Electrical Energy Conservation and Auditing

By

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Module II: (12 Hours)

Electrical energy audit: Energy consumption pattern and scenario of any region; Energy auditing: Need, types, methodology and approaches; Preliminary energy audit methodology (initial site visit and preparation required for detailed auditing, detailed energy audit activities, information and data collection, process flow diagram and process steps); Procedure and techniques: Data gathering, evaluation of saving opportunities, and energy audit reporting; and Energy audit instruments.

2.0 Introduction

- Energy is one of the major input for the development of any country
- Energy can be classified into several types based on the following criteria
    - Primary and Secondary Energy
    - Commercial and Non Commercial Energy
    - Renewable and Non Renewable Energy

Primary and Secondary Energy

- Primary Energy refers to all type of energy extracted or captured directly from natural resource
- Primary Energy further divided into two groups
    - Renewable (Solar, Wind, Geothermal, Tidal, Biomas, etc)
    - Non Renewable (Fossile Fules, Cruide Oil, Coal, NaturalGas, etc)
- All Fuels generally expressed in terms of toe (tonne of oil equivalent) and is based the following conversion factor

toe= 10x106 Kcal=11630kwh=41870MJ

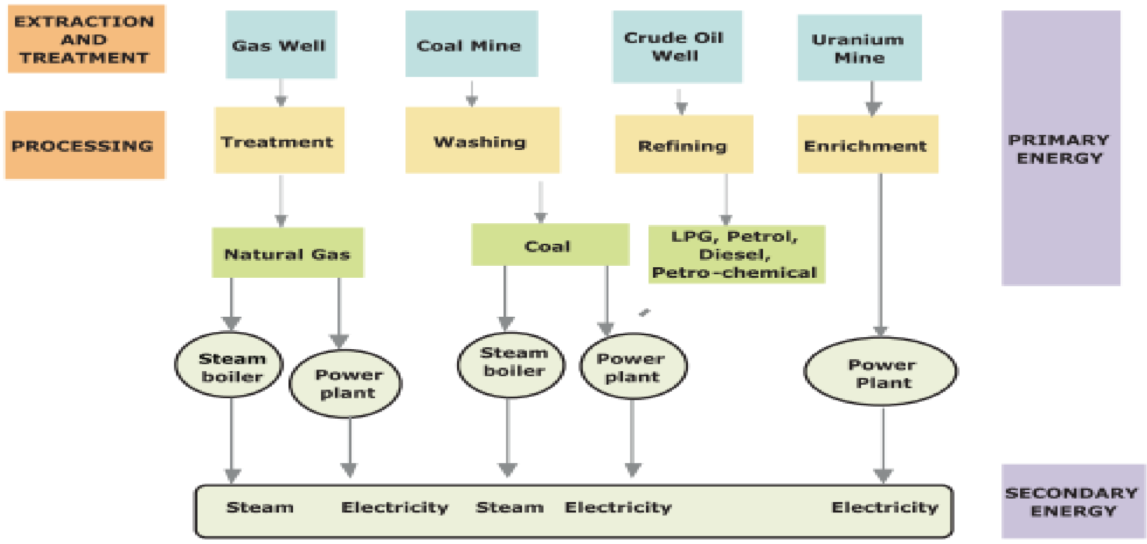


Figure 1.1 Major Primary and Secondary Energy Sources

Commercial and Non Commercial Energy

Commercial Energy

- The energy sources that are available in the market for a definite price are known as commercial energy.
- Examples: Electricity, lignite, coal, oil, natural gas etc.

Non-Commercial Energy

- The energy sources that are not available in the commercial market for a price are classified as non-commercial energy.
- Example: Firewood, agro waste in rural areas

Renewable and Non-Renewable Energy

- Renewable energy is energy obtained from sources that are essentially inexhaustible.
- Examples of renewable resources include wind power, solar power, geothermal energy, tidal power and hydroelectric power (See Figure 1.2).
- The most important feature of renewable energy is that it can be harnessed without the release of harmful pollutants.
- Non-renewable energy is the conventional fossil fuels such as coal, oil and gas, which are likely to deplete with time.

