a twenty year period.

Life cycle cost analysis (LCCA) is an approach used to assess the total cost of owning a facility or running a project. LCCA considers all the costs associated with obtaining, owning, and disposing of an investment.



Life cycle cost analysis is especially useful where a project comes with multiple alternatives and all of them meet performance necessities, but they differ with regards to the initial, as well as the operating, cost. In this case, the alternatives are compared to find one that can maximize savings.

For example, LCCA helps to determine which of the two alternatives will raise the initial cost but will reduce the operating cost. However, LCCA should not be used for the purpose of budget allocation.

Understanding Life Cycle Cost Analysis

Life cycle cost analysis is ideal for estimating the overall cost of a project's alternatives. It is also used to choose the right design to ensure that the chosen alternative will offer a lower overall ownership cost that is consistent with function and quality.

LCCA needs to be performed during the initial stages of the design process, as there is room to make changes and refinements that will ensure that the life cycle cost is reduced. The first step when performing an LCCA is determining the economic impact of the alternatives available. The effects are then quantified and expressed in monetary terms.

Costs

Various costs arise when procuring, operating, or disposing of a project. Project-related costs can be classified into initial costs, fuel costs, replacement costs, operation and maintenance costs, finance charges, and residual values.

Only relevant and significant costs in each of the categories above can be used to make investment-related decisions. Costs are considered significant when they are substantial enough to cause a dependable impact on a project's LCC.

All the costs involved are treated as base year values equivalent to present-day dollar amounts; LCCA transforms all dollar values into future year occurrence equivalents and then discounts all the values to their base dates. In such a way, it's easy to find their present value.

Life Cycle Cost Analysis for Infrastructure

Life cycle cost analysis can be used to assess different infrastructural sectors such as rail and urban transport, airports, highways, and ITS, as well as ports and industrial infrastructure. Such kinds of projects make use of capital expenditure, which is the initial cost involved when constructing or delivering an infrastructural asset. Simply put, it is the cost of construction for the infrastructure of choice.

The other thing that is important in infrastructural development is operating expense, which consists of a number of costs, including utility, manpower, insurance, equipment, health, and routine and planned repairs.

Replacement costs are incurred every cycle based on the predefined age of replacement for different assets and the manufacturer's preference.

Probably another important element of LCCA is disposal cost. When the disposal cost is incorporated, it is possible to offset any additional cost incurred during a particular year.

LCCA and Value Engineering

Rigorous modeling based on LCCA incorporates value engineering so that a project's cost outline can lower expenditures by a huge margin. The procedures are done through a series of tests on the cost of operation.

Modeling using LCCA requires a lot of flexibility when adjusting the types of costs associated with materials and assets used in a project over its lifetime. That way, a developer can access all the information relating to the financial impact connected with choosing a combination of project options.

LCCA and the Choice of Materials or Assets

Value engineering offers the potential to assist developers in choosing the right material and assets. Since a material or asset may come with a unique specification with regards to maintenance and the cost of acquisition, their overall characteristics will not be the same.

For example, the most expensive asset may provide superior performance and quality but will require a significant amount of maintenance. On the other hand, a cheaper material or asset may require less regular maintenance, but its overall cost is significantly lower.

Further simulation can be carried out to ascertain the timing of financial responsibilities in the different phases of an asset's useful life. Using LCCA in the right way can help users identify development groupings that can lead to favorable timing of financial exposure.

By using LCCA when carrying out tests, comparisons, and analyses, a user can work out enhanced development arrangements for infrastructural projects that offer a favorable financial experience and cost profile.

Final Word

Life cycle cost analysis offers a general framework that can be used to assess the need for additional costs during a project's useful life. With such knowledge in mind, it is possible to regulate cash outflows by forecasting requirements of a project.

