



ENERGY AUDIT MANUAL



Energy Management Centre - Kerala
Department of Power, Government of Kerala



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Web reference		
: www.bee-india.nic.in		
: www.energymanagertraining.com		
: www.keralaenergy.gov.in		



1. Introduction

This Energy Audit Manual has been prepared as a guideline document to Energy Audit Report and be an aid to those carrying out energy audits. This Energy Audit manual takes Energy Audit framework and fleshes it out for specific applications. It is both an interpretive guide and a benchmark of current best practice. Energy audits undertaken following the guidance of this Manual should assist energy auditors to produce a result that is technically accurate and complete as well as being of maximum use to the client. The Energy Audit Manual also aims to provide technical references that are commonly needed during an energy audit. The manual is intended to provide most of the reference information needed for a typical energy audit. Materials has been liberally drawn from Bureau of Energy Efficiency (BEE) and National Productivity Council (NPC) documents. A draft copy of the manual was published and hosted for five months (April 2011 – August 2011) in the website of Energy Management Centre -Kerala and communicated with Certified Energy Auditors (CEA) / Certified Energy Managers (CEM) and other stake holders for suggestions and comments. A presentation and detailed brainstorming discussions was carried in a panel comprising of Executive committee members of Energy Management Centre, and representative from Department of Power, Department of Environment & Climate Change, Agency for Non-Conventional Energy and Rural Technology (ANERT) Public works department ,Factories and Boilers, Kerala State Electricity Board, and educational institutions on 3rd September 2011. The points emerged from the meeting were included and the draft manual was modified accordingly.

2. Background

Since the earth summit, and the emergence of Agenda 21, as its pivotal and substantial outcome, energy as a sector and a component, got identified as the corner stone and balancing factor in the process of environment-development interaction, which decides the status and nature of sustainable development. It has also got accepted by the political leaderships of the world governments that to mold a development process, which is econo-ecologically sustainable, the management of energy for achieving the maximum end-use benefits and efficiency which include increased use of renewable energy resources as development priority. Further, at a time when economic growth, employment opportunities and balance of payment scenarios are negatively affected due increase in energy price in the developing and third world countries, and carbon dioxide and other energy consumption induced green house gases are increasing globally, especially due to heavy energy consumption in the developed countries, comprehensive management of energy becomes a priority of all the countries.

India, the most affected country in terms of energy shortage and increasing energy price become one of the first countries in the developing world to adopt energy management measures in all sectors of the economy on a priority basis, including promotion and popularization of renewable energy technology and resources. With liberalization and globalization of economy, energy management aimed at enhancing total energy efficiency in all sectors of the economy will become a major factor in determining the comprehensive competitiveness of the economy.

3. Scope

The manual provides technical references, some "how-to" information (how to produce a good energy balance, for example) and a guide on the expertise that should be sought for different applications. It was not the intention for this manual to provide a comprehensive list of savings opportunities, but rather to identify those opportunities that commonly occur. The Energy Audit Manual also provides references as to where detailed technical information can be found on these and on less common opportunities. The Energy Audit Manual is not intended to break new ground, but rather to collate and summarise existing information sources and in particular the individual experiences. These experiences can be quite different from those of energy auditors.

4. Audience of the Energy Audit Manual

The primary audience for this manual will be energy auditors with some experience who wish to advance and consolidate their capabilities in energy auditing. While not the primary focus, a secondary audience will be those wishing to become energy auditors, along with energy service providers and others who may engage the services of an energy auditor. It is expected that an energy auditor using this manual will, at the least, have a background of engineering knowledge and a certain level of experience. However, the manual would be of value to energy managers in that it indicates in a section on energy management how an energy audit can fit into an energy management programme. Energy Management Programmes Energy audits and the ensuing cost and energy saving opportunities identified in audits are best implemented in the context of an energy management programme that operates, and is formally recognized, as an integral part of the ongoing management activities of the entity for which it applies. For this reason one important function of an energy audit is to evaluate the energy management programme and suggest ways in which it could be improved. An energy audit should provide much of the essential information to progress an energy management programme and action. It should summarise key energy use and cost indices, provide a breakdown of where energy is used and give a table of recommended actions. An energy audit will also assist with preparing an Action Plan. The energy audit aspects of the energy management process include determining the level of detail (high, mid-range and detailed) that an energy auditor will appraise when an audit is carried out, as well as the extent of any recommendations arising from the audit process.

5. ENERGY AUDITING

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”.

5.1 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.

5.2 Type 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) Detailed Audit

5.2.1 Preliminary Energy Audit Methodology

Preliminary energy audit is a relatively quick exercise to:

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

5.2.2 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 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

5.3 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 presented below. Energy Manager and Energy Auditor may follow these steps to start with and add/change as per their needs and industry types

5.4 Ten Steps Methodology for Detailed Energy Audit:

Step No	PLAN OF ACTION	PURPOSE / RESULTS
Step 1	<u>Phase I –Pre Audit Phase</u> <ul style="list-style-type: none"> Plan and organise Walk through Audit Informal Interview with Energy Manager, Production / Plant Manager 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Conduct of brief meeting / awareness programme with all divisional heads and persons concerned (2-3 hrs.) 	<ul style="list-style-type: none"> Building up cooperation Issue questionnaire for each department Orientation, awareness creation
Step 3	<u>Phase II –Audit Phase</u> <ul style="list-style-type: none"> Primary data gathering, Process Flow Diagram, & Energy Utility Diagram 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Conduct survey and 	<ul style="list-style-type: none"> Measurements :



	monitoring	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	<ul style="list-style-type: none"> Conduct of detailed trials /experiments for selected energy guzzlers 	<ul style="list-style-type: none"> Trials/Experiments: <ul style="list-style-type: none"> 24 hours power monitoring (MD, PF, kWh etc.). Load variations trends in pumps, fan Boiler/Efficiency trials for (4 – 8 hours) Furnace Efficiency trials Equipments Performance experiments etc
Step6	<ul style="list-style-type: none"> Analysis of energy use 	<ul style="list-style-type: none"> Energy and Material balance & energy loss/waste analysis
Step 7	<ul style="list-style-type: none"> Identification and development of Energy Conservation (ENCON) opportunities 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Cost benefit analysis 	<ul style="list-style-type: none"> 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	<ul style="list-style-type: none"> Reporting & Presentation to the Top Management 	<ul style="list-style-type: none"> Documentation, Report Presentation to the top Management.
Step10	<p><u>Phase III –Post Audit phase</u></p> <ul style="list-style-type: none"> Implementation and Follow-up 	<p>Assist and Implement ENCON recommendation measures and Monitor the performance</p> <ul style="list-style-type: none"> Action plan, Schedule for implementation Follow-up and periodic review

5.4.1 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

5.4.2 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 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)

***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.

5.4.3 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.

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 analyzed, 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.

5.4.4 AUDIT REPORT

5.4.4.1 Carryout Detailed Analysis and Evaluation

Often, the limited time for on-site audit activities does not allow the auditors to carry out a detailed analysis of the energy audit information. Remember the on-site audit costs issue. At this point in the process, the data collected during the general and diagnostic audits are used to calculate the amounts of energy used in, and lost from, equipment and systems. By calculating the value of this energy, the auditors produce more accurate estimates of the savings to be expected from an energy project. Analysis of the energy surveys will indicate the energy services with the most potential for immediate improvement. A cost-benefit analysis based on future energy costs will show the merit of each potential improvement and help to set priorities. The least complicated approach to evaluating a potential energy project is to calculate the project's simple payback – that is, the installed costs of the project divided by the annual savings it produces. The result is a figure that represents the number of years it will take for the accumulated savings from the project to equal the cost.

Energy intensity ratios (i.e. energy used per unit of output) should be calculated quarterly or monthly for the entire plant, every operating department and each significant process. The energy intensity ratio will also indicate unfavourable energy consumption trends. In other words, this process lays the foundation for a systematic energy management approach.

5.4.4.2 Formulate Conclusions and Recommendations, Write a Draft of the Audit Report, and Review the Draft with the Auditee's Representative

At this point in the audit process, the selection of ESO's can be confirmed and finalized, with proper cost-benefit evaluations. The audit conclusions and recommendations can now be firmed up and a final report can be drafted. The content of the report should be shared with, and agreed on, by the Auditee's representative – for the same reasons that were stated earlier in the context of the closing meeting.

5.5 REPORT ON DETAILED ENERGY AUDIT

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Energy Audit Options at a glance & Recommendations

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5.7 Refrigeration system performance

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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 1 & Table 2) can be used as guidance for energy audit assessment and reporting.

Table 1. Summary of Energy Saving Recommendations

Sl.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 2. Types and Priority of Energy Saving Measures				
	Type of Energy Saving Options	Annual Electricity /Fuel savings KWH/MT or KL/MT	Annual Savings (Rs Lakhs)	Priority
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			

Finalize and Distribute the Audit Report

It is only at this point that the audit report can be finalized. Following that, it can be distributed to the client and the auditee, subject to previously received directives.

5.6 POST AUDIT ACTIVITIES – IMPLEMENTING ENERGY EFFICIENCY

The process of key importance – an energy audit – has been concluded. As soon as possible after the audit, the management team should review the results and decide on the course of action to be taken. At this point in the process, the facility is ready to act on ESOs and develop new operating scenarios. What follow then are the steps described previously in Section 4, “Setting up and running an effective energy management program”.

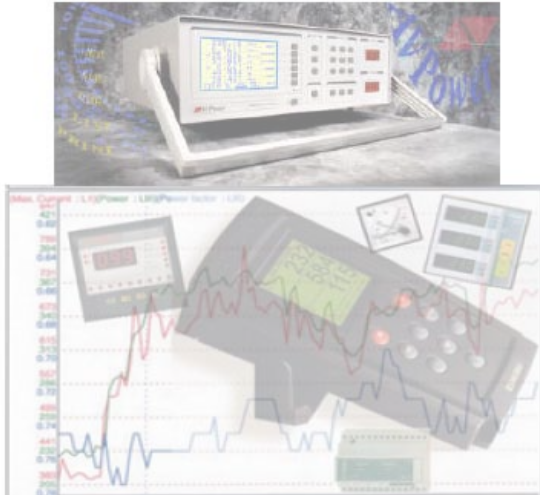




5.7 ENERGY AUDIT INSTRUMENTS







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, RPM, air velocity, noise and vibration, dust concentration, TDS, PH, moisture content, relative humidity, flue gas analysis – CO₂, O₂, 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.

	<p>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 online 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.</p>
	<p>Combustion analyzer: This instrument has in-built chemical cells which measure various gases such as O₂, CO, NO_x and SO_x.</p>
	<p>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.</p>
	<p>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 O₂ and CO₂ measurement.</p>
	<p>Contact thermometer: These are thermocouples, which measures for example flue gas, hot air, and hot water temperatures by insertion of probe into the stream. For surface temperature, a leaf type probe is used with the same instrument.</p>

	<p>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.</p>
	<p>Pitot Tube and manometer: Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows.</p>
	<p>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.</p>
	<p>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.</p>
	<p>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.</p>
	<p>Lux meters: Illumination levels are measured with a lux meter. It consists of a photocell, which senses the light output, converts to electrical impulses, which are calibrated as lux.</p>

6. ENERGY SAVING OPPORTUNITIES (ESO's)

6.1 Tariff Analysis:

Tariff analysis is a key process in carrying out an energy audit. Energy cost savings are achieved by reducing one, or both, of two main components:

1. The rate pay for energy (e.g. ₹/kWh and/or ₹/kVA), and
2. The amount of energy used (e.g. kWh and/or kVA).

This chapter focuses on the first component, which often provides cost saving opportunities at no capital cost.

6.2 Overview

Tariff analysis needs to be applied to all energy sources: electricity, Oil, gas (natural gas and LPG), diesel, coal, wood and other fuels used. An understanding of the fee structure for each energy source is essential for identifying where an energy audit should focus. It is important for determining what rates should be used in cost saving calculations. For example, the difference between gross and marginal costs of electricity needs to be analysed. In addition, tariff analysis of all fuels helps identify fuel switching opportunities.

Tariffs vary from energy source to energy source, supplier to supplier, and location to location in Kerala. For example, oil tends to be less expensive where it is reticulated compared with locations where it is supplied in bottles. Also, tariffs vary over time. Tariffs also for small users will almost always be different from those for large users of energy.

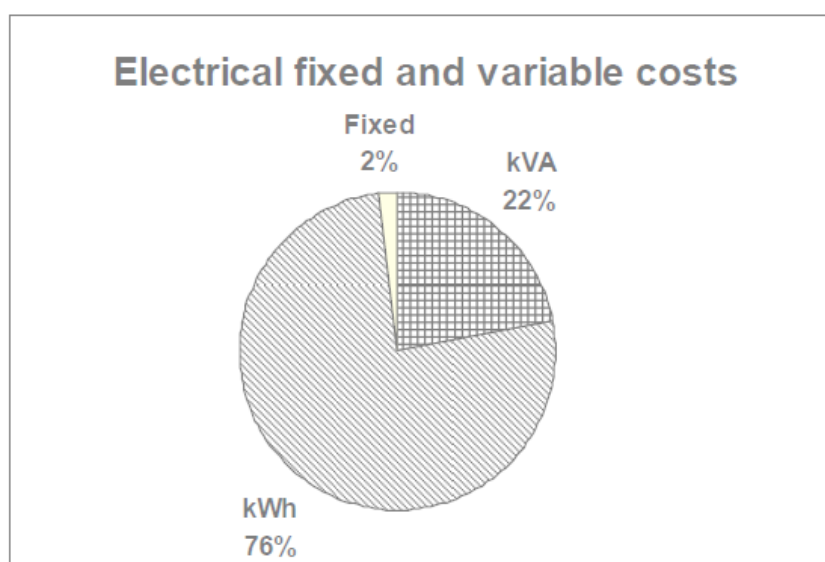
6.3 Electricity Tariffs

Electricity tariffs are the summation of network tariffs and supplier energy usage tariffs, and both can include fixed and variable charge components. Electricity tariffs vary by Network Company, electricity supplier, site management and type of electricity meter. At the industrial/commercial level, meters are often Time-Of-Day (TOD – tariff varies according to time of day) meters, but sometimes non-TOD meters are used. This usually occurs where the metered load is smaller.

6.4 Applying Tariff Analysis to Energy Audits

Tariff analysis is used in an energy audit to help calculate energy costs and savings accurately and to determine where emphasis should be focused in savings opportunities. For example, the energy auditor would usually focus on energy saving opportunities where a tariff structure is based mostly on ₹/kWh; whereas an energy auditor would put an equal amount of emphasis on reducing peak loads where the tariff had a significant peak load tariff. Some exceptions to this may occur; for example, in church electricity is only used for a short period each week resulting in the fixed tariff dominating the overall cost.

In the example below most (76%) of the electricity cost is a direct result of the kWh of electricity used. A significant proportion is based on maximum demand per half hour in terms of kVA (22%) and fixed charges are small (2%).



In this case, consideration should be focused initially on reducing consumption, with some cost saving opportunities also possible from reducing peak load kVA. All tariff variables should be presented to illustrate clearly how much effort should be put into different factors and fuels.

6.5 Savings Opportunities

Analysis of tariffs also needs to be undertaken to identify tariff cost saving opportunities. Energy use patterns need to be analysed and matched with all tariff options (including oil, gas and other fuels) available to determine what tariff will be most cost effective. This also needs to be done in combination with any likely



changes in energy use as a result of load growth or energy savings measures.

Analysis includes reviewing all factors that affect the tariff.

Factors to analyse in identifying tariff saving opportunities are:

- Energy use load patterns by day and year,
- Ability to load shift,
- Power factor at different loads,
- Fuel switching options, and
- All tariffs from all suppliers for all available fuels, e.g. electricity, coal,
- Diesel, gas, wood fuel, oil.

Power factor affects how much you pay for electricity if you use ToD meters and pay for kVA peaks or kVAR penalties. Often when power factor is less than 90%, particularly at peak load times, then correcting the power factor to above 90% usually provides an acceptable payback.

7. Energy Balance

Establishing an energy balance is an important part of a energy audit. It entails analysis of the site's energy use, identifying the sources of energy, determining the amount of energy supplied and detailing what the energy is used for. The analysis should identify important factors affecting energy use such as hours of operation and variations in loads during the day or year.

The process of producing an energy balance compares the amount of energy used in a year with the amount of theoretical energy the site should use (by calculation, usually of individual end uses). Where differences arise it can often lead to identifying areas of inefficiency.

7.1 Producing an Energy Balance:

An energy balance is a list of on-site equipment and a reconciliation of observed end-use and purchased energy. To reconcile energy use with energy purchased, all on-site items that use or produce energy should be listed with their normal (electricity, heat) power demand (or output) and typical "on" time schedule noted.