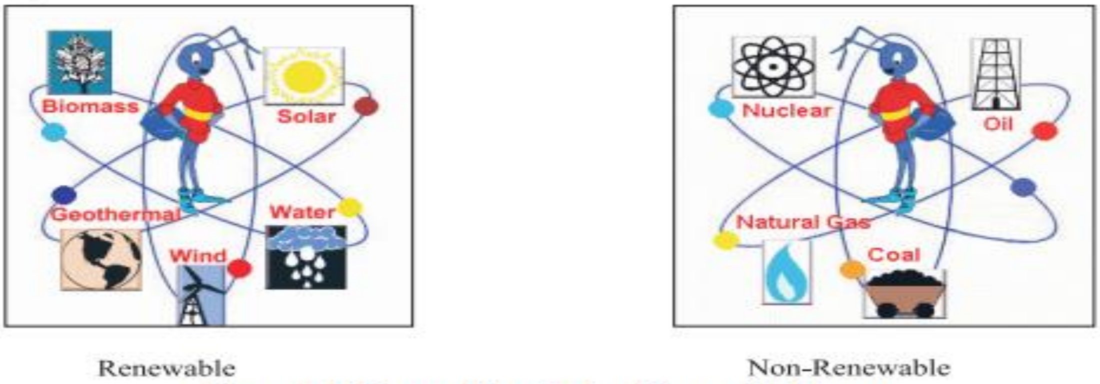


Figure 1.2 Renewable and Non-Renewable Energy

2.1 Energy consumption pattern and scenario of any region;

2.1.0 Global Primary Energy Reserves*

Coal

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

Oil

The global proven oil reserve was estimated to be 1147 billion barrels by the end of 2003. Saudi Arabia had the largest share of the reserve with almost 23%. (One barrel of oil is approximately 160 litres)

Gas

The global proven gas reserve was estimated to be 176 trillion cubic metres by the end of 2003. The Russian Federation had the largest share of the reserve with almost 27%. (*Source: BP Statistical Review of World Energy, June 2004)

2.1.1 Global Primary Energy Consumption:

The global primary energy consumption at the end of 2003 was equivalent to 9741 million tonnes of oil equivalent (Mtoe).

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

TABLE 1.1 PRIMARY ENERGY CONSUMPTION BY FUEL, 2003						
In Million tonnes oil equivalent						
Country	Oil	Natural Gas	Coal	Nuclear Energy	Hydro electric	Total
USA	914.3	566.8	573.9	181.9	60.9	2297.8
Canada	96.4	78.7	31.0	16.8	68.6	291.4
France	94.2	39.4	12.4	99.8	14.8	260.6
Russian Federation	124.7	365.2	111.3	34.0	35.6	670.8
United Kingdom	76.8	85.7	39.1	20.1	1.3	223.2
China	275.2	29.5	799.7	9.8	64.0	1178.3
India	113.3	27.1	185.3	4.1	15.6	345.3
Japan	248.7	68.9	112.2	52.2	22.8	504.8
Malaysia	23.9	25.6	3.2	-	1.7	54.4
Pakistan	17.0	19.0	2.7	0.4	5.6	44.8
Singapore	34.1	4.8	-	-	-	38.9
TOTAL WORLD	3636.6	2331.9	2578.4	598.8	595.4	9741.1

2.1.2 Indian Energy Scenario

Coal dominates the energy mix in India, contributing to 55% of the total primary energy production. Over the years, there has been a marked increase in the share of natural gas in primary energy production from 10% in 1994 to 13% in 1999. There has been a decline in the share of oil in primary energy production from 20% to 17% during the same period.

Energy Supply

Coal Supply

India has huge coal reserves, at least 84,396 million tonnes of proven recoverable reserves (at the end of 2003). This amounts to almost 8.6% of the world reserves and it may last for about 230 years at the current Reserve to Production (R/P) ratio. In contrast, the world's proven coal reserves are expected to last only for 192 years at the current R/P ratio.

Reserves/Production (R/P) ratio- If the reserves remaining at the end of the year are divided by the production in that year, the result is the length of time that the remaining reserves would last if production were to continue at that level. India is the fourth largest producer of coal and lignite in the world. Coal production is concentrated in these states (Andhra Pradesh, Uttar Pradesh, Bihar, Madhya Pradesh, Maharashtra, Orissa, Jharkhand, West Bengal).