Life-Cycle Cost Analysis (LCCA)

Life-cycle cost analysis (LCCA) is a method for assessing the total cost of facility ownership. It takes into account all costs of acquiring, owning, and disposing of a building or building system. LCCA is especially useful when project alternatives that fulfill the same performance requirements, but differ with respect to initial costs and operating costs, have to be compared in order to select the one that maximizes net savings. For example, LCCA will help determine whether the incorporation of a high-performance HVAC or glazing system, which may increase initial cost but result in dramatically reduced operating and maintenance costs, is cost-effective or not. LCCA is not useful for budget allocation.

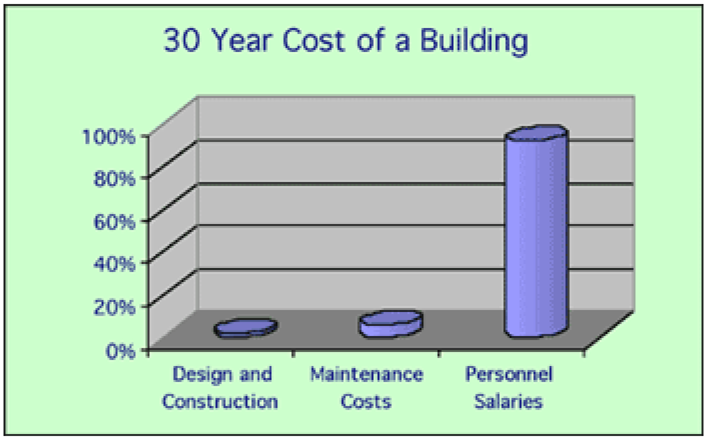
Lowest life-cycle cost (LCC) is the most straightforward and easy-to-interpret measure of economic evaluation. Some other commonly used measures are Net Savings (or Net Benefits), Savings-to-Investment Ratio (or Savings Benefit-to-Cost Ratio), Internal Rate of Return, and Payback Period. They are consistent with the Lowest LCC measure of evaluation if they use the same parameters and length of study period. Building economists, certified value specialists, cost engineers, architects, quantity surveyors, operations researchers, and others might use any or several of these techniques to evaluate a project. The approach to making cost-effective choices for building-related projects can be quite similar whether it is called cost estimating, value engineering, or economic analysis.

DESCRIPTION

A. Life-Cycle Cost Analysis (LCCA) Method

The purpose of an LCCA is to estimate the overall costs of project alternatives and to select the design that ensures the facility will provide the lowest overall cost of ownership consistent with its quality and function. The LCCA should be performed early in the design process while there is still a chance to refine the design to ensure a reduction in life-cycle costs (LCC).

The first and most challenging task of an LCCA, or any economic evaluation method, is to determine the economic effects of alternative designs of buildings and building systems and to quantify these effects and express them in dollar amounts.



Viewed over a 30 year period, initial building costs account for approximately just 2% of the total, while operations and maintenance costs equal 6%, and personnel costs equal 92%.

B. Costs

There are numerous costs associated with acquiring, operating, maintaining, and disposing of a building or building system. Building-related costs usually fall into the following categories:

- Initial Costs—Purchase, Acquisition, Construction Costs
- Fuel Costs
- Operation, Maintenance, and Repair Costs
- Replacement Costs
- Residual Values—Resale or Salvage Values or Disposal Costs
- Finance Charges—Loan Interest Payments
- Non-Monetary Benefits or Costs

Only those costs within each category that are relevant to the decision and significant in amount are needed to make a valid investment decision. Costs are relevant when they are different for one alternative compared with another; costs are significant when they are large enough to make a credible difference in the LCC of a project alternative. All costs are entered as base-year amounts in today's dollars; the LCCA method escalates all amounts to their future year of occurrence and discounts them back to the base date to convert them to present values.

INITIAL COSTS

Initial costs may include capital investment costs for land acquisition, construction, or renovation and for the equipment needed to operate a facility.

Land acquisition costs need to be included in the initial cost estimate if they differ among design alternatives. This would be the case, for example, when comparing the cost of renovating an existing facility with new construction on purchased land.