This data should be entered into a spreadsheet and the energy consumptions reconciled with metered data until a reasonable ($\pm 15\%$) balance is achieved with the observed day and night, winter and summer demands. If a 24-hour electrical use profile is developed it can then be compared with averaged TOD data.

Note that for gas and other fuels, their hour-by-hour use patterns are not normally available from metering data, so an average daily summer and winter balance is all that is usually attainable with these forms of energy.

An energy balance should be derived for all energy sources used at a site. This includes such energy sources as electricity, gas, diesel, coal and wood.

To complete an energy balance the amount of energy supplied is compared with the amount of energy being used by all energy end users. This should be done by obtaining the last 12 months of all energy invoices or other records to establish a total annual usage. Energy end users include, for example, boilers, refrigeration, lighting, HVAC, office equipment etc.

The process of comparing energy used / purchased with that consumed is usually iterative as indicated in the following steps:

1. Is kWh invoiced = kWh calculated?
2. If “Yes” or less than 5% difference then stop.
3. If “No” then review parameters and recalculate kWh calculated and return to Step “1”.

7.2 Energy Invoiced

The amount of energy purchased should be specified on each invoice. For electricity this is usually expressed in units of kWh. For other fuels such as coal or gas this may be expressed in units of MJ or GJ; or for coal in terms of tonnes or for wood in terms of cord or m³. Where different units are used they should be converted to a common unit such as kWh to make analysis comparable. In order to improve the accuracy of an energy balance a number of methods can be used in conjunction with the total energy invoiced:

- Analyse energy use per year for each energy type separately.
- Use sub meter energy information where available.
- Use energy use data logged from specific equipment or departments, considering how repeatable the logged data is, and how representative it is thought to be of annual usage.

7.3 Energy Calculated

To establish the calculated amount of energy being used it is necessary to document all on-site electrical and fuel-using items of equipment and their corresponding rated loads.

Refer to Table 7-1 below for an example of how energy supplied by heating fuels can be shown on a spreadsheet.

- * A solid measure, equivalent to cubic feet; a pile of wood, or other coarse material, eight feet long, four feet high, and four feet broad; originally measured with a cord or line.



Table 7-1 Energy Supplied by Heating Fuels

List of fuel using equipment by type and rating	A: Quantity	B: Heat load (kW)	C: Time operating at full load (hrs/year)	D: Total (AxBxC) (kWh/year)
Boilers				
Paint dryer				
TOTAL				

Refer Table 7-2 below for an example of how energy supplied by electricity can be shown on a spreadsheet.

Table 7-2 Energy Supplied by Electricity

List of fuel using equipment by type and rating	A: Quantity	B: Heat load (kW)	C: Time operating at full load (hrs/year)	D: Total (AxBxC) (kWh/year)
Lighting				
Fluorescent 36W(1.2m)				
Incandescent bulbs				
Compact fluorescent				
Halogen bulbs				
Office equipment				
Computers				
Printers				
Photocopiers				
Fax machines				
Total Electricity				

This approach is basic and suitable only for a small number of simple loads that operate at full capacity. Often equipment is not operating at rated power or full capacity nor is equipment operating at 100% efficiency. For example, some electric motors operate at 5% of rated power for most of the time and then reach 80% of rated power for a small amount of the time. Other examples are a boiler operating at 80% efficiency; heat pumps operating at 350% efficiency (in relation to their electrical input).

7.4 Heating/Cooling Plant

For heating technologies their efficiency values are used in combination with the calculated kWh, which is calculated based on the process demand for heat. For example, in a food cooking plant the thermal heat capacity of a product being cooked and the temperature it reaches needs to be calculated:

$$\begin{aligned} \text{kWh calculated} &= \text{kW heat demand} \times \text{Hours operating} / \text{Equipment efficiency} \\ &= \text{kWh heat demand} / \text{Equipment efficiency} \end{aligned}$$

$$\text{Where kWh heat demand} = \text{Thermal heat capacity (MJ/kg/o C)} \times \text{Product mass (kg/year)} \times \text{Temperature change (oC)} \times \text{kWh/MJ}$$

Table 7-3 below is an example of a more accurate approach for heating/cooling plant.

Table 7-3 Energy Supplied by Fuel (calculated from process outputs)

List of fuel equipment by type and rating	A: Qty	B: Efficiency (%)	C: Product mass or volume (kg or m3)	D: Product heat capacity (MJ/kg/oC)	E: Product temp. Change (oC)	F: Total (AxCx DxEx/BxkWh/MJ)(kWh/yr)
Boiler and distribution						
Paint dryer						
Total energy use						

Depending on the process, different calculations to that above may need to be made. For example, to use cooling thermal capacity in a cold store, or for timber drying use where an appropriate parameter such as GJ/m³ of timber dried could be used.

7.5 Electrical Equipment

For electrical technologies the hours of operation should be obtained from the operators or managers to ensure the most accurate calculations. For example, some equipment may only run eight hours a day during weekdays, and some may run all the time. The hours of operation affect the total energy use and may often be a factor in energy waste. Where actual hours of operation are unavailable they should be estimated. See Table 7-4.

Table 7-4 Energy Supplied by Electricity (calculated from motor outputs)

List of fuel equipment by type and rating	A: Qty	B: Efficiency (%)	C: Rated (output) load (kW)	D: Average operating load (% of rated capacity)	E: Time operating (hrs/yr)	F: Total (AxCx Dx E/B) (kWh/yr)
Motors						
Total electricity use						

Sometimes it is important to split the calculation table further by time of the week or time of the year if loads or times of operation vary between these periods.

In order to improve the accuracy of an energy balance a number of methods can be used when calculating energy use:

- Analyse energy use per hour for each energy type separately where possible
- Compare energy use per hour with load assumptions (which is useful to identify waste).
- Use energy use data logged hourly to test load assumptions.

It is also useful to indicate the reliability of the estimates used in the energy balance, e.g:

- A logged data from over six months time,
- B some logged data,
- C educated estimate based on observations, and
- D default assumption, from historical experience
- E wild guess, or value inserted to make the "balance".

7.6 Presenting an Energy Balance

Often an energy balance in an energy audit is presented as a pie chart illustrating the percentage of energy consumed by each technology type, e.g. boiler fuel 80%, boiler motors 2%, refrigeration 12%, lighting 4%, HVAC 1% and office equipment 1%.

Sometimes this may be presented separately for electricity and for other fuels where the energy use provided by one is significantly larger than the others. The tables or spreadsheets used to calculate the energy balance should be included in the energy audit report, preferably in an appendix. The energy auditor should also describe how

the energy balance is derived and specify key assumptions made. For example, “It is assumed that the water pumps operate for six months of the year only.”

7.7 Benchmarks and How to Use Them

Benchmarking involves establishing specific energy consumption by calculating an energy use index (EUI). The EUI is calculated by dividing energy use by a production or output parameter. The EUI can be calculated for annual, monthly or even daily energy use and production. These calculated EUIs are compared with benchmark EUIs from similar industries to evaluate whether the site being audited has a low, average or high energy use.

$EUI = \text{energy use/output parameter.}$

7.8 Determining Benchmarks

For manufacturing sites, monthly energy use will usually vary with production. Also, at times of low production or no production energy will normally still be used, such as for security lights, and this will increase the EUI.

It is therefore necessary to use another method to compare energy use with production by plotting energy use with production. This provides a more useful and accurate comparison.

Figure 7-1 below is a scatter diagram with each point representing one month’s energy use and production. The trend line shows the average energy usage for production.

The point for February corresponds to a month of low electricity use compared with production; while the points for September and December show a worse than average index corresponding to an increase in electricity use without any increase in production.

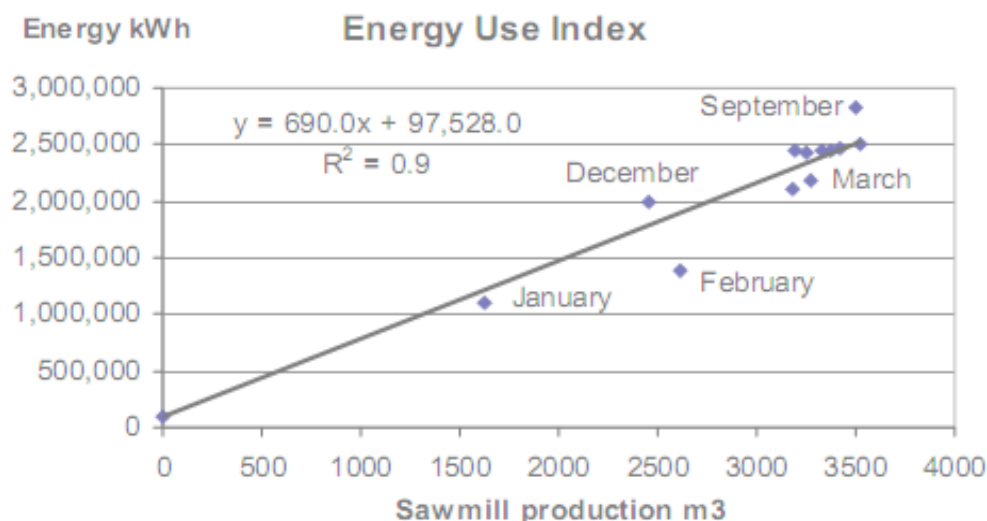


Figure 7-1 Energy Use versus Production

Where the line cuts the vertical axis represents the monthly “fixed” energy use that does not vary with production. This could be energy used for security lighting, which is on whether there is production or not, or could indicate inefficiencies, such as leaks in a compressed air system. In September, energy use was unusually high. By discussing this variance with the client an explanation may be provided and saving opportunities may be identified.

The EUI for this example is approximately 690kWh per cubic metre. The measure of correlation of the monthly energy used with production is represented by the R2 value. A value of 1.0 means there is complete correlation, while a value of 0 indicates that there is no correlation between output and production. A decision on investigating the variance should take into account the nature of the variability as well as the R2 value.

8. Energy Management

8.1 Definition & Objectives of Energy Management

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

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

Another comprehensive definition is

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

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

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

8.2 Principles of Energy Management

The principles of Energy Management involve the following:

- Procure all the energy needed at the lowest possible price (Example: buy from original sources, review the purchase terms)
- Manage energy use at the highest energy efficiency (Example: improving energy use efficiency at every stage of energy transport, distribution and use)
- Reusing and recycling energy by cascading (Example: waste heat recovery)
- Use the most appropriate technology (select low investment technology to meet the present requirement and environment condition)
- Reduce the avoidable losses. (Make use of wastes generated within the plant as sources of energy and reducing the component of purchased fuels and bills)

Energy should be viewed, as any other valuable raw material resource required running a business – not as mere overhead and part of business maintenance. Energy has costs and environmental impacts. They need to be managed well in order to increase the business' profitability and competitiveness and to mitigate the



seriousness of these impacts. All organizations can save energy by applying the same sound management principles and techniques they use elsewhere in the business for key resources such as raw materials and labour. These management practices must include full managerial accountability for energy use. The management of energy consumption and costs eliminates waste and brings in ongoing, cumulative savings.

8.3 Strategy Considerations

The purpose of this section is to convince upper management of the value of systematic energy management in achieving the organization's strategic objectives.

In essence, the strategic goal of most organisations is to gain a competitive advantage by seizing external and internal opportunities so as to improve the profitability of their operations, products and sales and their marketplace position. Developing a successful corporate strategy requires taking into account all of the influences on the organization's operation and integrating the various management functions into an efficiently working whole. Energy management should be one of these functions.

In the process, an organization may wish to first conduct a review of its strengths, weaknesses, opportunities and threats (SWOT analysis) that would also include various legal and environmental considerations (such as emissions, effluent, etc.).

Inevitably, this analysis would identify future threats to profitability, and ways to reduce costs should be sought. Energy efficiency improvement programs should, therefore, become an integral part of the corporate strategy to counter such threats. They will help to improve profit margins through energy savings. Applying good energy management practices is just as important to achieving these savings as the appropriate process technology. It should be remembered that any operational savings translate directly to bottom-line improvement, rupee for rupee.

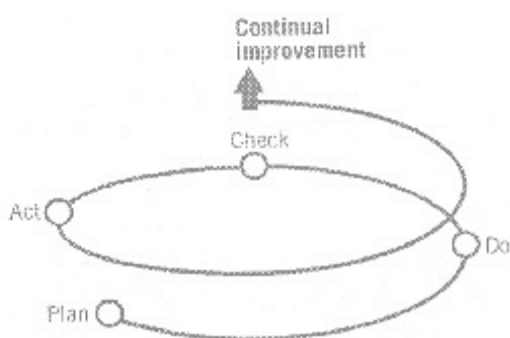
With concern for the environment currently increasing, it is likely that energy efficiency improvement programs would be driven by the company's environmental policy. They would become a part of the organization's overall environmental management system. This would ensure that energy issues could be raised at the corporate level and receive proper attention.

Examples of the benefits of a consistent and integrated approach to achieving energy savings are prevalent throughout the world. Often, production can be

increased without using extra energy if existing technologies have been managed within a company's energy management scheme. That scheme should form an integral part of the company's quality and environmental management systems, providing a comprehensive tool for managing and implementing. The integration of energy into the overall management system should involve evaluation of energy implications in every management decision in the same way as economic, operational, quality and other aspects are considered.

8.4 Defining the Program

The setting up an effective energy management program follows proven principles of establishing any management system. These principles fit any size and type of organization. As defined by Dr. W. Edward Deming, the process should have four steps, which when broken down, require several activities as shown in the figure.



The points depicted in the diagram are generic. As each of the energy efficiency improvement programs is site – specific, the actual approaches to their development will vary. The following brief examination of these individual points will provide a simplified blueprint to energy management program implementation.

8.5 ENERGY MANAGEMENT PROGRAM – HOW TO IMPLEMENT IT

8.5.1 Obtain Insight:

The first step in implementing an energy management program is the energy audit. It consists of documentary research, surveys (including interviews and observations) and analysis to determine where and how energy is used and may be lost. The energy audit is the cornerstone of the energy management program. The energy audit is necessary in order to identify opportunities for energy management and savings. It establishes "ground zero," the base from which the progress and success of energy management can be measured.

8.5.2 Get Management Commitment:

Energy management must be a matter of concern to everybody in the company before it can succeed. Without strong, sustained and visible support of the

company's top management, the energy management program is doomed to failure. Employees will apply their best efforts to the program only when they see that their supervisors are fully committed. Hence, it is crucial that top management rallies to the cause and provide full support and enthusiastic participation. Because the program involves everybody, the support of union officials should be secured very early on.

8.5.3 Nominate an Energy Manager:

Preferably a senior manager in the role of energy manager should head the Energy management structure. The person will give the program enough clout and stature to indicate to the entire workforce that energy management is a commitment that everyone must take seriously. The champion should demonstrate a high level of enthusiasm and deep conviction about the benefits of the energy efficiency program. A typical example of organizational structure of an energy management and location of an energy manager are shown in figure 1. The location of energy management function in a typical corporate sector and larger organization is shown in figure 2.