Oil Supply

Oil accounts for about 36 % of India's total energy consumption. India today is one of the top ten oil-guzzling nations in the world and will soon overtake Korea as the third largest consumer of oil in Asia after China and Japan. The country's annual crude oil production is peaked at about 32 million tonne as against the current peak demand of about 110 million tonne. In the current scenario, India's oil consumption by end of 2007 is expected to reach 136 million tonne(MT), of which domestic production will be only 34 MT. India will have to pay an oil bill of roughly $50 billion, assuming a weighted average price of $50 per barrel of crude. In 2003- 04, against total export of $64 billion, oil imports accounted for $21 billion. India imports 70% of its crude needs mainly from gulf nations. The majority of India's roughly 5.4 billion barrels in oil reserves are located in the Bombay High, upper Assam, Cambay, Krishna-Godavari. In terms of sector wise petroleum product consumption, transport accounts for 42% followed by domestic and industry with 24% and 24% respectively. India spent more than Rs.1,10,000 crore on oil imports at the end of 2004.

The ever rising import bill

Year	Quantity (MMT)	Value (Rs Crore)
1996-97	33.90	18,337
1997-98	34.49	15,872
1998-99	39.81	19,907
1999-00	57.80	40,028
2000-01	74.10	65,932
2001-02	84.90	80116
2002-03	90	85,042
2003-04	95	93,159
*2004-05	100	1,30,000

* Estimated

Source: Ministry of Petroleum and Natural Gas

Natural Gas

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

Electrical Energy Supply

The all India installed capacity of electric power generating stations under utilities was 1,12,581 MW as on 31st May 2004, consisting of 28,860 MW- hydro, 77,931 MW - thermal and 2,720 MW- nuclear and 1,869 MW- wind (Ministry of Power). The gross generation of power in the year 2002-2003 stood at 531 billion units (kWh).

Nuclear Power Supply

Nuclear Power contributes to about 2.4 per cent of electricity generated in India. India has ten nuclear power reactors at five nuclear power stations producing electricity. More nuclear reactors have also been approved for construction.

Hydro Power Supply

India is endowed with a vast and viable hydro potential for power generation of which only 15% has been harnessed so far. The share of hydropower in the country's total generated units has steadily decreased and it presently stands at 25% as on 31st May 2004. It is assessed that exploitable potential at 60% load factor is 84,000 MW.

Final Energy Consumption

Final energy consumption is the actual energy demand at the user end. This is the difference between primary energy consumption and the losses that takes place in transport, transmission & distribution and refinement. The actual final energy consumption (past and projected) is given in Table 1.2.

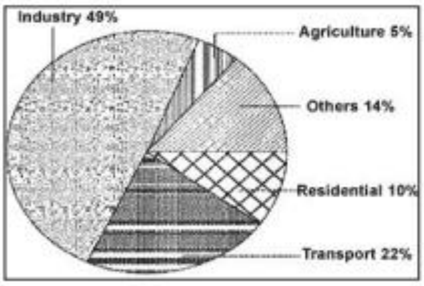
TABLE 1.2 DEMAND FOR COMMERCIAL ENERGY FOR FINAL CONSUMPTION (BAU SCENARIO)

Source	Units	1994-95	2001-02	2006-07	2011-12
Electricity	Billion Units	289.36	480.08	712.67	1067.88
Coal	Million Tonnes	76.67	109.01	134.99	173.47
Lignite	Million Tonnes	4.85	11.69	16.02	19.70
Natural Gas	Million Cubic Meters	9880	15730	18291	20853
Oil Products	Million Tonnes	63.55	99.89	139.95	196.47

Source: Planning Commission *BAU:_Business As Usual*

Sector Wise Energy Consumption in India

The major commercial energy consuming sectors in the country are classified as shown in the Figure 1.5. As seen from the figure, industry remains the biggest consumer of commercial energy and its share in the overall consumption is 49%. (Reference year: 1999/2000)



2.2 Energy Audit: Nee, Types and Methodology:

Energy Audit is the key to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial energy audit is an effective tool in defining and pursuing comprehensive energy management programme. As per the Energy Conservation Act, 2001, Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption".

2.2.0 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.