Construction costs: Detailed estimates of construction costs are not necessary for preliminary economic analyses of alternative building designs or systems. Such estimates are usually not available until the design is quite advanced and the opportunity for cost-reducing design changes has been missed. LCCA can be repeated throughout the design process if more detailed cost information becomes available. Initially, construction costs are estimated by reference to historical data from similar facilities. Alternately, they can be determined from government or private-sector cost estimating guides and databases. The Tri-Services Parametric Estimating System (TPES) developed models of different facility types by determining the critical cost parameters (i.e., number of floors, area and volume, perimeter length) and relating these values through algebraic formulas to predict costs of a wide range of building systems, subsystems, and assemblies.

Detailed cost estimates are prepared at the submittal stages of design (typically at 30%, 60%, and 90%) based on quantity take-off calculations. These estimates rely on cost databases such as the *Commercial Unit Price Book (C-UPB)* or the *R. S. Means Building Construction Cost Database*.

Testing organizations such as ASTM International and trade organizations have reference data for materials and products they test or represent.

ENERGY AND WATER COSTS

Operational expenses for energy, water, and other utilities are based on consumption, current rates, and price projections. Because energy, and to some extent water consumption, and building configuration and building envelope are interdependent, energy and water costs are usually assessed for the building as a whole rather than for individual building systems or components.

Energy usage: Energy costs are often difficult to predict accurately in the design phase of a project. Assumptions must be made about use profiles, occupancy rates, and schedules, all of which impact energy consumption. At the initial design stage, data on the amount of energy consumption for a building can come from engineering analysis or from a computer program such as eQuest. EnergyPlus™ (DOE) and DOE-2 require more detailed input not usually available until later in the design process. Other software packages, such as the proprietary programs TRACE (Trane), ESPRE (EPRI), and HAP (Carrier) have been developed to assist in mechanical equipment selection and sizing and are often distributed by manufacturers.

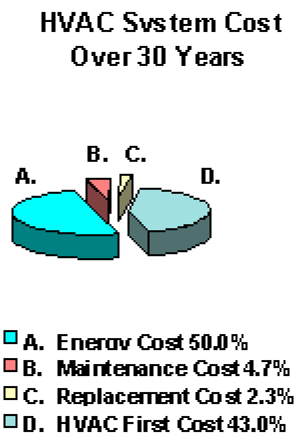
When selecting a program, it is important to consider whether you need annual, monthly, or hourly energy consumption figures and whether the program adequately tracks savings in energy consumption when design changes or different efficiency levels are simulated.

Energy prices: Quotes of current energy prices from local suppliers should take into account the rate type, the rate structure, summer and winter differentials, block rates, and demand charges to obtain an estimate as close as possible to the actual energy cost.

Energy price projections: Energy prices are assumed to increase or decrease at a rate different from general price inflation. This differential energy price escalation needs to be taken into account when estimating future energy costs. Energy price projections can be obtained either from the supplier or from energy price escalation rates published annually on April 1 by DOE in *Discount Factors for Life-Cycle Cost Analysis, Annual Supplement to NIST Handbook 135*.

Water Costs: Water costs should be handled much like energy costs. There are usually two types of water costs: water usage costs and water disposal costs. DOE does not publish water price projections.

OPERATION, MAINTENANCE, AND REPAIR COSTS



Courtesy of Washington State Department of General Administration

Non-fuel operating costs, and maintenance and repair (OM&R) costs are often more difficult to estimate than other building expenditures. Operating schedules and standards of maintenance vary from building to building; there is great variation in these costs even for buildings of the same type and age. It is therefore especially important to use engineering judgment when estimating these costs.

Supplier quotes and published estimating guides sometimes provide information on maintenance and repair costs. Some of the data estimation guides derive cost data from statistical relationships of historical data (Means, BOMA) and report, for example, average owning and operating costs per square foot, by age of building, geographic location, number of stories, and number of square feet in the building. The Whitestone Research Facility Maintenance and Repair Cost Reference gives annualized costs for building systems and elements as well as service life estimates for specific building components. The U.S. Army Corps of Engineers, Huntsville Division, provides access to a customized OM&R database for military construction.