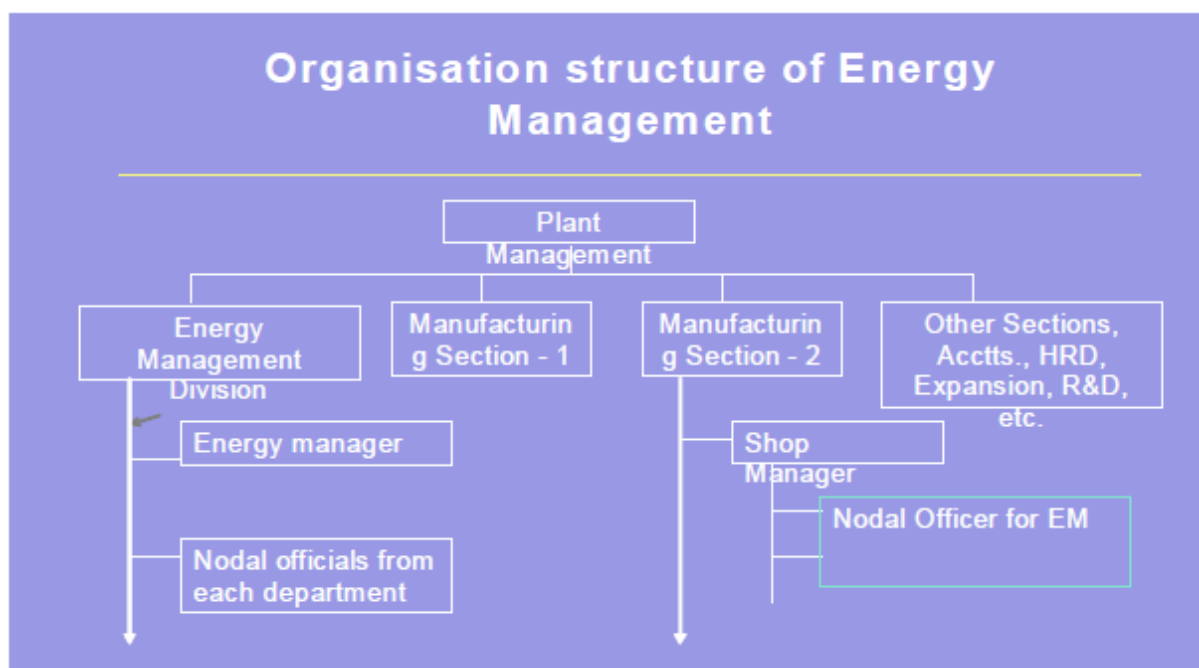


Figure 8-1

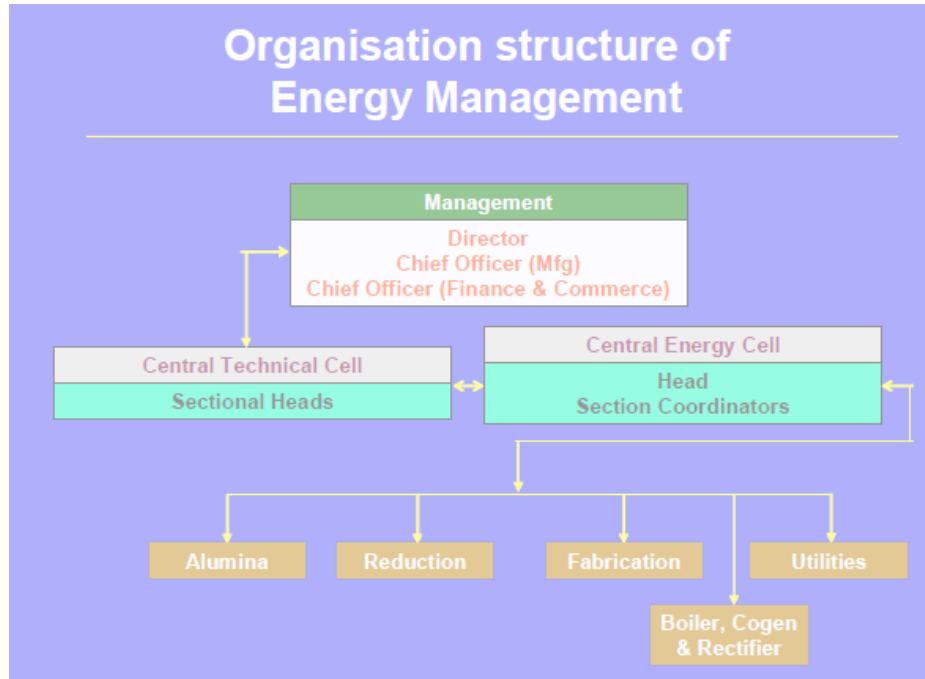
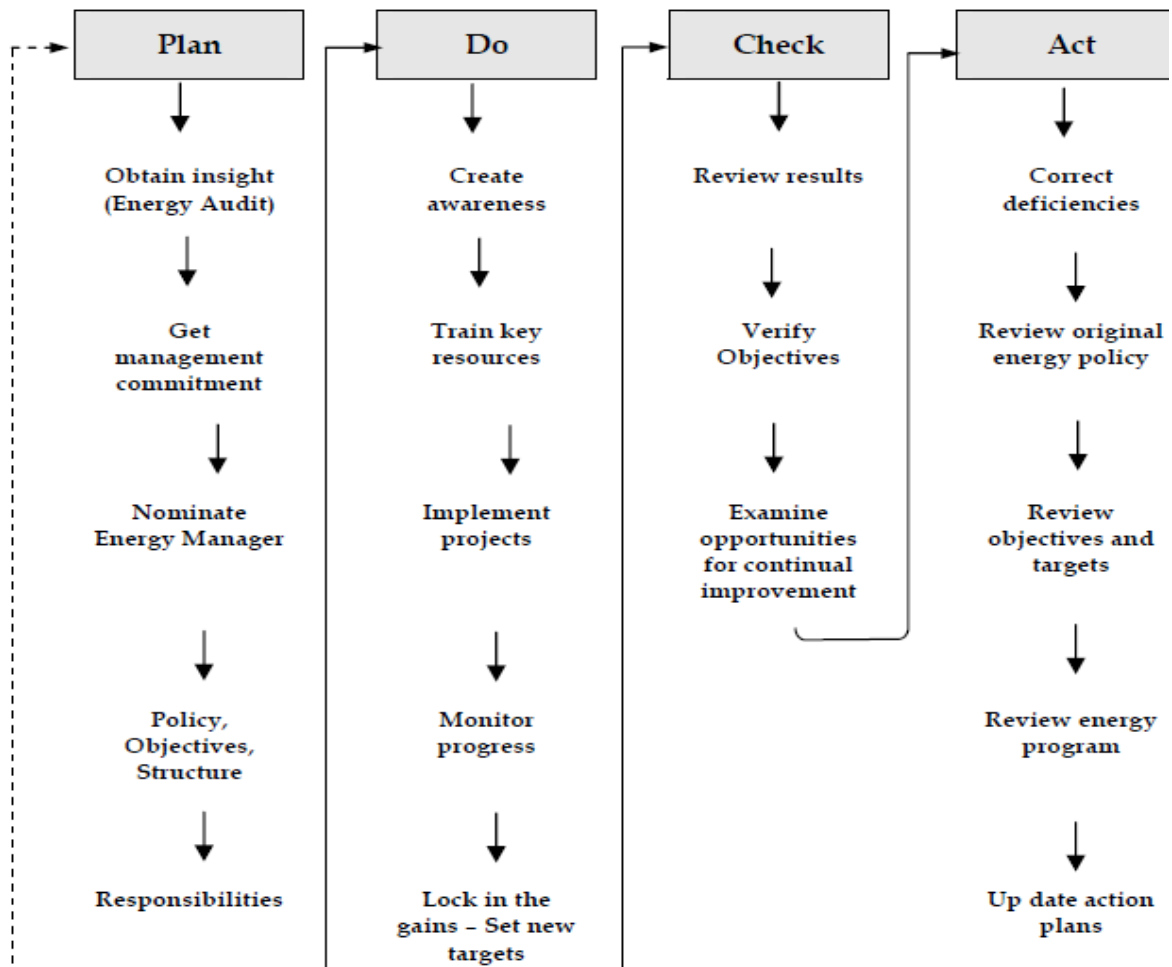
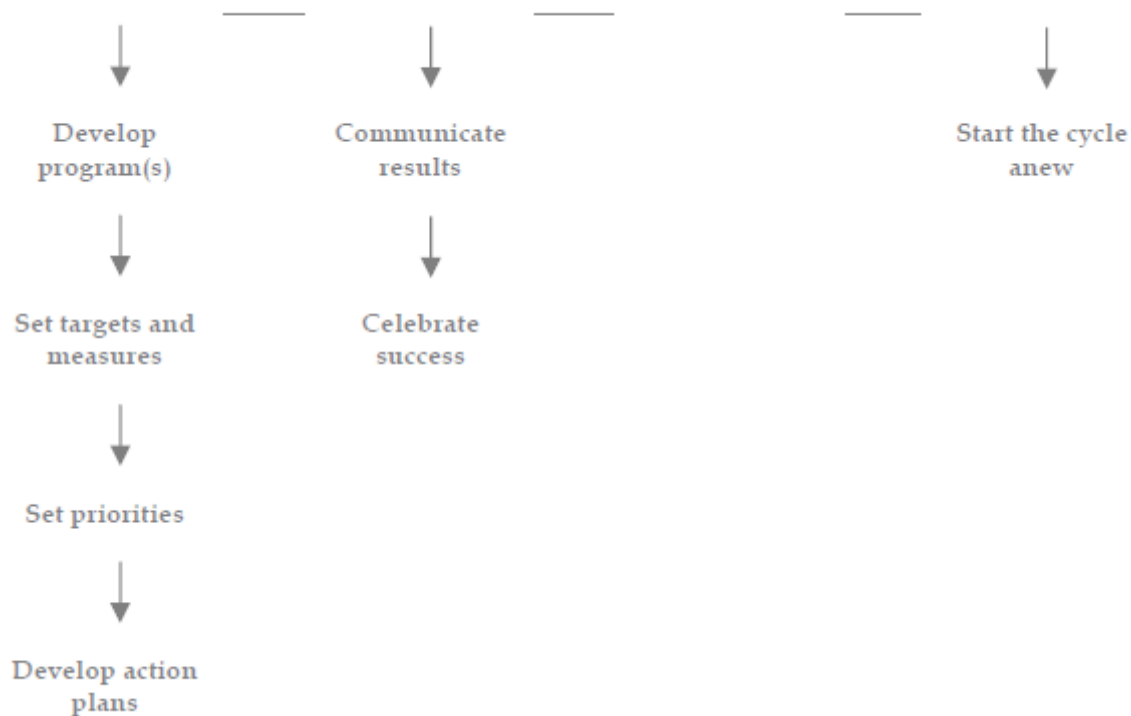


Figure 8-2

Figure 8-3. Energy management plan at a glance





8.5.4 Set Energy Policy, Objectives and Structure:

The launch of the energy management program should start with a strong policy statement from the chief executive to the employees, followed up immediately by a presentation that explains the benefits of efficient energy use. The energy policy should be developed in step with the company's strategic goals and in agreement with other policies (quality, production, environment, etc.) and the company's vision and mission statements.

In order to give the program legitimacy – apart from showing strong, sustained and visible support – top management must make and keep other important commitments:

- To view the energy management program to be as important as production;
- To provide the resources necessary; and
- To report on progress to shareholders and employees.

The effectiveness of an energy management program depends on the time and effort allowed to be spent by those who are charged with its implementation. Therefore, adequate operational funding is essential.

In setting the objectives, the organization should consider its priorities and its financial, operational and business requirements and make them specific. The



objectives should be measurable, realistic and clearly defined and should be communicated to all.

A written energy management policy will guide efforts to improve energy efficiency, and represents a commitment to saving energy. It will also help to ensure that the success of the program is not dependent on particular individuals in the organization. An energy management policy statement includes a declaration of commitment from senior management, as well as general aims and specific targets relating to:

- Energy consumption reduction (electricity, fuel oil, gas, petrol etc.)
- Energy cost reduction (by lowering consumption and negotiating lower unit rates)
- Timetables
- Budgetary limits
- Energy cost centers
- Organisation of management resources.

A sample of energy management policy is given below.

ENERGY MANAGEMENT POLICY XYZ Co. Limited	
We XYZ Co. Limited in its endeavor to play leading role in the important economic issue of our Nation, it is committed and continually striving to be the lowest specific energy consumer in the industry it operates.	
We believe that Communication, Culture and Commitment are the key driving forces for us in making Energy Conservation (ENCON) a way of life at our plant. We plan to achieve this by following:	
<ul style="list-style-type: none">• Manage efficiently the utilization of energy resources (like Natural gas, Naphtha, Fuel oil), updating hardware, operational practices and employ cleaner and more efficient technology as appropriate.• Train and educate our Employees/Residents to be the trendsetter in the areas of ENCON.• Carry out regular internal and external audits to identify and communicate areas of improvements and benchmark continuously our performance against the world best, to identify the ENCON opportunities.• Share and enrich our experiences on energy conservation with other organization, and own group companies.	
As a part of ENCON strategy, we are committed to reduce our specific energy consumption of urea @ 1.0% minimum every year till 2011, by promoting the culture of innovation and creativity, and aligning the commitment at all levels.	
Date:	s/d
Place:	President



8.5.5 Assign Responsibilities:

The Energy Manager chairs the Energy Management Committee (EMC) and takes overall personal responsibility for the implementation and success of the program and accountability for its effectiveness. The energy Manager should have the appropriate technical knowledge and training and certification as well as free access to senior management. Beyond these requirements, the ideal person will have skills in leadership, motivation, communication, facilitating and mediation, persistence, determination and the willingness to advocate for the cause of energy efficiency. The person should also have an excellent follow-through on issues and with members of the EMC.

The other part of the Energy Managers duties is to report regularly and frequently on the status of the energy management program, especially when a project has reached its energy-saving target.

Specific responsibilities and accountabilities for the energy management program may be assigned to area managers. Line managers must also learn why effective energy management is needed and how they can contribute to it. As well, with the concept of energy being a managed resource and its use spanning several operational departments, their managers must be made accountable for its use within their area. That may not happen overnight, though, as monitoring equipment and consumption measurements are not often available at first.

EMC should include representatives from each major energy-using department, from maintenance, from production operators, as well as from various functions, including finance, purchasing, environment and legal. Members should be prepared to make recommendations that affect their areas and to conduct investigations and studies. Energy management generally works best when specific tasks are assigned and people are held responsible.

In smaller organizations, all management staff should have energy consumption reduction duties.

8.5.6 Develop Program(s) For Energy Efficiency Management:

A successful approach to developing an energy efficiency improvement program would include the following items:

- A long-term savings plan;
- A medium-term plans for the entire facility;
- A first-year detailed project plan; and
- Action to improve energy management, including the implementation of an energy monitoring system.

The last point should also capture the energy savings that will assuredly result from improved housekeeping practices alone. Companies around the world report that these measures alone can save 10 to 15 percent of energy costs merely through the elimination of wasteful practices. The energy management plan should be ongoing and have a number of energy-saving projects coordinated together, rather than be implemented haphazardly or in a bit-by-bit fashion. The energy manager should share with the EMC members all the available information about energy use and challenge them to explore ways to conserve energy in their respective areas or departments. Using this information, define realistic energy-saving goals that should offer enough incentive to challenge the employees. Establish a reporting system to track progress toward these goals, with adequate frequency.

8.5.7 Set Targets and Measures:

What you can measure, you can control. Often, there is only rudimentary measuring equipment in place, particularly in smaller facilities. That should not be an impediment to starting an energy efficiency improvement project, however. More gauges, sensors and other equipment can be added as the energy management effort accelerates. In fact, early successes with energy-saving projects will provide strong justification for acquisition of new metering equipment.

Targets should be measurable and verifiable. To ensure that they are realistic, apply standards that indicate how much energy should be used for a particular application. Measure current performance against industry standards or calculated practical and theoretical energy requirements. Wherever possible, attempt to express the targets in relation to the unit of production. Always set targets and standards in familiar energy consumption units (e.g. MJ, GJ, Btu, therms, kWh). Use MJ or GJ (these are preferred, as are all SI units) or Btu units to permit comparison across energy sources. When a target level is reached and the results level off, the target should be reset at a new, progressive value.

8.5.8 Set Priorities:

Certainly, do pay due consideration to business needs. But remember that one has to walk before one can run; start with small, easily and quickly achievable targets. That will be a great source of motivation to employees – seeing that it can be done and that progress is being made will lead them to feel that they are successful. As well, EMC members will gain experience and confidence before tackling more complex or longer-horizon targets.

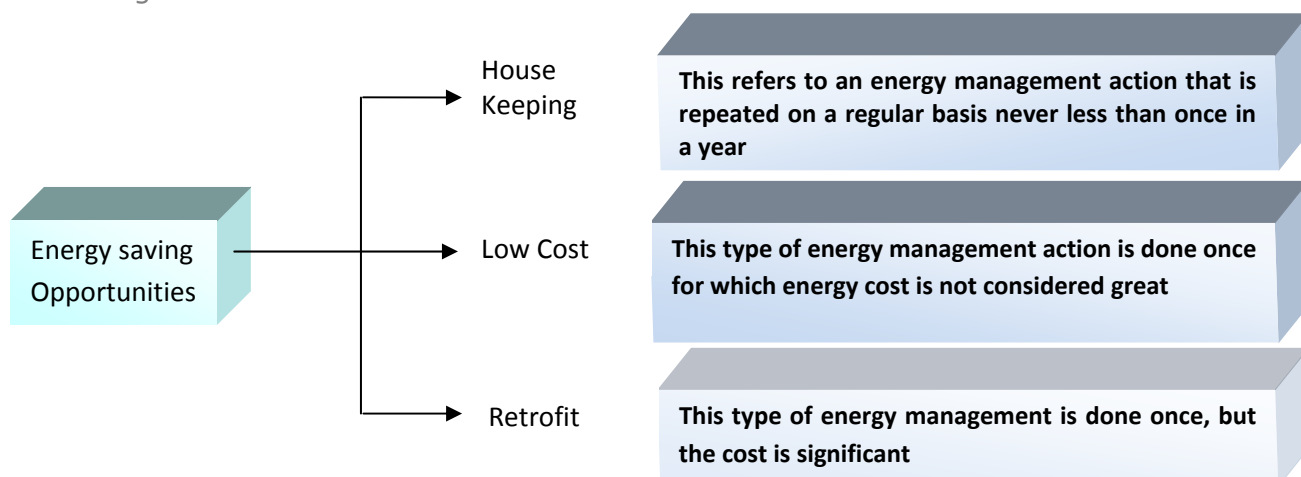
8.5.9 Develop Action Plans:

Be specific – an action plan is a project management and control tool. It should contain identification of personnel and their responsibilities, the specific tasks, their area and timing. It should also indicate specified resource requirements (money, people, training, etc.) and timelines for individual projects and their stages. Several project management software packages are on the market to facilitate the creation of Gantt charts, which are used to monitor and control project fulfillment, costs and other data. When selecting energy efficiency projects for implementation, look for *Energy saving opportunities (ESO's)*. This term represents the ways that energy can be used wisely to save money. Typically, in most areas, these can be divided into three categories, as seen in the diagram below.