2.2.1Type of Energy Audit:

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 two types.

i) **Preliminary Audit**

ii) **Targeted Audit**

iii) **Detailed Audit**

2.2.2 Preliminary Energy Audit Methodology:

Preliminary energy audit is a relatively quick exercise to:

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

2.2.3 Targeted Energy Audit Methodology:

- Targeted energy audits often results from preliminary audits.
- They provide data and detailed analysis on specified target project.
- For example an Organization may target its light system or boiler system or steam system or compressed air system with a view of effecting energy savings.
- Targeted audits therefore involved detailed survey of the target subjects and analysis of the energy flows and cost associated with the targets.
- Final outcome is the recommendations regarding action to be taken.

2.2.4 Detailed Energy Audit Methodology:

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

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

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

Detailed energy auditing is carried out in three phases: Phase I, II and III.

Phase I - Pre Audit Phase

Phase II - Audit Phase

Phase III - Post Audit Phase

A Guide for Conducting Energy Audit at a Glance

Industry-to-industry, the methodology of Energy Audits needs to be flexible.

A comprehensive ten-step methodology for conduct of Energy Audit at field level is pre- sented below. Energy Manager and Energy Auditor may follow these steps to start with and add/change as per their needs and industry types.

Ten Steps Methodology for Detailed Energy Audit

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

		- Boiler/Efficiency trials for (4 – 8 hours) - Furnace Efficiency trials Equipments Performance experiments etc
Step6	• Analysis of energy use	• Energy and Material balance & energy loss/waste analysis
Step 7	• Identification and development of Energy Conservation (ENCON) opportunities	• Identification & Consolidation ENCON measures • Conceive, develop, and refine ideas • Review the previous ideas suggested by unit personal • Review the previous ideas suggested by energy audit if any • Use brainstorming and value analysis techniques • Contact vendors for new/efficient technology
Step 8	• Cost benefit analysis	• Assess technical feasibility, economic viability and prioritization of ENCON options for implementation • Select the most promising projects • Prioritise by low, medium, long term measures
Step9	• Reporting Identification and the Top Management	• Documentation, Report Presentation to the top Management.
	<u>Phase III –Post Audit phase</u>	
Step10	• Implementation and Follow-up	Assist and Implement ENCON recommendation measures and Monitor the performance • Action plan, Schedule for implementation • Follow-up and periodic review

Phase I -Pre Audit Phase Activities

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

Initial Site Visit and Preparation Required for Detailed Auditing

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

During the initial site visit the Energy Auditor/Engineer should carry out the following actions: -

• Discuss with the site's senior management the aims of the energy audit.

• Discuss economic guidelines associated with the recommendations of the audit.

• Analyse the major energy consumption data with the relevant personnel.

• Obtain site drawings where available - building layout, steam distribution, compressed air distribution, electricity distribution etc.

• Tour the site accompanied by engineering/production

The main aims of this visit are: -

• To finalise Energy Audit team
• To identify the main energy consuming areas/plant items to be surveyed during the audit.
• To identify any existing instrumentation/ additional metering required.
• To decide whether any meters will have to be installed prior to the audit eg. 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 (eg.compressed air, steam).
6. Sources of energy supply (e.g. electricity from the grid or self-generation)
7. Potential for fuel substitution, process modifications, and the use of co-generation systems (combined heat and power generation).
8. Energy Management procedures and energy awareness training programs within the establishment.

Existing baseline information and reports are useful to get consumption pattern, production cost and productivity levels in terms of product per raw material inputs. The audit team should collect the following baseline data:
- Technology, processes used and equipment details
- Capacity utilisation - Amount & type of input materials used
- Water consumption
- Fuel Consumption
- Electrical energy consumption
- Steam consumption
- Other inputs such as compressed air, cooling water etc
- Quantity & type of wastes generated
- Percentage rejection / reprocessing
- Efficiencies / yield

DATA COLLECTION HINTS

It is important to plan additional data gathering carefully. Here are some basic tips to avoid wasting time and effort:
• Measurement systems should be easy to use and provide the information to the accuracy that is needed, not the accuracy that is technically possible
• Measurement equipment can be inexpensive (flow rates using a bucket and stopwatch)
• The quality of the data must be such that the correct conclusions are drawn (what grade of prod uct 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 exchang er)