REPLACEMENT COSTS

The number and timing of capital replacements of building systems depend on the estimated life of the system and the length of the study period. Use the same sources that provide cost estimates for initial investments to obtain estimates of replacement costs and expected useful lives. A good starting point for estimating future replacement costs is to use their cost as of the base date. The LCCA method will escalate base-year amounts to their future time of occurrence.

RESIDUAL VALUES

The residual value of a system (or component) is its remaining value at the end of the study period, or at the time it is replaced during the study period. Residual values can be based on value in place, resale value, salvage value, or scrap value, net of any selling, conversion, or disposal costs. As a rule of thumb, the residual value of a system with remaining useful life in place can be calculated by linearly prorating its initial costs. For example, for a system with an expected useful life of 15 years, which was installed

5 years before the end of the study period, the residual value would be approximately 2/3 (=(15-10)/15) of its initial cost.

OTHER COSTS

Finance charges and taxes: For federal projects, finance charges are usually not relevant. Finance charges and other payments apply, however, if a project is financed through an Energy Savings Performance Contract (ESPC) or Utility Energy Services Contract (UESC). The finance charges are usually included in the contract payments negotiated with the Energy Service Company (ESCO) or the utility.

Non-monetary benefits or costs: Non-monetary benefits or costs are project-related effects for which there is no objective way of assigning a dollar value. Examples of non-monetary effects may be the benefit derived from a particularly quiet HVAC system or from an expected, but hard-to-quantify productivity gain due to improved lighting. By their nature, these effects are external to the LCCA, but if they are significant they should be considered in the final investment decision and included in the project documentation. See Cost-Effective—Consider Non-Monetary Benefits Such as Aesthetics, Historic Preservation, Security, and Safety.

To formalize the inclusion of non-monetary costs or benefits in your decision making, you can use the analytical hierarchy process (AHP), which is one of a set of multi-attribute decision analysis (MADA) methods that consider non-monetary attributes (qualitative and quantitative) in addition to common economic evaluation measures when evaluating project alternatives. ASTM E 1765 *Standard Practice for Applying Analytical Hierarchy Process (AHP) to Multiattribute Decision Analysis of Investments Related to Projects, Products, and Processes* published by ASTM International presents a procedure for calculating and interpreting AHP scores of a project's total overall desirability when making building-related capital investment decisions. A source of information for estimating productivity costs, for example, is the WBDG Productive Branch.

C. Parameters for Present-Value Analysis

DISCOUNT RATE

In order to be able to add and compare cash flows that are incurred at different times during the life cycle of a project, they have to be made time-equivalent. To make cash flows time-equivalent, the LCC method converts them to present values by discounting them to a common point in time, usually the base date. The interest rate used for discounting is a rate that reflects an investor's opportunity cost of money over time, meaning that an investor wants to achieve a return at least as high as that of her next best investment. Hence, the discount rate represents the investor's minimum acceptable rate of return.

The discount rate for federal energy and water conservation projects is determined annually by FEMP; for other federal projects, those not primarily concerned with energy or water conservation, the discount rate is determined by The Office of Management Budget. These discount rates are real discount rates, not including the general rate of inflation.

COST PERIOD(S)

Length of study period: The study period begins with the base date, the date to which all cash flows are discounted. The study period includes any planning/construction/implementation period and the service or occupancy period. The study period has to be the same for all alternatives considered.
Service period: The service period begins when the completed building is occupied or when a system is taken into service. This is the period over which operational costs and benefits are evaluated. In FEMP analyses, the service period is limited to 40 years.
Contract period: The contract period in ESPC and UESC projects lies within the study period. It starts when the project is formally accepted, energy savings begin to accrue, and contract payments begin to be due. The contract period generally ends when the loan is paid off.

DISCOUNTING CONVENTION

In OMB and FEMP studies, all annually recurring cash flows (e.g., operational costs) are discounted from the end of the year in which they are incurred; in MILCON studies they are discounted from the middle of the year. All single amounts (e.g., replacement costs, residual values) are discounted from their dates of occurrence.