It should be noted that the division between low cost and retrofit is normally a function of the size, type and financial policy of the organization.

8.5.10 Create Awareness:

The entire workforce should be involved in the energy efficiency improvement effort. Therefore, everybody should be aware of the importance of reducing energy consumption in bringing about savings, as well as of the broader environmental benefits of energy efficiency improvements – how the reductions in energy use translate into a decrease of CO₂ emissions, for example. Various means can be employed (seminars, quizzes, demonstrations, exhibits) to convey the message. A well-executed awareness campaign should optimally result in heightened personal interest and willingness of people to get involved. Employees should know their roles and responsibilities in the overall energy management effort and how their own personal performance can influence the outcome. That should include knowledge of the potential consequences of not improving to the company's and society's well being.





Creating awareness about the importance of saving energy will help substantially in the implementation of virtually-no-cost energy-saving measures through better housekeeping.

8.5.11 Train Key Resources:

Members of the EMC, line managers and others who will be involved in the energy management program – and have a greater influence upon energy consumption than others – should receive appropriate training. That could include energy-saving practices pertinent to these employees' jobs or essential energy monitoring and measuring techniques.

Training can be organized in two stages. The first stage involves specific training for selected employees. The second – following in due course – is a strategy for integrating energy management training into the existing company training matrix in order to ensure that energy training is regularly covered. General team training (e.g. in conflict management and problem solving) should also be provided to the EMC members.

8.5.12 Implement Projects:

The implementation of energy-saving projects should involve a coordinated, coherent set of projects linked together for the energy efficiency improvement program to be most effective. If several energy projects are contemplated, the interactions between them must also be considered.

Start capitalizing on your selected Energy saving opportunities as soon as possible. Start with projects that yield modest but quickly obtainable savings, especially projects to correct the obvious sources of waste found in the initial energy audit. The savings thus achieved will encourage the EMC to seek greater savings in the areas of less obvious energy consumption, such as energy used by machinery and in processes.

Do not overlook the importance of improving energy housekeeping practices in the overall energy management program.

During the first six months of an energy management program, a target of 5 percent savings is generally acceptable. A longer first phase, and a correspondingly higher target, may cause enthusiasm to wane. Hence, start with projects that are simpler and bring results quickly to boost the confidence and interest of the EMC members.

Follow up on activities of individuals charged with specific responsibilities and be mindful of the implementation schedule. The energy manager should meet with the committee regularly to review progress, update project lists, evaluate established



goals and set new goals as required. To sustain interest, the EMC should run a program of activities and communications, and the energy manager should make periodic progress reports to management, reviewing the program and re-establishing support for it with each report.

8.5.13 Monitor Progress:

By continuously monitoring the energy streams entering the facility and their usage, the EMC can gather much information that will help it assess progress of its program and plan future projects. Energy-use monitoring produces data for activities such as the following:

- Determining whether progress is being made;
- Managing energy use on a day-to-day basis to make prompt corrections of process conditions that have caused sudden excessive consumption;
- Determining trends in energy usage and using that information in the budgeting process;
- Calculating the return on investment (i.e. the cost savings achieved from data gathered by the energy monitoring system);
- Providing positive reinforcement that helps employees to willingly adopt the new energy-saving practices;
- Comparing the results of an implemented energy-saving measure to the projections in order to identify problems with the project's performance and improve techniques for estimating costs and benefits of energy efficiency improvements for future projects;
- tracking the performance of projects in which suppliers made performance guarantees;
- Reporting energy improvements accurately to senior management, thus ensuring management commitment;
- Setting future energy use reduction targets and monitoring progress toward new goals; and
- Selecting areas of the facility for a future detailed energy audit.

In a large facility with many different functions, energy monitoring is done with metering equipment installed at strategic points to measure the flow of energy sources – such as steam, compressed air or electricity – to each major user. Energy performance is then gauged by calculating the amount of energy consumed per unit of production. Measurement expressions in SI units are preferred, as they enable global comparisons (e.g. MJ or GJ used per tonne of steel produced in a steel plant, or kWh per tonne of cement production in a cement plant). Calculating energy



performance helps managers identify wasteful areas of their facility and lets managers take responsibility for energy use in their areas. When monitoring shows that energy consumption is declining as improvements are being made, attention can be turned to the next area of concern.

8.5.14 Lock in the Gains – Set New Targets:

Without vigilant attention to energy management, the gains could fade away and the effort could disintegrate. To make the new energy saving measures stick, pay sustained attention to the implemented project until the measure has become a well-trenched routine.

Remember that energy management is an issue of technology as well as people. If practices and procedures have been changed as the result of the project, take the time and effort to document it in a procedure or work instruction. That will ensure the future consistency of the practice, as well as serve as a training and audit tool.

Once a target has been met on a sustained basis over a period of several weeks, it is time to review it. It can become the new standard, and a new, progressive target can be set. Target setting helps to involve the entire workforce in energy projects by giving them goals to achieve. By setting targets in a step-wise, improving fashion, managers will learn to treat energy as a resource that must be managed with attention equal to that for other process inputs, such as labour and raw materials.

8.5.15 Communicate the Results:

This extremely important step needs to be well executed in order to foster the sense that everybody is a part of the energy management effort. Regular reports taken from the monitored data encourage staff by showing them that they are progressing toward their goals. The emphasis should be on simplified graphical, visual representation of the results – use charts, diagrams or “thermometers” of fulfillment posted prominently on bulletin boards where people can see them. Someone should be in charge of posting the information and updating it regularly. The format and colours may be changed from time to time in order to maintain the visual interest of the information. Stay away from a dry format of reporting – use a representation that people can understand. For example, express savings in rupees, rupees per employee or rupees per unit of production. Show it on a cumulative basis, i.e. how it contributes to the company’s profit picture.

8.5.16 Celebrate the Success:

This is often an overlooked yet very important segment of a program. People crave and value recognition. A myriad of ways can be employed to recognize the achievement and highlight the contribution of teams (rather than the contribution of



individuals, which can be divisive!). Giveaways of thematic T-shirts, hats and other merchandise; dinners; picnics; company-sponsored attendance at sporting events; – the possibilities are endless. Celebrating success is a motivational tool that also brings psychological closure to a project. The achievement of a target should be celebrated as a milestone on the way to continual improvement of energy efficiency in the plant.

8.5.17 Review Results:

In order to keep the energy management issue alive and to sustain interest, regular reporting to the management team is necessary. Energy management updates should be a permanent agenda item of regular operations management review meetings, just as quality, production, financial and environmental matters are. Results of the implemented project are reviewed, adjustments are made, conflicts are resolved and financial considerations are taken into account.

8.5.18 Verify Effectiveness:

Has the project lived up to the expectations? Is the implemented energy efficiency improvement really effective?. Is it being maintained? To support the credibility of the energy management effort, the effectiveness of measures taken must be verified, so adjustments could be made and the future project managed better.

8.5.10 Examine Opportunities for Continual Improvements:

Often one project opens the door to another idea. The energy efficiency improvement program is an ongoing effort. The EMC and all employees should be encouraged to examine and re-examine other opportunities for further gains as a matter of course. That is the essence of continual improvement, which should be promoted in the interest of any organization. In some companies, this is a permanent item on the agenda of EMC meetings.

8.5.19 Correct Deficiencies:

Information gained from monitoring data, from the input from EMC and others, from the review of results and from the verification of the project's effectiveness may indicate that a corrective action is required. The energy manager is responsible for arranging this action with the EMC team and the personnel from the respective area. The root cause of the deficiency will be determined, and the required corrective action will be initiated. Remember to document it, as necessary. Future energy efficiency projects will benefit from the lessons learned.

8.5.20 Review Original Energy Policy, Objectives and Targets, Energy Efficiency Improvement Program and Action Plans:

These steps ensure the continued relevancy and currency of the energy policy. Objectives and targets support the policy. As they change in time, they must be reviewed to ensure that priorities are maintained in view of present conditions. This review should take place annually or semi-annually.

The energy efficiency improvement program and action plans are “living” documents. Frequent updating and revisions are necessary as old projects are implemented and new ones initiated and as business conditions change. The energy manager leads that activity. She/he needs to get input from the EMC and others and seek approval of the updates from the management team.

8.5.21 ENERGY MANAGEMENT SKILL DEVELOPMENT:

Managers, technical staff and operations staff with energy management responsibilities will need training in energy management skills and techniques. They should be trained to plan energy efficiency in their respective fields, helps them develop a thorough understanding of energy and gives them a step-by-step guide to reach their objectives. Training workshops should be geared to give participants to enable them to carry out energy use monitoring and tracking, to plan and execute energy efficiency programs where energy consumption can be cut without compromising system performance. Training programs on how to carryout energy efficiency project feasibility (both technical and financial) are also necessary.

9. LIGHTING SYSTEM

9.1 Introduction

Lighting is an essential service in all the industries. The power consumption by the industrial lighting varies between 2 to 10% of the total power depending on the type of industry. Innovation and continuous improvement in the field of lighting, has given rise to tremendous energy saving opportunities in this area.

Lighting is an area, which provides a major scope to achieve energy efficiency at the design stage, by incorporation of modern energy efficient lamps, luminaires and gears, apart from good operational practices.

9.2 Basic Terms in Lighting System and Features

9.2.1 Lamps

Lamp is equipment, which produces light. The most commonly used lamps are described briefly as follows:

Incandescent lamps:

Incandescent lamps produce light by means of a filament heated to incandescence by the flow of electric current through it. The principal parts of an incandescent lamp, also known as GLS (General Lighting Service) lamp include the filament, the bulb, the fill gas and the cap.

Reflector lamps:

Reflector lamps are basically incandescent, provided with a high quality internal mirror, which follows exactly the parabolic shape of the lamp. The reflector is resistant to corrosion, thus making the lamp maintenance free and output efficient.

Gas discharge lamps:

The light from a gas discharge lamp is produced by the excitation of gas contained in either a tubular or elliptical outer bulb.

The most commonly used discharge lamps are as follows:

- Fluorescent tube lamps (FTL)
- Compact Fluorescent Lamps (CFL)
- Mercury Vapour Lamps

- Sodium Vapour Lamps
- Metal Halide Lamps

9.2.2 Luminaire :

Luminaire is a device that distributes filters or transforms the light emitted from one or more lamps. The luminaire includes all the parts necessary for fixing and protecting the lamps, except the lamps themselves. In some cases, luminaires also include the necessary circuit auxiliaries, together with the means for connecting them to the electric supply. The basic physical principles used in optical luminaire are reflection, absorption, transmission and refraction.

9.2.3 Control Gear

The gears used in the lighting equipment are as follows:

- Ballast: A current limiting device, to counter negative resistance characteristics of any discharge lamps. In case of fluorescent lamps, it aids the initial voltage build-up, required for starting.
- Ignitors: These are used for starting high intensity Metal Halide and Sodium vapour lamps.

9.2.4 Illuminance

This is the quotient of the illuminous flux incident on an element of the surface at a point of surface containing the point, by the area of that element.

The lighting level produced by a lighting installation is usually qualified by the illuminance produced on a specified plane. In most cases, this plane is the major plane of the tasks in the interior and is commonly called the working plane. The illuminance provided by an installation affects both the performance of the tasks and the appearance of the space.

9.2.5 Lux (lx)

This is the illuminance produced by a luminous flux of one lumen, uniformly distributed over a surface area of one square metre. One lux is equal to one lumen per square meter.

9.2.6 Luminous Efficacy (lm/W)

This is the ratio of luminous flux emitted by a lamp to the power consumed by the lamp. It is a reflection of efficiency of energy conversion from electricity to light form.

9.2.7 Colour Rendering Index (RI)

Is a measure of the degree to which the colours of surfaces illuminated by a given light source confirm to those of the same surfaces under a reference illuminant; suitable allowance having been made for the state of Chromatic adaptation.

Table.9.1 Luminous Performance Characteristics of Commonly Used Luminaries

LUMINOUS PERFORMANCE CHARACTERISTICS OF COMMONLY USED LUMINARIES					
Type of lamp	Lumens / Watt		Color rendering Index	Typical application	Life (hours)
	Range	Avg.			
Incandescent	8-18	14	Excellent	Homes, restaurants, general lighting, emergency lighting	1000
Fluorescent Lamps	46-60	50	Good w.r.t. coating	Offices, shops, hospitals, homes	5000
Compact fluorescent lamps (CFL)	40-70	60	Very good	Hotels, shops, homes, offices	8000-10000
High pressure mercury (HPMV)	44-57	50	Fair	General lighting in factories, garages, car parking, flood lighting	5000
Halogen lamps	18-24	20	Excellent	Display, flood lighting, stadium exhibition grounds, construction areas	2000-4000
High pressure sodium (HPSV) SON	67-121	90	Fair	General lighting in factories, ware houses, street lighting	6000-12000
Low pressure sodium (LPSV) SOX	101-175	150	Poor	Roadways, tunnels, canals, street lighting	6000-12000

9.3 Recommended Illuminance Levels for Various Tasks / Activities / Locations

Recommendations on Illuminance

9.3.1 Scale of Illuminance:

The minimum illuminance for all non-working interiors, has been mentioned as 20 Lux (as per IS 3646). A factor of approximately 1.5 represents the smallest significant difference in subjective effect of illuminance. Therefore, the following scale of illuminances is recommended. 20–30–50–75–100–150–200–300–500–750–1000–1500–2000, Lux

9.3.2 Illuminance ranges:

Because circumstances may be significantly different for different interiors used for the same application or for different conditions for the same kind of activity, a range of illuminances is recommended for each type of interior or activity intended of a single value of illuminance. Each range consists of three successive steps of the recommended scale of illuminances. For working interiors the middle value (R) of each range represents the recommended service illuminance that would be used unless one or more of the factors mentioned below apply.

The higher value (H) of the range should be used at exceptional cases where low reflectance or contrasts are present in the task, errors are costly to rectify, visual work is critical, accuracy or higher productivity is of great importance and the visual capacity of the worker makes it necessary. Similarly, lower value (L) of the range may be used when reflectance's or contrasts are unusually high, speed & accuracy is not important and the task is executed only occasionally.

9.3.3 Recommended Illumination:

The following Table gives the recommended illuminance range for different tasks and activities for chemical sector. The values are related to the visual requirements of the task, to user's satisfaction, to practical experience and to the need for cost effective use of energy.(Source IS 3646 (Part I) : 1992).

For recommended illumination in other sectors, reader may refer *Illuminating Engineers Society Recommendations Handbook/*



Chemicals

Petroleum, Chemical and Petrochemical works	
Exterior walkways, platforms, stairs and ladders	30-50-100
Exterior pump and valve areas	50-100-150
Pump and compressor houses	100-150-200
Process plant with remote control	30-50-100
Process plant requiring occasional manual intervention	50-100-150
Permanently occupied work stations in process plant	150-200-300
Control rooms for process plant	200-300-500

Pharmaceuticals Manufacturer and Fine chemicals manufacturer

Pharmaceutical manufacturer.