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

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

Example: A flowchart of Penicillin-G manufacturing is given in the figure3.1 below. Note that waste stream (Mycelium) and obvious energy wastes such as condensate drained and steam leakages have been identified in this flow chart

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

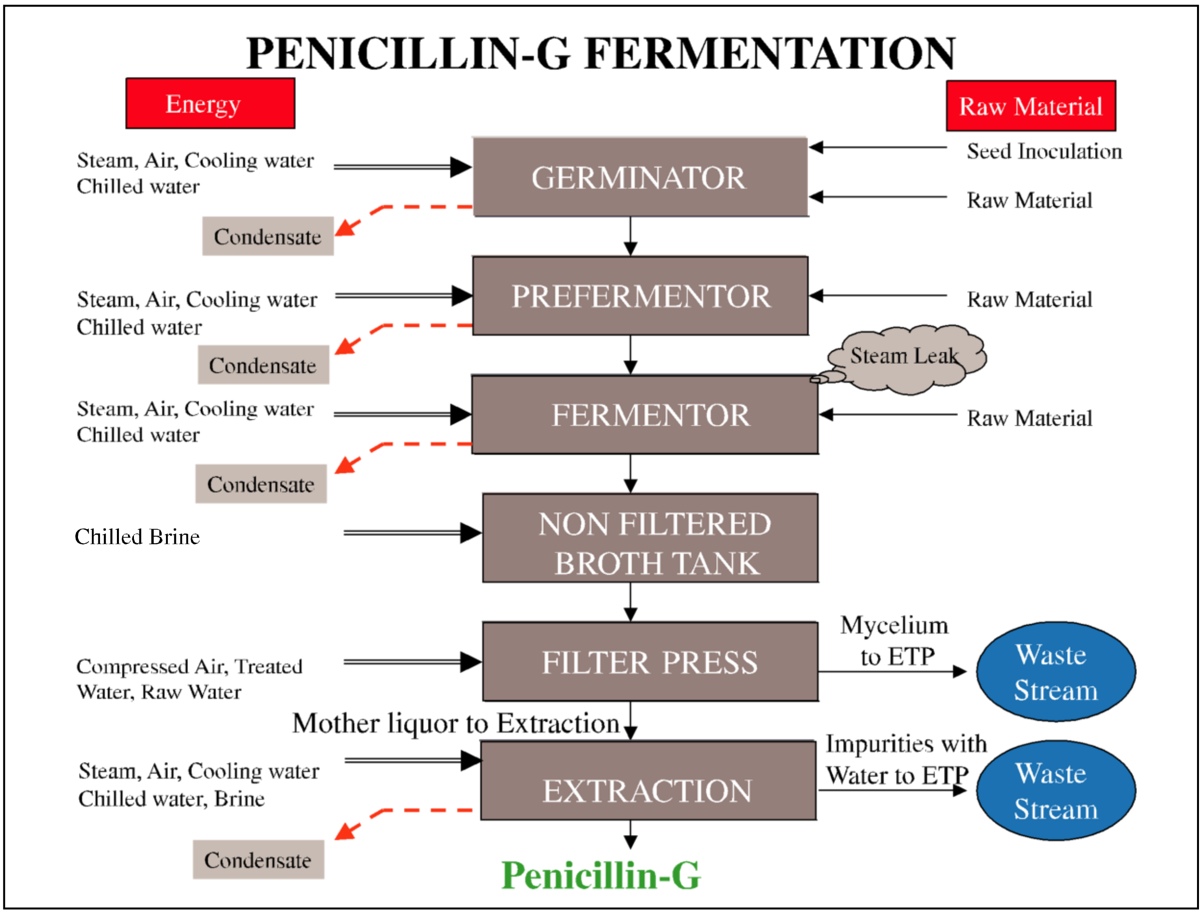


Figure 2.1

2.3 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

4.0 Detailed Process flow diagram and Energy& Material balance

4.1 Flow chart showing flow rate, temperature, pressures of all input-output streams

4.2 Water balance for entire industry

5.0 Energy efficiency in utility and process systems

5.1 Specific Energy consumption

5.2 Boiler efficiency assessment

5.3 Thermic Fluid Heater performance assessment

5.4 Furnace efficiency Analysis

5.5 Cooling water system performance assessment

5.6 DG set performance assessment

5.7 Refrigeration system performance

5.8 Compressed air system performance

5.9 Electric motor load analysis

5.10 Lighting system

6.0 Energy Conservation Options & Recommendations

6.1 List of options in terms of No cost/ Low Cost, Medium cost and high investment Cost, Annual Energy & Cost savings, and payback

6.2 Implementation plan for energy saving measures/Projects

ANNEXURE

A1. List of Energy Audit Worksheets

A2. List of instruments

A3. List of Vendors and Other Technical details

The following Worksheets (refer Table 3.2 & Table 3.3) can be used as guidance for energy audit assessment and reporting.