TREATMENT OF INFLATION

An LCCA can be performed in constant dollars or current dollars. Constant-dollar analyses exclude the rate of general inflation, and current-dollar analyses include the rate of general inflation in all dollar amounts, discount rates, and price escalation rates. Both types of calculation result in identical present-value life-cycle costs.
Constant-dollar analysis is recommended for all federal projects, except for projects financed by the private sector (ESPC, UESC). The constant-dollar method has the advantage of not requiring an estimate of the rate of inflation for the years in the study period. Alternative financing studies are usually performed in current dollars if the analyst wants to compare contract payments with actual operational or energy cost savings from year to year.

D. Life-Cycle Cost Calculation

After identifying all costs by year and amount and discounting them to present value, they are added to arrive at total life-cycle costs for each alternative:

$$LCC = I + Repl - Res + E + W + OM\&R + O$$

LCC = Total LCC in present-value (PV) dollars of a given alternative
I = PV investment costs (if incurred at base date, they need not be discounted)
Repl = PV capital replacement costs
Res = PV residual value (resale value, salvage value) less disposal costs
E = PV of energy costs
W = PV of water costs

OM&R = PV of non-fuel operating, maintenance and repair costs
O = PV of other costs (e.g., contract costs for ESPCs or UESCs)

E. Supplementary Measures

Supplementary measures of economic evaluation are Net Savings (NS), Savings-to-Investment Ratio (SIR), Adjusted Internal Rate of Return (AIRR), and Simple Payback (SPB) or Discounted Payback (DPB). They are sometimes needed to meet specific regulatory requirements. For example, the FEMP LCC rules (10 C.F.R. § 436, Subpart A) require the use of either the SIR or AIRR for ranking independent projects competing for limited funding. Some federal programs require a Payback Period to be computed as a screening measure in project evaluation. NS, SIR, and AIRR are consistent with the lowest LCC of an alternative if computed and applied correctly, with the same time-adjusted input values and assumptions. Payback measures, either SPB or DPB, are only consistent with LCCA if they are calculated over the entire study period, not only for the years of the payback period.

All supplementary measures are relative measures, i.e., they are computed for an alternative relative to a base case.

NS = Net Savings: operational savings less difference in capital investment costs

SIR = Savings-to-Investment Ratio: ratio of operational savings to difference in capital investment costs
AIRR = Adjusted Internal Rate of Return: annual yield from an alternative over the study period, taking into account reinvestment of interim returns at the discount rate
SPB = Simple Payback: time required for the cumulative savings from an alternative to recover its initial investment cost and other accrued costs, without taking into account the time value of money
DPB = Discounted Payback: time required for the cumulative savings from an alternative to recover its initial investment cost and other accrued costs, taking into account the time value of money

F. Evaluation Criteria

Lowest LCC (for determining cost-effectiveness)
NS > 0 (for determining cost-effectiveness)
SIR > 1 (for ranking projects)
AIRR > discount rate (for ranking projects)
SPB, DPB < than study period (for screening projects)

G. Uncertainty Assessment In Life-Cycle Cost Analysis

Decisions about building-related investments typically involve a great deal of uncertainty about their costs and potential savings. Performing an LCCA greatly increases the likelihood of choosing a project that saves money in the long run. Yet, there may still be some uncertainty associated with the LCC results. LCCAs are usually performed early in the design process when only estimates of costs and savings are available, rather than certain dollar amounts. Uncertainty in input values means that actual outcomes may differ from estimated outcomes.

There are techniques for estimating the cost of choosing the "wrong" project alternative. Deterministic techniques, such as sensitivity analysis or breakeven analysis, are easily done without requiring additional resources or information. They produce a single-point estimate of how uncertain input data affect the analysis outcome. Probabilistic techniques, on the other hand, quantify risk exposure by deriving probabilities of achieving different values of economic worth from probability distributions for input values that are uncertain. However, they have greater informational and technical requirements than do deterministic techniques. Whether one or the other technique is chosen depends on factors such as the size of the project, its importance, and the resources available. Since sensitivity analysis and break-even analysis are two approaches that are simple to perform, they should be part of every LCCA.