Grinding, granulating, mixing, drying, tableting, sterilising, washing, preparation of solutions, filling, capping, wrapping, hardening	300-500-750
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Fine chemical manufacturers

Exterior walkways, platforms, stairs and ladders	30-50-100
Process plant	50-100-150
Fine chemical finishing	300-500-750
Inspection	300-500-750
Soap manufacture	
General area	200-300-500
Automatic processes	100-200-300
Control panels	200-300-500
Machines	200-300-500

Paint works

General	200-300-500
Automatic processes	150-200-300
Control panels	200-300-500
Special batch mixing	500-750-1000
Colour matching	750-100-1500

9.4 Methodology of Lighting System Energy Efficiency Study

A step-by-step approach for assessing energy efficiency of lighting system is given below:

Step–1: Inventories the Lighting System elements, & transformers in the facility as per following typical format (Table – 9.2 and 9.3).

Table – 9.2 DEVICE RATING, POPULATION AND USE PROFILE					
S. No.	Plant Location	Lighting Device & Ballast Type	Rating in Watts Lamp & Ballast	Population Numbers	No. of hours / Day

Table – 9.3 LIGHTING TRANSFORMER / RATING AND POPULATION PROFILE:				
S. No.	Plant Location	Lighting Transformer Rating (kVA)	Numbers Installed	Meter Provisions Available Volts / Amps / kW / Energy

In case of distribution boards (instead of transformers) being available, fuse ratings may be inventorised along the above pattern in place of transformer kVA.

Step–2: With the aid of a lux meter, measure and document the lux levels at Various plant locations at working level, as daytime lux and night time lux values alongside the number of lamps "ON" during measurement.

Step–3: With the aid of portable load analyzer, measure and document the voltage, current, power factor and power consumption at various input points, namely the distribution boards or the lighting voltage transformers at the same as that of the lighting level audit.

Step–4: Compare the measured lux values with standard values as reference and identify locations as under lit and over lit areas.

Step–5: Collect and Analyse the failure rates of lamps, ballasts and the actual life expectancy levels from the past data.

Step–6: Based on careful assessment and evaluation, bring out improvement options, which could include :

- i) Maximise sunlight use through use of transparent roof sheets, north light roof, etc.
- ii) Examine scope for replacements of lamps by more energy efficient lamps, with due consideration to luminaire, color rendering index, lux level as well as expected life comparison.
- iii) Replace conventional magnetic ballasts by more energy efficient ballasts, with due consideration to life and power factor apart from watt loss.
- iv) Select interior colours for light reflection.
- v) Modify layout for optimum lighting.
- vi) Providing individual / group controls for lighting for energy efficiency such as: On / off type voltage regulation type (for illuminance control)
 - a. Group control switches / units
 - b. Occupancy sensors
 - c. Photocell controls
 - d. Timer operated controls
 - e. Pager operated controls
 - f. Computerized lighting control programs
- vii) Install input voltage regulators / controllers for energy efficiency as well as longer life expectancy for lamps where higher voltages, fluctuations are expected.
- viii) Replace energy efficient displays like LED's in place of lamp type displays in control panels / instrumentation areas, etc.

9.5 Case Examples

9.5.1 Energy Efficient Replacement Options

The lamp efficacy is the ratio of light output in lumens to power input to lamps in watts. Over the years development in lamp technology has led to improvements in efficacy of lamps. However, the low efficacy lamps, such as incandescent bulbs, still constitute a major share of the lighting load. High efficacy gas discharge lamps suitable for different types of applications offer appreciable scope for energy conservation. Typical energy efficient replacement options, along with the per cent energy saving, are given in Table-9.4.

Table-9.4. SAVINGS BY USE OF HIGH EFFICACY LAMPS						
Sector	Lamp type				Power saving	
	Existing		Proposed		Watts	%
Domestic/Commercial	GLS	100 W	*CFL	25 W	75	75
Industry	GLS	13 W	*CFL	9 W	4	31
	GLS	200 W	Blended	160 W	40	20
	TL	40 W	TLD	36 W	4	10
Industry/Commercial	HPMV	250 W	HPSV	150 W	100	37
	HPMV	400 W	HPSV	250 W	150	35

9.5.2 Energy Saving Potential in Street Lighting

The energy saving potential, in typical cases of replacement of inefficient lamps with efficient lamps in street lighting is given in the Table 9.5

Table 9.5 SAVING POTENTIAL BY USE OF HIGH EFFICACY LAMPS FOR STREET LIGHTING							
Existing lamp			Replaced units			Saving	
Type	W	Life	Type	W	Life	W	%
GLS	200	1000	ML	160	5000	40	7
GLS	300	1000	ML	250	5000	50	17
TL	2 X 40	5000	TL	2 X 36	5000	8	6
HPMV	125	5000	HPSV	70	12000	25	44
HPMV	250	5000	HPSV	150	12000	100	40
HPMV	400	5000	HPSV	250	12000	150	38

9.6 Some Good Practices in Lighting

9.6.1 Installation of energy efficient fluorescent lamps in place of "Conventional" fluorescent lamps.

Energy efficient lamps are based on the highly sophisticated tri-phosphor fluorescent powder technology. They offer excellent colour rendering properties in addition to the very high luminous efficacy.

9.6.2 Installation of Compact Fluorescent Lamps (CFL's) in place of incandescent lamps.

Compact fluorescent lamps are generally considered best for replacement of lower wattage incandescent lamps. These lamps have efficacy ranging from 55 to 65

lumens/Watt. The average rated lamp life is 10,000 hours, which is 10 times longer than that of a normal incandescent lamp. CFL's are highly suitable for places such as Living rooms, Hotel lounges, Bars, Restaurants, Pathways, Building entrances, Corridors, etc.

9.6.3 Installation of metal halide lamps in place of mercury / sodium vapour lamps.

Metal halide lamps provide high color rendering index when compared with mercury & sodium vapour lamps. These lamps offer efficient white light. Hence, metal halide is the choice for colour critical applications where, higher illumination levels are required. These lamps are highly suitable for applications such as assembly line, inspection areas, painting shops, etc. It is recommended to install metal halide lamps where colour rendering is more critical.

9.6.4 Installation of High Pressure Sodium Vapour (HPSV) lamps for applications where colour rendering is not critical.

High pressure sodium vapour (HPSV) lamps offer more efficacy. But the colour rendering property of HPSV is very low. Hence, it is recommended to install HPSV lamps for applications such as street lighting, yard lighting, etc.

9.6.5 Installation of LED panel indicator lamps in place of filament lamps.

Panel indicator lamps are used widely in industries for monitoring, fault indication, signaling, etc.

Conventionally filament lamps are used for the purpose, which has got the following disadvantages:

- High energy consumption (15 W/lamp)
- Failure of lamps is high (Operating life less than 1,000 hours)
- Very sensitive to the voltage fluctuations Recently, the conventional filament lamps are being replaced with Light Emitting Diodes (LEDs).

The LEDs have the following merits over the filament lamps.

- Lesser power consumption (Less than 1 W/lamp)
- Withstand high voltage fluctuation in the power supply.
- Longer operating life (more than 1,00,000 hours)

It is recommended to install LEDs for panel indicator lamps at the design stage.

9.6.6 Light distribution

Energy efficiency cannot be obtained by mere selection of more efficient lamps alone. Efficient luminaires along with the lamp of high efficacy achieve the optimum efficiency. Mirror-optic luminaires with a high output ratio and batwing light distribution can save energy.

For achieving better efficiency, luminaires that are having light distribution characteristics appropriate for the task interior should be selected. The luminaires fitted with a lamp should ensure that discomfort glare and veiling reflections are minimised. Installation of suitable luminaires, depends upon the height - Low, Medium & High Bay. Luminaires for high intensity discharge lamp are classified as follows:

- Low bay, for heights less than 5 metres.
- Medium bay, for heights between 5 – 7 metres.
- High bay, for heights greater than 7 metres.

System layout and fixing of the luminaires play a major role in achieving energy efficiency. This also varies from application to application. Hence, fixing the luminaires at optimum height and usage of mirror optic luminaries leads to energy efficiency.

9.6.7 Light Control

The simplest and the most widely used form of controlling a lighting installation is "On-Off" switch. The initial investment for this set up is extremely low, but the resulting operational costs may be high. This does not provide the flexibility to control the lighting, where it is not required.

Hence, a flexible lighting system has to be provided, which will offer switch-off or reduction in lighting level, when not needed. The following light control systems can be adopted at design stage:

- **Grouping of lighting system, to provide greater flexibility in lighting control**

Grouping of lighting system, which can be controlled manually or by timer control.

- **Installation of microprocessor based controllers**

Another modern method is usage of microprocessor / infrared controlled dimming or switching circuits. The lighting control can be obtained by using logic units located in

the ceiling, which can take pre-programme commands and activate specified lighting circuits. Advanced lighting control system uses movement detectors or lighting sensors, to feed signals to the controllers.

- **Optimum usage of daylighting**

Whenever the orientation of a building permits, day lighting can be used in combination with electric lighting. This should not introduce glare or a severe imbalance of brightness in visual environment. Usage of day lighting (in offices/air conditioned halls) will have to be very limit-ed, because the air conditioning load will increase on account of the increased solar heat dissipation into the area. In many cases, a switching method, to enable reduction of electric light in the window zones during certain hours, has to be designed.

- **Installation of "exclusive" transformer for lighting**

In most of the industries, lighting load varies between 2 to 10%. Most of the problems faced by the lighting equipment and the "gears" is due to the "voltage" fluctuations. Hence, the lighting equipment has to be isolated from the power feeders. This provides a better voltage regulation for the lighting. This will reduce the voltage related problems, which in turn increases the efficiency of the lighting system.

- **Installation of servo stabilizer for lighting feeder**

Wherever, installation of exclusive transformer for lighting is not economically attractive, servo stabilizer can be installed for the lighting feeders. This will provide stabilized voltage for the lighting equipment. The performance of "gears" such as chokes, ballasts, will also improved due to the stabilized voltage.

This set up also provides, the option to optimise the voltage level fed to the lighting feeder. In many plants, during the non-peaking hours, the voltage levels are on the higher side. During this period, voltage can be optimised, without any significant drop in the illumination level.

- Installation of high frequency (HF) electronic ballasts in place of conventional ballasts

New high frequency (28–32 kHz) electronic ballasts have the following advantages over the traditional magnetic ballasts:

- Energy savings up to 35%
- Less heat dissipation, which reduces the air conditioning load

- Lights instantly
- Improved power factor
- Operates in low voltage load
- Less in weight
- Increases the life of lamp

The advantage of HF electronic ballasts, out weigh the initial investment (higher costs when compared with conventional ballast). In the past the failure rate of electronic ballast in Indian Industries was high. Recently, many manufacturers have improved the design of the ballast leading to drastic improvement in their reliability. The life of the electronic ballast is high espe-cially when, used in a lighting circuit fitted with a automatic voltage stabiliser.

The Table 9.6 gives the type of luminaire, gear and controls used in different areas of industry.

TABLE 9.6 TYPES OF LUMINAIRE WITH THEIR GEAR AND CONTROLS USED IN DIFFERENT INDUSTRIAL LOCATIONS				
Location	Source	Luminaire	Gear	Controls
Plant	HID/FTL	Industrial rail reflector: High bay Medium bay Low bay	Conventional/low loss electronic ballast	Manual/electronic
Office	FTL/CFL	FTL/CFL	Electronic/low loss	Manual/auto
Yard	HID	Flood light	Suitable	Manual
Road peripheral	HID/PL	Street light luminaire	Suitable	Manual

10. ELECTRICAL SYSTEMS

Electricity is the most widely used form of energy in most facilities; yet electrical systems are among the least understood of all plant systems. In most industrial operations, four kinds of opportunities for reducing electrical costs are available:

- reduce peak demand, i.e. the maximum power (in kW/kVA), required by the facility;
- reduce the total energy (measured in kWh) consumed in the facility;
- improve the power factor of the facility; and
- shift energy consumption to a time when energy costs are lower.

10.1 Understanding electrical billings:

Understanding the billing rate structure used by your utility is an important first step in taking control of electrical costs. Most industrial and commercial facilities are billed for electricity according to a general-service rate schedule in which the customer pays for the peak power demand (kW/kVA) and energy consumption (kWh). Most general-service rate structures also impose financial penalties on plants that have a low power factor.

10.2 Time-of-use rates:

Many utilities have time-of-use or time-differentiated rates for customers whose peak demand exceeds a certain level. These pricing schemes offer very low rates to customers who can shift high-demand operations away from the times of day when the utility receives its peak demand for energy. The utility benefits from a more consistent daily load pattern, and the customer pays less.

10.3 Time-shifting consumption and real-time pricing

Some utilities now offer their major customers real-time pricing, a scheme in which, each day, the utility gives the customer the rates proposed for each hour of the following day. Because of fluctuations in demand, electricity rates vary widely through the day, and the customer that can schedule its highconsumption activities to low-cost times of day can realize substantial savings. Software is available for estimating energy costs in a variety of situations. These estimates usually require complex analyses to arrive at the best mode of use, depending on operational restraints imposed by factors such as equipment requirements. Some software will even estimate control capabilities based on the consumption pattern decided after analysis.

10.4 ENERGY SAVING OPPORTUNITIES:

Look at the electrical load analysis and, using some of the ideas shown in the following, develop a systematic management approach to electrical power usage. Consider using one of the predictive, “smart” demand side management (DSM) programs that are available on the market. DSM refers to installing efficiency devices to lower or manage the peak electric load or demand. A network of on-line electrical metering enables real-time data to be collected from the meters and the computerized energy management system to predict and control the electrical demand. When the demand approaches preset targets, non-essential operations are cut off and held back to shave the peak demand.

Remember also that the effort must be broad-based and have the support of the operators. An awareness campaign should be the start.

- Are the employees aware of the energy and utilities cost and of the level of those expenditures in the plant?
- Is there an effective communications system in place to share the results of the conservation efforts with everybody?

10.5 Reducing Peak Demand:

A facility’s peak demand is the sum of the power (kW/kVA) required to run all the electrical equipment currently in operation. Thus, the demand peak increases and decreases as equipment is turned on and off and as the load goes up and down.

Peak demand charges are based on the highest peak occurring in the billing period, even if that peak lasts for only one or two hours. Since demand peaks are usually predictable, they can be lowered by:

- shedding loads – shutting off non-essential equipment during the peak period
- shifting loads – re-scheduling operations so that some activities take place during off-peak times of the day; and
- Improving processes to reduce electrical power requirements.

If, after the implementation of all peak-reducing measures, the peak demand still continues to be unacceptably high, consider installing on-site, engine-driven generators to kick in and help shave the peak load.

10.6 Reducing Energy Consumption

Reducing energy consumption is the simplest part of an electricity cost reduction plan. First, implement all the usual cost-saving methods, such as the following:

- turning off unnecessary lights and retrofitting lighting systems with appropriate energy-efficient fixtures;

- shutting down unneeded equipment;
- replacing drives between motor and driven equipment with more energyefficient variable speed drives (VSDs), investigating the use of hydraulic drives and converting motors to soft-start technology;
- replacing driven equipment with more energy-efficient equipment; and
- Replacing old electric motors with new, high-efficiency motors.

Then, look at processes and examine the power usage in various sub-systems (e.g. HVAC, refrigeration, conveying and material handling and compressed air, as detailed in the subsequent sections of this Guide) so as to reduce electricity consumption.

10.7 Improving the Power Factor:

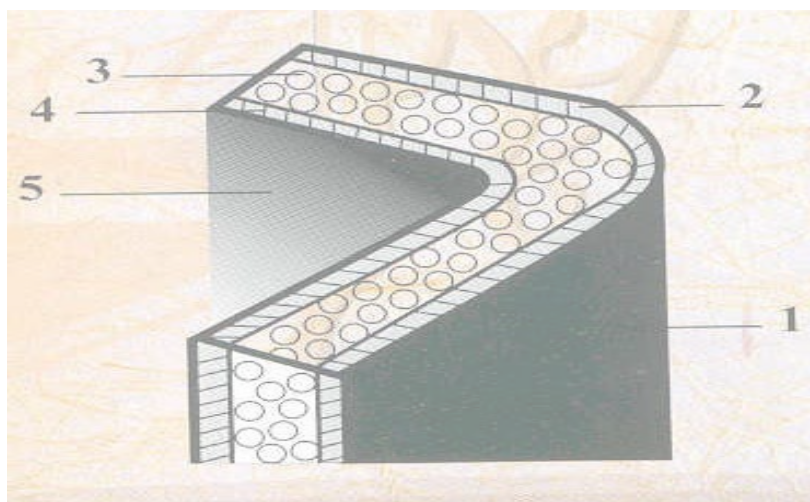
The power factor (PF) of an industrial facility is calculated as a ratio of kW (resistive power) divided by kVA (resistive plus reactive power). Remember that the resistive component of the electrical power does the useful work. A low PF is normally caused by inductive loads used by equipment such as transformers, lighting ballasts and induction motors, particularly underloaded motors. Electrical utility companies penalize customers whose PF is less than 90 percent.