TABLE 3.2 SUMMARY OF ENERGY SAVING RECOMMENDATIONS					
S.No.	Energy Saving Recommendations	Annual Energy (Fuel & Electricity) Savings (kWh/MT or kl/MT)	Annual Savings Rs.Lakhs	Capital Investment (Rs.Lakhs)	Simple Payback period
1					
2					
3					
4					
Total					

TABLE 3.3 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			

Table 4.4 Reporting Format for Energy Conservation Recommendations		
A: Title of Recommendation	:	**Combine DG set cooling tower with main cooling tower**
B: Description of Existing System and its Operation	:	Main cooling tower is operating with 30% of its capacity. The rated cooling water flow is 5000 m^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
Temperature across cooling tower (operating)	=	4 °C
% loading of main cooling tower	=	(3000 x 4)/(5000 x 8) = 30%
Capacity of DG Set cooling tower	=	240 m^3/hr
Temp across the tower	=	5°C
Heat Load (240x1000 x 1x 5)	=	1200,000 kCal/hr
Power drawn by the DG set cooling tower		
No of pumps and its rating	=	2 Nos x 7.5 kW
No of fans and its rating	=	2 Nos x 22 kW
Power consumption@ 80% load	=	(22 x2 +7.5 x2) x.80 = 47 kW
Additional power required for main cooling tower for additional water flow of 240m^3/h (66.67 l/s) with 6 kg/cm^2	=	(66.67 x 6) / (102 x 0.55) = 7 kW
Net Energy Savings	=	47 – 7 = 40 kW
E: Cost Benefits		
Annual Energy Saving Potential	=	40 kWx 8400hr = 3,36,000 Units/Year
Annual Cost Savings	=	3,36,000 xRs.4.00 = Rs.13.4 Lakh per year
Investment (Only cost of piping)	=	Rs 1.5Lakhs
Simple Payback Period	=	**Less than 2 months**

Phase III - Post Audit Phase

On completion of energy audit, energy action plan should be prepared. The energy action plan list the ENCONs which should be implemented first, and suggest an overall implementations schedule. Energy audit is incomplete without monitoring and its associated feedback. Monitoring consists of collecting and interpreting data. The data to be collected depends upon goals chosen in the energy action plan. Electrical power consumption and fuel consumption must be evaluated and monitored.

The monitoring data should provide direct feedback to those most able to implement the changes. Often additional instruments should be installed in various departments in addition to main meeting.

Monitoring should result in more action. Good practices should be replicated. If the gap between planned objectives and actual achievement in large, reasons should be analysed and new objectives, new action should be installed and result should be monitored. In this way, analysis, action and monitoring are a cycle process.

3.4 Energy Audit Instruments

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

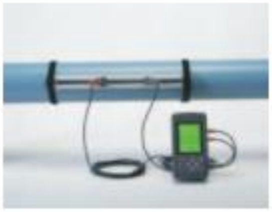
Basic Electrical Parameters in AC &DC systems - Voltage (V), Current (I), Power factor, Active power (kW), apparent power (demand) (kVA), Reactive power (kVAr), Energy consumption (kWh), Frequency (Hz), Harmonics, etc.

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

 	**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 flue gas. Calorific values of common fuels are fed into the microprocessor which calculates the combustion efficiency.
	**Fyrite:** A hand bellow pump draws the flue gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. A separate fyrite can be used for O_2 and CO_2 measurement.

	**Contact thermometer:** These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature, a leaf type probe is used with the same instrument.
	**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 / Ultra sonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter.

 Tachometer	 Stroboscope	**Speed Measurements:** In any audit exercise speed measurements are critical as thay 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.