SENSITIVITY ANALYSIS

Sensitivity analysis is the technique recommended for energy and water conservation projects by FEMP. Sensitivity analysis is useful for:

- identifying which of a number of uncertain input values has the greatest impact on a specific measure of economic evaluation,
- determining how variability in the input value affects the range of a measure of economic evaluation, and
- testing different scenarios to answer "what if" questions.

To identify critical parameters, arrive at estimates of upper and lower bounds, or answer "what if" questions, simply change the value of each input up or down, holding all others constant, and recalculate the economic measure to be tested.

BREAK-EVEN ANALYSIS

Decision-makers sometimes want to know the maximum cost of an input that will allow the project to still break even, or conversely, what minimum benefit a project can produce and still cover the cost of the investment.

To perform a break-even analysis, benefits and costs are set equal, all variables are specified, and the break-even variable is solved algebraically.

Sensitivity analysis and break-even analysis, and a number of other approaches to risk and uncertainty assessment, both deterministic and probabilistic, are described in detail in *Techniques for Treating Uncertainty and Risk in the Economic Evaluation of Building Investments* , by Harold Marshall, NIST Special Publication 757, September 1988.

H. Design And Analysis Tools

The use of computer programs can considerably reduce the time and effort spent on formulating the LCCA, performing the computations, and documenting the study. Listed below are several LCCA-related software programs:

- Building Life-Cycle Cost (BLCC) Program—Economic analysis tool developed by the National Institute of Standards and Technology for the U.S. Department of Energy Federal Energy Management Program (FEMP).

APPLICATION

LCCA can be applied to any capital investment decision in which relatively higher initial costs are traded for reduced future cost obligations. It is particularly suitable for the evaluation of building design alternatives that satisfy a required level of building performance but may have different initial investment costs, different operating and maintenance and repair costs, and possibly different lives. LCCA provides a significantly better assessment of the long-term cost-effectiveness of a project than alternative economic methods that focus only on first costs or on operating-related costs in the short run.

LCCA was among the many design and analysis tools used to transform this turn of the century building located in downtown Tacoma, WA into an energy efficient showcase building.Courtesy of Washington State Department of General Administration

LCCA can be performed at various levels of complexity. Its scope might vary from a "back-of-the-envelope" study to a detailed analysis with thoroughly researched input data, supplementary measures of economic evaluation, complex uncertainty assessment, and extensive documentation. The extensiveness of the effort should be tailored to the needs of the project.

Assignment
UNIT - II
Energy Management
BME - 56

Q.1. Define the term energy audit and what is the need of Energy audit.

Q.2. Write down the different method and classification of Energy audit and Explain each of them.

Q. 3. Define ~~the~~ and Explain Energy Audit Methodology for different types of energy audits.

Q. 4. Draw the process flow diagram and Explain it for a plant manufacturing.

Q. 5. Write down the Name of different instruments which are used in energy audit and Explain the working of Each

Q. 6 Elaborate about Energy audit team

Q. 7. Draw an energy flow chart and Explain it.

Q.8. Explain the I^{st} Law and 2^{nd} Law of thermodynamics and what is the role of these laws in Energy audit Explain.

Q.9. Discuss about the Mass and Energy balances.

Q.10. Define and Explain the following terms :-

(i). Exergy (ii) Anergy

Q.11. ~~Def~~ Derive the formula for availability for a Heat Engine which is operating between source temperature T_1 and Sink temperature T_2.

Q.12. prove that with the heat transfer through temperature difference, the availability decreases.

Q.13. Give the classification of energy Conservation measures and explain each of them.

Q.14. What kind of energy conservation opportunities are identified after carrying out the energy audit.

Q.15. What are the different energy conserva-tion areas auditing a plant or building, we get Explain it.

Q.16. What are the different methods of energy storage, Explain each of them by mentioning merits, demerits and applications.

Q.17. How the energy is transmit in different energy sources, explain.

Q.18. Explain data base for energy Management.