It is in the interest of the facility to maintain a high PF so that the capacity charge (kVA) by the utility does not exceed the established value. The most common way to improve the PF is to add capacitors to the electrical system. Capacitors are normally installed in one of three configurations:

- as a bank at a main switchboard or central distribution location;
- in smaller groups at a motor control centre; or
- Individually, on large power users.

Multiple-capacitor installations usually include a controller that monitors the plant PF and switches capacitors into the circuit as needed to keep the PF high.

11. THERMAL INSULATION



Thermal insulation on process equipment and piping has several functions:

- Preventing losses and gains of heat;
- maintaining consistent process temperatures;
- protecting employees from burns and frostbite;
- preventing condensation from forming on cold equipment surfaces; and
- Maintaining comfortable working environments around hot or cold process equipment.

The benefits of installing or increasing insulation on process equipment and piping are particularly attractive if fuel costs have increased since the equipment was designed and installed. Thermal insulation deteriorates over time, and re-evaluation of long-established systems may show that the insulation is inadequate or damaged.

Economic thickness of insulation:

The key step in an analysis of insulation involves determining the most economic thickness to install, which means the thickness of insulation that saves the most energy per Rupees in installation cost.

Keep moisture out

Insulation that depends on air-filled voids to function effectively must be kept dry. Exposure to moisture, particularly in the case of loose-fibre or open-cell foam insulation types, causes the displacement of insulating air by heatconducting water or ice.

Protecting insulation from moisture/water ingress is just as important as selecting the most effective type of insulation and installing an economic thickness. The practical requirement, then, is to make waterproofing an integral part of any insulating job.

- Install adequate, leak-proof vapour barriers on the interior (warm) side of walls, ceilings or floors.
- Weatherproof exterior walls by cladding or other treatment that prevents water infiltration.
- Maintain the integrity of water-impervious roof membrane by regular inspection and maintenance.
- Cover insulated pipes with suitable cladding (whether for indoor or outdoor applications) with sealed joints, and maintain its integrity by inspection and prompt repair of damaged sections.
- For high-temperature applications, choose a vapour-permeable covering that will allow moisture to pass outward.

The economic thickness of insulation is the thickness that provides the highest insulation for the lowest cost. One way of improving cost savings through insulation is to upgrade to the levels of insulation as per the recommended thickness tables.

11.1 ENERGY SAVING OPPORTUNITIES

11.1.1 Housekeeping ESO's

- Repair damaged insulation.
- Repair damaged coverings and finishes.
- Maintain safety requirements.

11.1.2 Low-Cost ESO's

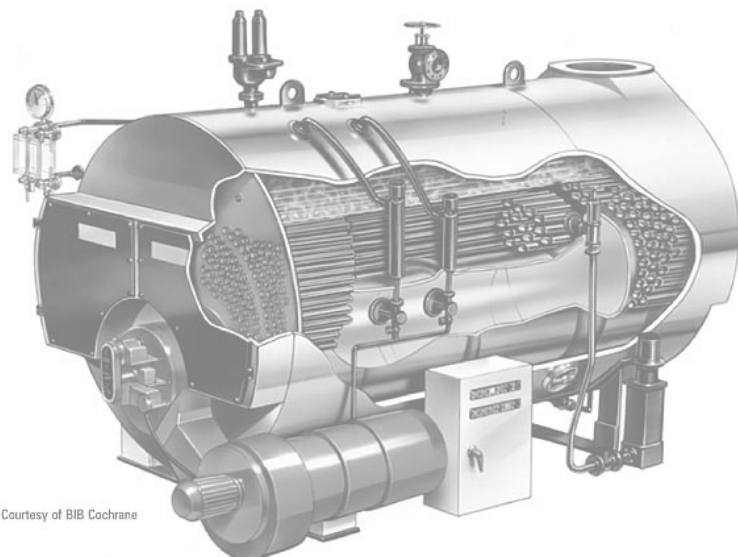
- Insulate un-insulated pipes.
- Insulate un-insulated vessels.
- Add insulation to reach recommended thickness.

11.1.3 Retrofit ESO's

- Upgrade existing insulation levels.
- Review economic thickness requirements.
- Insulate major un-insulated equipment/process areas.

12. BOILER PLANT SYSTEM

In many industrial facilities, the boiler plant system is the largest fuel user. A boiler plant program of energy management should begin with an assessment of current boiler efficiencies. Boiler performance monitoring should then be done regularly to gauge the effect of established energy-saving measures and to set improvement targets. The simplest way to calculate fuel-to-steam efficiency is the direct method of calculation, using steam generation and fuel consumption data from operating logs.



12.1 Direct method for calculating boiler efficiency

- Measure steam flow (in kg) over a set period (e.g. one hour). Use steam integrator readings if available.
- Measure the flow of fuel over the same period, using the gas or oil integrator.
- Convert both steam and fuel flow to identical energy unit (e.g. MJ or kJ).
- Calculate the efficiency using the following equation:

$$\text{Efficiency} = [\text{steam energy} / \text{fuel energy}] \times 100.$$

The objective of improving boiler efficiency is to reduce heat losses from the boiler system. Heat losses occur in many forms, such as

- Flue gas;
- Fouled heat-exchange surfaces;
- Hot blow down water; and
- Hot condensate.

12.2 HEAT LOST IN FLUE GAS

12.2.1 Excess Air.

Combustion air is the amount theoretically needed to achieve complete combustion of a given fuel. It is fixed by the oxygen content required to convert all of the carbon and hydrogen in fuel to carbon dioxide and water. Air supplied to the boiler over this theoretical amount is called excess air. In practice, some excess air is always required to ensure complete combustion, but most burners operate with more excess air than they need. Hence, it must be controlled. Excess air reduces boiler efficiency by absorbing heat that would otherwise be transferred to the boiler water

and carrying it up the stack. Excess air can be measured with a flue gas analyser. If the flue gas contains too much excess air, a qualified burner technician should adjust the burner and combustion air dampers to reduce excess air levels over the boiler operating range. The boiler should operate in the “zone of maximum combustion efficiency”. Remember also that along with controlling the excess combustion air in the burner, it is just as important to guard against infiltration (ingress) of unwanted air into the boiler combustion cavity or the flue system through cover leaks, observation ports, faulty gaskets and other openings. Deploying of modern combustion technology, including electronic control, oxygen regulations, flue gas analysers and economizers will bring significant overall energy savings.

12.2.2 Heat-Recovery Methods

Heat loss in flue gas can be substantially reduced by equipment that diverts the thermal energy in flue gases to other parts of the boiler plant. For example, heat exchangers called economizers transfer heat from flue gas to boiler feed water, and combustion-air pre-heaters use the energy in hot flue gases to heat combustion air. A particularly energy-efficient heat recovery option is the direct-contact flue gas condensing unit, which sprays water through the flue gas stream and passes the heated spray water through a heat exchanger to transfer the heat to boiler makeup water or other plant processes. Flue gas condensers recover the latent heat of vaporization and much of the sensible heat from water vapour in the flue gas, and can reduce the flue gas temperature to 38°C. An incidental advantage of direct-contact flue gas condensing is that it removes particles and acid gases (such as SO₂) from exhaust. Some boiler installations deploy heat-reclaim burners to preheat the combustion air. The burners that contain compact beds of heat-storing material cycle rapidly to allow short-time heat storage and reclamation. The combustion air is preheated to within 85 to 95 percent of the flue gas temperature. All boilers would benefit from adding an economizer, air heater or flue gas condenser; however, a comparative analysis of the options is needed to determine which would be most effective.

12.3 Fouled heat-exchange surfaces.

12.3.1 Soot and Scale.

The transfer of heat to boiler water is inhibited by the accumulation of soot on the fireside of a heat-exchange surface and scale on the waterside. Fouled heat

exchanger surfaces also raise flue gas temperatures and increase heat loss from the stack. To keep heat-exchange surfaces clean of soot and scale, ensure that

- Both fireside and waterside surfaces are inspected carefully whenever the boiler plant is shut down;
- Boiler feed water is treated as required to reduce deposits; and
- Soot blowers, brushes or manual lances are used as required.

12.4 Heat recovery from blow down water.

Boiler water must be blown down periodically to prevent scale from forming. If blow down is too excessive; however, heat, water and water-treatment chemicals are wasted. Often, more water is blown down than required to prevent scale formation; in addition, the blow down is usually scheduled once a day or once a shift, so the amount of dissolved solids immediately after blow down is far below the maximum acceptable. Total dissolved solids should be tested and the blow down rate should be adjusted periodically, as minimum measures. If blow down can be done more often, and in smaller amounts, the solids content can be maintained much closer to the maximum desired. Once optimum blow down rates are established, attention can be given to recovering heat from blow down water. This is usually accomplished in two stages:

- Use a flash tank to generate low-pressure steam from the blow down (flash steam can be used in other heating applications such as the de-aerator).
- Use the remaining water in a heat exchanger to preheat make-up water.

12.5 Heat loss in condensate

Whenever possible, hot condensate from steam-using equipment should be returned to the boiler. The loss of condensate from the steam system increases consumption of water, water-treatment chemicals and the thermal energy needed to heat the make-up water. Heat may be lost in the form of flash steam that develops when the process pressure – under which the condensate is returned – is released. This may be partly recovered by submerging the condensate return inlet in the tank or by installing a spray condenser fitted to the top of the tank. A more efficient way is to employ a steam-condensate closed system that allows condensate to return in a closed pressurized loop to be re-boiled. Such a system uses less equipment for the steam process and does not suffer any losses.

12.6 Low NOx combustion

Nitrogen oxides, referred to collectively as NO_x, are generated by the reaction of nitrogen and oxygen at high temperature in the boiler combustion chamber. The main source of reactants is fresh combustion air, which is high in oxygen. NO_x production will not necessarily decrease in direct proportion to fuel economies. The most common way to reduce NO_x production is to reduce the flame temperature by one of several techniques, such as the following:

- Staged-air combustion, in which combustion air is added to fuel in the burner progressively from several locations; and
- flue gas recirculation, in which some flue gas is returned to the burner, thus reducing

the flue temperature and the amount of reactants available to the

12.7 NO_x reaction.

Much research in the low-NO_x technology done in recent years resulted in the development of burners that reduce NO_x but do not affect thermal efficiency appreciably. The appropriate techniques are fuel type-specific. With exceptions, the techniques to control NO_x are not designed to save energy, but they do reduce stack emissions, an equally important goal.

The following energy saving opportunities are in addition to those previously mentioned in this section.

12.8 ENERGY SAVING OPPORTUNITIES

12.8.1 Housekeeping ESO's

- Regularly check water treatment procedures.
- Operate at the lowest steam pressure (or hot water temperature) that is acceptable to the demand requirements.
- Minimize load swings and schedule demand where possible to maximize the achievable boiler efficiencies.
- Check the boiler efficiency regularly.
- Monitor and compare performance-related data to established standards regularly.
- Monitor the boiler excess air regularly.
- Keep burners in proper adjustment.
- Replace or repair any missing or damaged insulation.
- Periodically calibrate measurement equipment and tune the combustion control system.



12.8.2 Low-Cost ESO's

- Install performance monitoring equipment.
- Relocate the combustion air intake.
- Add insulation.
- Reduce boiler excess air.

12.8.3 Retrofit ESO's

- Install an economizer.
- Install a flue gas condenser.
- Install a combustion air heater.
- Incorporate a heat pump.
- Install a new boiler.
- Upgrade the burner.
- Install the turbulator in the fire tube boiler.
- Convert from oil to gas (more a financial saving than an energy saving).
- Install an electric coil burner.

13. STEAM SYSTEM

13.1 Introduction

Steam has been a popular mode of conveying energy since the industrial revolution. Steam is used for generating power and also used in process industries such as sugar, paper, fertilizer, refineries, petrochemicals, chemical, food, synthetic fibre and textiles. The following characteristics of steam make it so popular and useful to the industry:

- Highest specific heat and latent heat
- Highest heat transfer coefficient
- Easy to control and distribute
- Cheap and inert.

13.2 Properties of Steam

Water can exist in the form of solid, liquid and gas as ice, water and steam respectively. If heat energy is added to water, its temperature rises until a value is reached at which the water can no longer exist as a liquid. We call this the "saturation" point and with any further addition of energy, some of the water will boil off as steam. This evaporation requires relatively large amounts of energy, and while it is being added, the water and the steam released are both at the same temperature. Equally, if steam is made to release the energy that was added to evaporate it, then the steam will condense and water at same temperature will be formed.

13.3 Steam Table:

The steam table lists the properties of steam at varying pressures and temperatures:

EXTRACT FROM THE STEAM TABLES					
Pressure (kg/cm ²)	Temperature °C	Enthalpy in kCal/kg			Specific Volume (m ³ /kg)
		Water (hf)	Evaporation (hfg)	Steam (hg)	
1	100	100.09	539.06	639.15	1.673
2	120	119.92	526.26	646.18	0.901
3	133	133.42	517.15	650.57	0.616
4	143	143.70	509.96	653.66	0.470
5	151	152.13	503.90	656.03	0.381
6	158	159.33	498.59	657.92	0.321
7	164	165.67	493.82	659.49	0.277
8	170	171.35	489.46	660.81	0.244

The Steam Phase Diagram

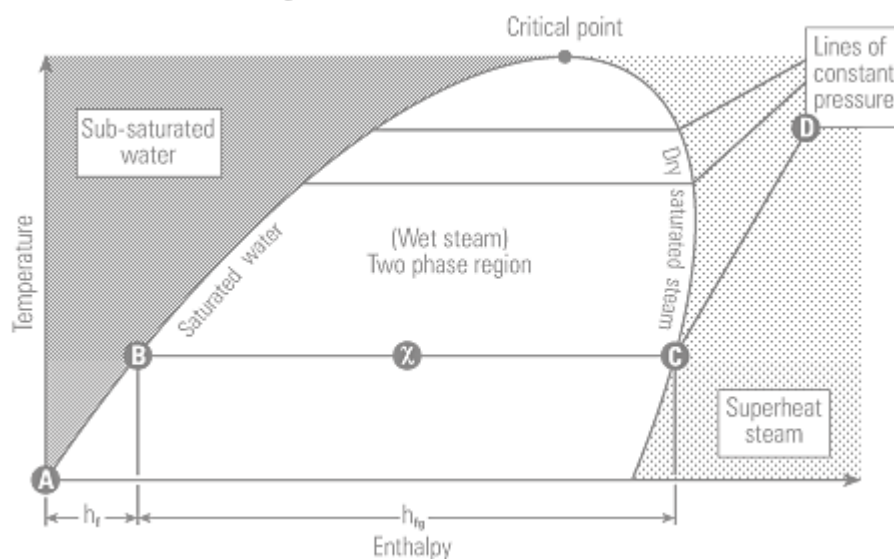


Figure Steam Phase Diagram

Figure illustrates the relationship between the enthalpy and the temperature at various different pressures, and is known as a phase diagram.

As water is heated from 0°C to its saturation temperature, its condition follows the saturated liquid line until it has received all of its liquid enthalpy, h_f , (A - B).

If further heat continues to be added, it then changes phase to saturated steam and continues to increase in enthalpy while remaining at saturation temperature, h_{fg} , (B - C).

As the steam/water mixture increases in dryness, its condition moves from the saturated liquid line to the saturated vapour line. Therefore at a point exactly halfway between these two states, the dryness fraction (χ) is 0.5. Similarly, on the saturated vapour line the steam is 100% dry.

Once it has received all of its enthalpy of evaporation, it reaches the saturated vapour line. If it continues to be heated after this point, the temperature of the steam will begin to rise as superheat is imparted (C - D).

The saturated liquid and saturated vapour lines enclose a region in which a steam/water mixture exists - wet steam. In the region to the left of the saturated liquid line only water exists, and in the region to the right of the saturated vapour line only superheated steam exists.

The point at which the saturated liquid and saturated vapour lines meet is known as the critical point.

As the pressure increases towards the critical point the enthalpy of evaporation decreases, until it becomes zero at the critical point. This suggests that water changes directly into saturated steam at the critical point.

Above the critical point only gas may exist. The gaseous state is the most diffuse state in which the molecules have an almost unrestricted motion, and the volume increases without limit as the pressure is reduced.

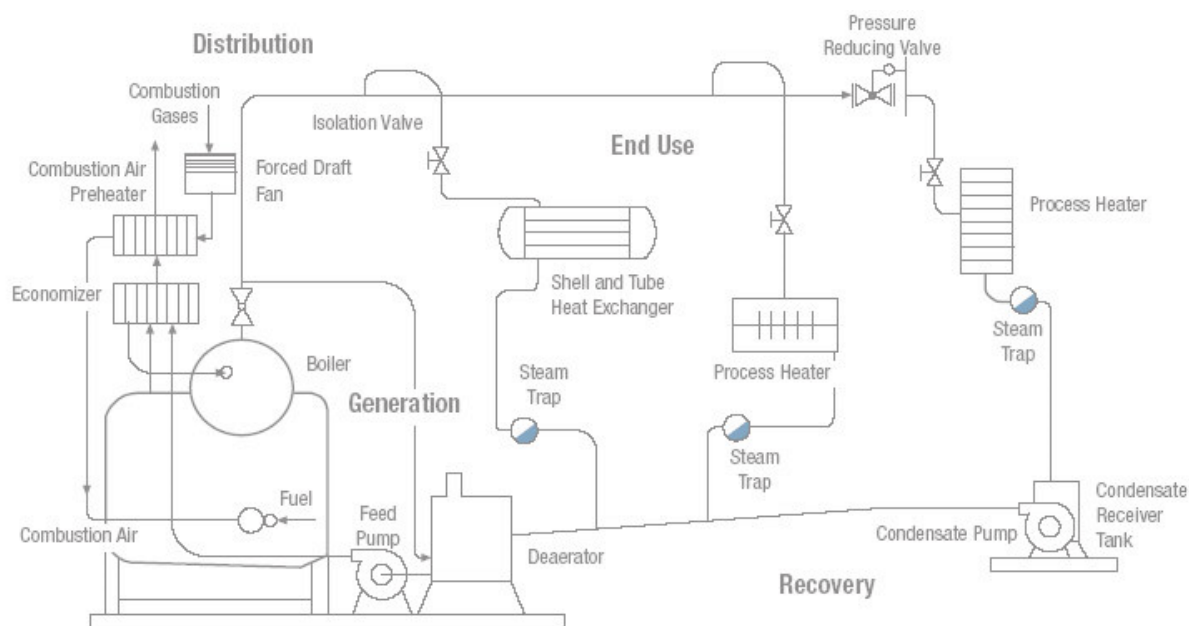
The critical point is the highest temperature at which liquid can exist. Any compression at constant temperature above the critical point will not produce a phase change.

Compression at constant temperature below the critical point however, will result in liquefaction of the vapour as it passes from the superheated region into the wet steam region.

The critical point occurs at 374.15°C and 221.2 bar (a) for steam. Above this pressure the steam is termed supercritical and no well-defined boiling point applies.

13.4 Steam And Condensate System

A steam-distribution and condensate-return system should deliver steam efficiently from the boiler plant to heating systems and processing equipment and return condensate to the boiler for re-use. Some energy is always lost from a steam and condensate system, most significantly in steam trap loss. Others include heat loss from piping and fittings (insulated and un-insulated), leaks and flash losses, condensate loss to drain and overall system losses. This section is intended to help you find and correct the sources of energy loss.



Steam And Condensate System

13.4.1 Pipe redundancy

Redundant steam pipes serve little or no purpose, yet they are at the same temperature as the rest of the system and so the heat loss per length of pipe remains the same. Moreover, the redundant pipes receive scant maintenance of insulation, leaks and steam traps. In addition, the heat losses from the extra piping add to the space heat load of the facility and thus to the ventilation and air-conditioning requirements.

In any review and rationalization of the steam and condensate network, the first step should be to eliminate redundant pipe work. It is estimated that in older facilities it is possible to reduce the length of piping by 10 to 15 percent. Redundant pipe work wastes energy.

13.4.2 Steam leaks

Steam leaks at pipe fittings, valves and traps can result in substantial energy losses. Also, water leaked from the system must be replaced and chemically treated, which is a less apparent but still expensive consequence.

13.4.3 Steam trap losses

Steam traps are key components of an efficient steam and condensate system. However, because defective traps are difficult to detect, they are also among the chief causes of energy loss. Energy losses from steam traps occur for several reasons:

- the trap fails in the open position and permits live steam to escape;
- the wrong type or size of trap is installed;
- the trap is installed in the wrong place; and
- the method used to install the trap was faulty.

All facilities that use steam for heating or process should implement a regular steam trap inspection and maintenance program.

13.4.4 Heat loss through un-insulated pipes and fittings

Bare or improperly insulated steam pipes are a constant source of wasted energy because they radiate heat to the surroundings instead of transporting it to steam-using equipment. The heat losses reduce the steam pressure at the terminal equipment. This situation increases the boiler load because extra steam is required to make up the losses.



All steam pipes should be inspected frequently. Un-insulated steam pipes should be insulated, and the insulation should be inspected and replaced when damaged. Loose-fiber insulation (e.g. mineral and glass fiber, cellulose) loses effectiveness when wet and outdoor pipes are particularly vulnerable to moisture. Therefore, pipe inspections should cover vapour barriers and weatherproof jackets. The economic thickness of insulation for steam pipes (i.e. the best compromise between the cost of insulation and the potential savings in energy) is based on the size of the pipe and the temperature of the environment. However, energy loss is not restricted to the piping system. Process equipment and terminal heating units can also represent a major source of energy loss.

13.5 ENERGY SAVING OPPORTUNITIES

13.5.1 Housekeeping ESO's

- Set up steam trap maintenance program and procedures.
- Check and maintain proper equipment operation.
- Check and correct steam and condensate leaks.
- Maintain good steam quality (i.e. maintain chemical treatment program).
- Check control settings.
- Repair damaged insulation.
- Shut down equipment when not needed.
- Shut down steam and condensate branch systems when not needed.

13.5.2 Low-Cost ESO's

- Improve condensate recovery.
- Overhaul pressure-reducing stations.
- Operate equipment efficiently.
- Insulate uninsulated pipes, flanges, fittings and equipment.
- Remove redundant steam and condensate piping.
- Reduce steam pressure where possible.
- Re-pipe systems or relocate equipment to shorten pipe lengths.
- Repair, replace or add air vents.
- Optimize location of sensors.
- Add measuring, metering and monitoring equipment.

13.5.3 Retrofit ESO's

- Upgrade insulation.
- Eliminate steam use where possible.
- Institute a steam trap replacement program.



- Optimize pipe sizes.
- Recover flash steam.
- Stage the depressurization of condensate.
- Recover heat from condensate.
- Install closed-loop pressurized condensate return.
- Meter steam and condensate flows.

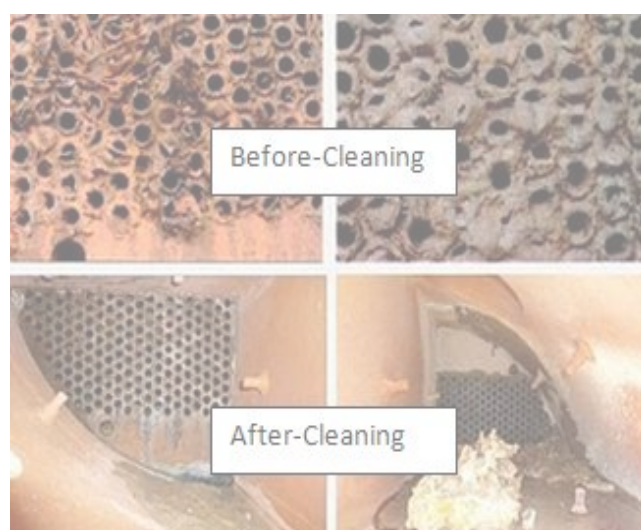
14. HEAT EXCHANGE EQUIPMENT (STEAM AND WATER)

In this section, only the indirect heating or cooling will be considered; this refers to situations where steam or cooling water is separated from a receiving product by a membrane. Steam-heated and water-cooled equipment performs many important process functions, and efficient heating and cooling of process equipment depends on several factors:

- unimpeded heat transfer, both from the steam to the process and from the process to the cooling water, which requires clean heat-transfer surfaces and exclusion of air and condensate from steam;
- rapid removal of condensate from process equipment;
- control of heat losses and gains from process equipment;
- use of process equipment only when necessary; and
- prompt detection and repair of steam and water leaks.

14.1.1 CLEANLINESS OF HEAT-TRANSFER SURFACES

The surfaces between the steam and the product being heated should be kept as clean as possible. Build up of scale on the steam side or sludge on the process side dramatically reduces the efficiency of heat transfer. In water cooled equipment, buildup on heat-transfer surfaces causes similar problems. The sign of this condition in a heating system is an increase in steam



pressure; in a cooling system, it is an increase in the flow rate of cooling water. In both cases, the system is working to overcome the reduction in heat-transfer efficiency caused by scale or sludge.

14.1.2 REMOVING CONDENSATE

Problems caused by condensate usually arise because the condensate is prevented from draining away as it forms. Accumulations of condensate inhibit process heating by preventing steam from entering the equipment. Faulty steam traps, steam coils and heat exchangers are usually the source of condensate problems. With steam traps, the right type and size must be installed, and they must be installed correctly and kept in good working order. Steam coils and heat exchangers also must be installed correctly to ensure that condensate drains efficiently; in a heat exchanger, efficient drainage also ensures that accumulated condensate does not cause water hammer. Water hammer refers to a pressure rise in a pipeline caused by a sudden change in the rate of flow or stoppage of flow in the line – such as flash steam being obstructed by poorly draining condensate. The steam pushes the condensate in “slugs” which act like a battering ram. It is accompanied by a sharp “hammering” sound and vibrations that mechanically stress the pipe work system, often causing serious damage.

14.1.3 INSULATING HEATING AND COOLING EQUIPMENT

Uninsulated heating equipment increases the load on the steam system, which must make up for the heat loss to the surroundings. Applying insulation to the exterior surface of heating equipment reduces the rate of heat loss to the surroundings. Uninsulated cooling equipment similarly increases cooling load because the cooling system must also remove heat gained from the environment. Applying insulation to the exterior surfaces of the equipment reduces the rate of heat transfer from surroundings.

14.2 ENERGY SAVING OPPORTUNITIES

14.2.1 Housekeeping ESO's

- Repair leaks.
- Check and maintain the integrity of insulation.
- Maintain the correct function of instruments.
- Check and maintain steam separators and steam traps.
- Clean heat-transfer surfaces.
- Check and maintain steam quality.



- Reduce steam temperature and pressure where possible.
- Slope heating coils to remove condensate.

14.2.2 Low-Cost ESO's

- Shut down equipment.
- Lock controls.
- Operate equipment at capacity.
- Install thermostatic air vents.
- Add measuring and monitoring devices.
- Access control device locations.

14.2.3 Retrofit ESO's

- Convert from indirect to direct steam heating where justified.
- Install/upgrade insulation.
- Use equipment heat for building heating.
- Stabilize steam and water demand by reviewing process scheduling so as to flatten the peak demands.
- Recover heat from waste streams

15. HEATING, VENTILATING AND AIR-CONDITIONING SYSTEMS

Facilities are served by many different kinds of heating, ventilating and air conditioning

(HVAC) systems, both for human comfort and to meet process requirements. HVAC systems are generally designed to compensate for heat loss and heat gain and to provide ventilation and control of temperature and humidity. An energy



management program for an HVAC system should begin with an assessment of the established HVAC systems to determine their type, function and operating procedures. This assessment will help identify areas of energy waste and opportunities to improve efficiency. Since HVAC systems vary widely from plant to plant, performance improvements and energy cost savings will also vary widely. Three important

factors determine the energy use of an HVAC system:

- the required indoor thermal quality and air quality;
- the internal heat generation from lighting and equipment; and
- the design and layout of the building.

Aspects of HVAC and building design cannot really be dealt with separately since they affect one another.

15.1 ENERGY SAVING OPPORTUNITIES

15.1.1 Housekeeping ESO's

Improving energy-related housekeeping practices is the obvious place to start an energy cost-reduction plan. This happens, to a large degree, by changing people's habits and promoting awareness of energy savings. Here are some of the activities, which cost little or nothing in capital outlay:

- Shut down unneeded equipment during idle or unoccupied periods.

- Shut off lights, computers, photocopiers and other heat-producing equipment when not required; upgrade lighting technology.
- Consider increased use of (northern) day lighting, where possible.
- Check and recalibrate control components such as room thermostats, air and water temperature controllers, set them properly and verify setting of time clocks.
- Establish minimum and maximum temperatures for heating and cooling during occupied and unoccupied periods and re-adjust controls accordingly.
- Adjust airflow rates to suit changing occupancy conditions and use of building space.
- Ensure that vents are open in summer and closed in winter.
- Adjust and tighten damper linkages.
- Check and adjust motor drives on fans and pumps for belt tension and coupling alignment.
- Prevent restrictions of airflow by checking/replacing air system filters.
- Shut off exhaust and make-up air systems to areas such as kitchens and laundries when they are not in use.
- Replace damaged or missing insulation on piping and duct systems.
- Replace or repair crushed or leaking ducts in the air system.
- Clean heat exchange surfaces, heating units and heating coils.

15.1.2 COST-REDUCTION MEASURES

One of the major sources of waste is heating or cooling excess amounts of outdoor air. Excess outdoor air enters buildings by infiltration and through HVAC systems.

15.1.2.1 Reduce heat gain

Reducing heat gain in air-conditioned spaces will reduce the energy used for cooling. Heat gain can be reduced by the following measures:

- Improve building fabric (e.g. insulation, solar shading).
- Shield the building with shade trees.
- Reduce lighting where possible (i.e. upgrade the lighting system).
- Consider increased use of daylighting (particularly northern light).
- Add insulation to hot surfaces.
- Isolate heat-generating equipment and provide local exhaust and make-up air.
- Block unneeded windows.

15.1.2.2 Reduce heat losses

Reducing losses of space heat saves heating energy and leads to improved working conditions and higher worker productivity. Where they apply, the following measures work well:

- Improve building insulation.
- Insulate cold conduits such as pipes and ducts.
- Block unneeded windows.
- Upgrade windows and doors (see tip at left).
- Control air leakage out of the facility (ex-filtration).

15.1.2.3 Reduce humidification requirements

The amount of humidification required in an industrial environment is usually dictated by the process and may require considerable energy.

- Examine current humidification levels for human comfort and production requirements– can they be lowered?
- Make frequent cleaning and monitoring of water used for humidification a part of routine maintenance to ensure efficient operation and to avoid damage to other HVAC components.
- Consider using high-pressure water atomization instead of compressed air humidification for substantial energy savings.

15.1.2.4 Implement an energy management system

For most plants, warehouses and offices that operate less than 24 hours per day or seven days per week, energy savings can be realized from temperature setbacks and reductions in ventilation rates. Depending on the complexity of the HVAC system, implementing an energy management system may be as simple as installing programmable thermostats or as elaborate as installing full direct digital controls.

- Install self-regulating controls for the lighting and ventilation systems.
- Interconnect the controls for spaces with separate heating and cooling systems to prevent simultaneous heating and cooling.
- Install load analysers in the controls of multi-zone and dual duct systems to optimize hot and cold deck temperatures.
- Install load analysers in the controls of terminal reheat systems to optimize the supply air temperature and minimize the reheat load.

15.1.3 Other Low-Cost ESO's

- Install time clocks to shut down the air system or switch to 100 percent recirculation when the space served is unoccupied.
- Install control interlocks to shut down heating or cooling system pumps when no output is required.
- Install economizer controls on the central air handling system to use outdoor air to replace refrigerated cooling when appropriate.
- Add automatic control valves at unit heaters and fan-coil heaters to shut off the flow of water or steam when fans are not running.
- Consider installing variable-speed drives to a centrifugal chiller – savings of up to 40 percent versus a conventional chiller may be possible.
- Provide lockable covers on automatic controls and thermostats to prevent unauthorized adjustment or tampering.

15.1.4 RETROFIT ESO's

15.1.4.1 Heat recovery

An effective way to cut HVAC energy costs is to apply heat recovery technology. However, the biggest problem with these systems is maintenance. Often in a plant environment, the prime effort goes into maintaining production to the detriment of everything else, and that includes the maintenance of heat recovery systems. A poorly maintained heat recovery system may eliminate energy savings and lead to deterioration of indoor air quality. Heat recovery involves reclaiming heat from the building and from process exhaust air and using it to heat make-up air in winter and to coolmake-up air in summer. Both latent heat and sensible heat can be recovered and, if the plant is humidified, may provide considerable savings. The following conditions produce the highest payback with a heat recovery system:

- High-volume, high-temperature differential exhaust, especially if localized;
- High indoor humidity requirements;
- Low internal heat generation in the plant; and
- Existence of a ducted make-up air system.

A heat recovery system should be considered if at least one of these conditions is fulfilled; it may then be economical. Usually, recovery of 65 percent of exhaust heat can be accomplished with a reasonable payback period. However, recent developments now allow heat recovery from even small temperature-gradient streams, and a suitable application should be investigated.

Among the major types of heat recovery equipment are:

- Heat-recovery wheel;
- Heat-pipe heat exchanger;
- Stationary surface air-to-air heat exchanger;
- Run-around glycol-loop heat recovery; and
- Heat pump-based systems.

Each type has advantages and disadvantages. The most suitable type should be selected after a thorough analysis of the proposed application.

15.1.4.2 Equipment Upgrades

Modifying or converting an established, inefficient HVAC system to improve efficiency will save energy.

- Utilizing adjustable speed drives for fans and pumps will improve the HVAC system's operating efficiency and reduce costs.
- Converting constant volume, terminal reheats systems into variable air volume (VAV) systems saves fan energy as well as heating and cooling energy. Multi-zone and dual-duct systems also present opportunities for savings by conversion to VAV systems.
- In areas where heat losses are high, such as in shipping and receiving areas and vehicle repair bays, replacing conventional convection heating systems with gas-fired infrared heaters will save energy. With the radiant heating system, space temperatures can be kept much lower without reducing occupants' comfort.
- Replace electric resistance heaters – the most expensive form of space heating – with an alternative source, such as direct or indirect gas firing or (where possible) boilers.
- For chilled water systems, several options exist:
 - Cooling towers and plate-type heat exchangers can be installed.

15.1.5 Other Retrofit ESO's

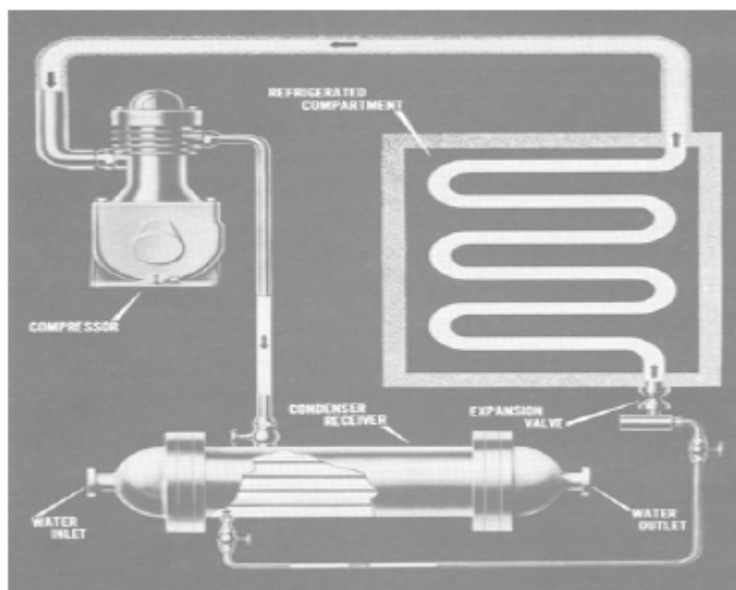
- Install local air treatment units (e.g. electronic air cleaners, activated charcoal odour-absorbing filter, high-efficiency filters) to allow increased (perhaps up to 100 percent) re-circulation of indoor air and reduction of outdoor air required for ventilation.
- Install a separate air system to serve an area that has a unique requirement that would affect the operation of a large central system (e.g. areas that have large heat gain or fluctuating occupancy).



- To reduce overall ventilation, reduce building airflow rates by moving conditioned air from spaces that require a high-quality environment through spaces that have less demanding requirements.
- Install a computerized energy management system to monitor and integrate the control function of the building's energy systems including lighting and HVAC.
- Consider a new heat pump system instead of a new air-conditioning system if winter heating is required. The higher equipment costs will be offset by reduced heating costs during the winter season.

16. REFRIGERATION AND HEATPUMP SYSTEM

Industry uses refrigeration for storage and for processing. The main purpose of a refrigerating system is to remove heat from a process and discharge it to the surroundings. An energy management program for a refrigeration system should begin with an assessment of the local temperatures, process



requirements, refrigeration equipment and systems to identify areas of energy waste and opportunities to improve efficiency. In refrigeration, there are only a few basic ways to save energy, and the following questions should be asked:

- Can we do away with some refrigeration needs?
- Can we remove/reduce some of the refrigeration loads?
- Can we raise the refrigeration temperatures?
- Can we improve the way the refrigeration plant operates?
- Can we reclaim waste heat?

The purpose of the following brief mention of industrial heat pumps (IHPs) is to alert the reader to the many advantages that this relatively new technology offers and to stimulate the integration of IHPs into the wider process heating system.

IHPs are devices that use low-grade heat (such as waste-process heat or water, or ground heat) as the heat sources and deliver this heat at higher temperatures for industrial process for heating or pre-heating. Some IHPs can also work in reverse, as chillers, dissipating process heat as well.

The types of heat pumps include

- air-to-air;
- water-to-air;
- air-to-water; and
- water-to-water.

The latter category, used in ground-source heat extraction (or dissipation) applications, is increasingly being considered for applicability. Perhaps because of the newness of the technology – or the lack of IHP knowledge among engineering

firms and target industries or the small numbers of available demonstration projects – the wider use of IHPs is only beginning. Yet, using an IHP system is a valuable method of improving the energy efficiency of industrial processes, which contributes to reducing primary energy consumption.

The major categories of IHPs can be described as follows:

- closed compression cycle, driven by
 - electric motor
 - diesel engine;
- absorption cycle, of two types:
 - heat pump
 - heat transformer;
- mechanical vapour recompression (MVR); and
- thermal vapour recompression (TVR).

To discuss these systems is beyond the scope of this Guide. However, a knowledgeable consulting engineer can help in selecting and designing the most suitable system for a given application.

16.1 ENERGY SAVING OPPORTUNITIES

16.1.1 Housekeeping ESO's

There are numerous opportunities for energy and rupees savings in industrial refrigeration. Typically, industrial refrigeration merits little attention and is poorly understood compared with boiler plants. To improve the situation i.e. learning to identify the losses of energy and then reducing these losses is good energy management.

Improving energy-related housekeeping practices is the obvious place for an energy cost education plan to start. Housekeeping measures generally involve the following activities, which cost little or nothing in capital outlay:

- Operators may lack proper understanding of refrigeration efficiency issues—educate and train them first.
- Be vigilant in addressing operation and maintenance issues as they arise.
- Establish a regular testing program so that problems are quickly identified.
- Establish maintenance and preventive maintenance programs.
- Clean heat-transfer surfaces (evaporator, condenser) frequently.
- Inspect insulation on suction lines frequently and repair damage promptly.
- Calibrate controls and set temperatures to the highest acceptable levels.

- Keep refrigerant charges at specified levels; eliminate leaks.
- Ensure free circulation of air around condensing units and cooling towers.
- Ensure that heating and cooling systems are run simultaneously only when absolutely necessary.
- Eliminate ingress of moisture to refrigerated rooms from ambient air and water hoses (remember that to evaporate one litre of water requires approximately 500 kg of refrigeration energy).
- Keep the doors to refrigerated areas closed.
- Ensure that controls for defrosting are set properly and review the setting regularly.
- If water for condensers is supplied from cooling towers, ensure that they are effectively maintained to obtain the lowest water temperature possible.
- Measure the compressor coefficient of performance (COP) and the overall system's COP, which includes auxiliary equipment.
- Check for the correct head pressure control settings.
- Use low ambient temperatures to provide free cooling to suitable loads during winter and shoulder seasons.

16.1.2 Cost-Reduction Measures

A refrigeration system is analogous to a pumping system that pumps water from a low level to a high level. The higher the pump has to lift the water, the more energy it consumes per unit volume of water. Most cost-reduction measures for refrigeration systems are designed to increase the difference between the temperatures at which condensation and evaporation take place, thereby increasing the COP. The following cost-reduction measures increase the COP by reducing or allowing the reduction of condensing temperatures:

- De-superheat vaporized refrigerant by use of a heat exchanger or by injecting liquid refrigerant into the hot gas discharge (enhances condenser efficiency).
- Use floating head pressure.
- Use liquid pressure boost to allow further reduction in condensing pressure.
- Move the outdoor condenser coil into a clean, cool exhaust-air system.
- Equip the cooling tower with an automatic water-treatment system.

The following cost-reduction measures increase the COP by increasing evaporation temperature:

- Set the evaporator temperature as high as the process permits.
- Install automatic controls to use higher evaporator temperatures under part-load conditions.

Other cost-reduction measures are designed to fine-tune controls to operate the system at peak efficiency, thus reducing heat gain and peak electricity demand. Some of these cost-reduction measures are as follows:

- Upgrade automatic controls in refrigeration plants to provide accurate readings and to permit flexible operation.
- Reschedule production cycles to reduce peak electricity demand.
- Install variable-speed drive fan motors on cooling towers, evaporative coolers and air-cooled condensers.
- Upgrade insulation.
- Replace inadequate doors to cold areas.
- In winter, operate evaporative coolers and condensers with dry coils to eliminate heat tracing and pan heating.
- Consider eliminating hot gas bypass by cycling the refrigeration system.
- Avoid the use of compressor capacity control systems, which throttle the inlet gas flow, raise the discharge pressure or use hot gas bypass.

16.1.3 RETROFIT ESO's

Retrofitting may present opportunities for the greatest energy savings but it requires a more detailed energy analysis and the capital cost is usually higher. Retrofitting permits more radical ways to save energy, such as the following:

16.1.3.1 Matching the Compressor to the Required Duty

Use the best compressors suited for duty at any given time. Sequence the compressors on the basis of the load and their respective efficiencies. Correct sequencing is most important in the case of part loads. Ensure that only one compressor operates at part load. If a choice of compressors exists for part load operation, use a reciprocating compressor instead of a screw or centrifugal compressor, which has poor part-load performance.

16.1.3.2 Switching to a Different Energy Source

Internal combustion engines or turbines fuelled with natural gas, diesel or other fuels can replace electric motors to drive refrigeration compressors. This may provide a less expensive energy input and has a better part-load efficiency than electrical motors. Moreover, it may help to reduce the peak power demand. The capital and maintenance costs of replacing prime motors are often too high to justify; however, since the combustion-driven unit affords heat recovery from the engine/turbine jacket and exhaust to supply other heating loads, overall cost savings can be achieved.



16.1.3.3 Absorption Refrigeration

The most promising alternative to mechanical refrigeration is absorption chilling, which does not require electrical energy input. It becomes more economical when reject heat from plant processes or a cogeneration system is available. Energy savings may offset the comparatively high cost of absorption equipment.

16.1.3.4 Using Thermal Coolant Storage

Thermal coolant storage saves energy by permitting the use of smaller refrigeration equipment operated at peak efficiency for long periods. Thermal storage is most useful in facilities where the cooling load tends to peak. A plant where the cooling load is constant for more than 16 hours per day cannot benefit from thermal storage. Coolant storage, using ice tanks, eutectic salts or super cooled secondary refrigerant will maximize the use of night-rate power. It will also reduce the requirement for additional chiller capacity if increased cooling demand is needed. Thermal storage reduces compressor cycling and allows continuous operation at full-load and higher efficiency.

16.1.3.5 Reclaiming Condenser Heat

Heat reclaimed from the refrigeration cycle can be used for domestic water heating, space heating or process heating. Also, the system COP may improve when a cooler condenser medium is available. Here are some ways to use reclaimed heat:

- Recover heat from superheated refrigerant vapour to offset energy required for process heat or to heat make-up water.
- Preheat domestic or process water.

16.1.3.6 Other Methods

Providing decentralized systems in which loads are distributed according to local requirements can usually save energy. For example, if a large system operates at a low evaporator temperature when only a small portion of the load requires low temperature, a small low-temperature system can be installed to serve the special area; the main system can operate at a higher evaporator temperature, improving its COP.

16.1.4 OTHER RETROFIT ESO's



- Segregate refrigeration systems according to temperature; optimize the thermodynamic balance of the refrigeration cycle to dedicate equipment to the minimum required conditions for each process.
- For refrigeration systems that use hairpin coils, consider the use of computer controlled expansion valves and a monitoring system to substantially save electrical energy.
- Consider installing a closed loop system for cooling compressors and condensers.
- Consider replacing shell-and-tube exchangers with high-efficiency plate heat exchangers.
- Make a reasoned, forward-looking choice between 1) using well, river or lake water (where available) as a lower-temperature cooling medium to reduce condensing temperatures and 2) a ground-source heat pump system.
- Use a heat pump to upgrade the low temperature waste heat to a temperature suitable for building heating or process uses.
- Consider adapting an ice-pond system for reliable, low-cost, non-CFC industrial process cooling, at less than 20 percent of the operating energy costs associated with conventional mechanical compression systems. It integrates the benefits of biological ice-nucleators, optimized water atomizing and microcomputer process automation with conventional outdoor ice manufacturing techniques.
- Consider using only water as a refrigerant for process cooling water (e.g. plastic injection). Energy savings of 20 to 50 percent are possible.
- Consider installing secondary refrigeration using volatile fluids at low temperatures.

17. WATER AND COMPRESSED AIR SYSTEM

17.1 WATER SYSTEMS

A facility may have several water systems, some for process use (process cooling water, chilled water) and some for building services (potable water, domestic hot water). Whatever their function, water systems tend to have similar inefficiencies and Energy saving opportunities. The energy cost in operating water systems can be



reduced with proper attention to the following areas:

- detecting and eliminating leaks;
- examining water use patterns and reducing water consumption to the minimum necessary;
- imaginative re-use and recirculation of process and cooling waters;
- reduction of friction losses and the associated pressure drops;
- reduction of heat loss from hot water systems and heat gain to chilled water system; and
- correct choice and sizing of pumps and reduction of pump operating time.

Knowing the local rates, you can calculate the unnecessary costs above. Chances are that there may be several leaks in a plant at the same time.

17.1.1 COOLING WATER

A cooling-water system should be designed to recirculate water through the cooling tower. This will drastically reduce water purchases, treatment costs and the cost of disposal down the sewer.

Evaluate the economics of a cooling tower installation from



a long-range perspective. Take into account the costs of electricity to operate fans and pumps, water treatment and make-up water to compensate for evaporation and blow down, and maintenance.

17.1.2 HOT AND CHILLED WATER SYSTEMS

Pipes carrying hot or chilled water should be well insulated to prevent heat loss or heat gain. Chilled-water piping should also have a vapour barrier to prevent condensation from saturating the open-fiber insulation.

17.1.3 OTHER WATER SYSTEMS

Water pumps should be shut off when the systems they are serving are not operating. This measure will reduce the electricity costs for pumping and, in the case of cooling water, the cost of water treatment. Strainers and filters should be checked regularly to ensure that they do not become clogged. Clogged filters cause losses in pipeline pressure. To prevent water losses, inspect pipes frequently and repair leaks promptly; also, reduce evaporation from tanks by installing covers.

17.1.4 ENERGY SAVING OPPORTUNITIES

17.1.4.1 Housekeeping ESO's

- Install good housekeeping practices in all employees maintain awareness and transform the newly acquired knowledge into habit.
- Do not let water run unnecessarily (taps, hoses, eyewash fountains, drinking fountains, etc.).
- Check and adjust as necessary the appropriate water heating set points, aiming at the minimum required temperature levels.
- Prevent or minimize (particularly hot) water tank overflow occurrences.
- Maintain proper control over water treatment to ensure that design flows are maintained.
- Maintain properly monitoring and control equipment.

17.1.4.2 Low-Cost ESO's

- Install water meters in different process areas to monitor consumption on an ongoing basis. Use the data to identify zones, equipment and crews with either inconsistent or inefficient performance to correct deficiencies and to set progressively tighter consumption targets.



- Review the areas where high-volume, low-pressure rinsing or flushing makes sense

(e.g. at the bottle filler) and where the use of low-volume, high pressure water flow

(nozzles) is called for.

- Identify all hoses and ensure that the smallest diameter necessary is used for the task.
- Fit hoses with automatic cut-off valves (guns) where appropriate.
- Re-use all rinse water from cleaning operations, with due regard to product quality implications, wherever possible (for example, during the cleaning in place last rinse).
- Collect uncontaminated cooling water for re-uses.
- Install adequate holding tanks to suit the requirements of water re-use system.
- Install water system expansion tanks to serve two purposes. When the water is hot, wastage through relief valves will be prevented. When the water is cold, the contracted volume would demand make-up water to keep the system filled.
- Ensure that hot and cold pipes and water systems are properly and adequately insulated.
- Install flow regulators for sanitary uses: delayed closing/timed flow taps on hand wash basins in restrooms and reduced-flow showerheads.
- Reduce water leakage/waste by bringing the water pressure down in areas where high pressure is not needed.

17.1.4.3 Retrofit ESO's

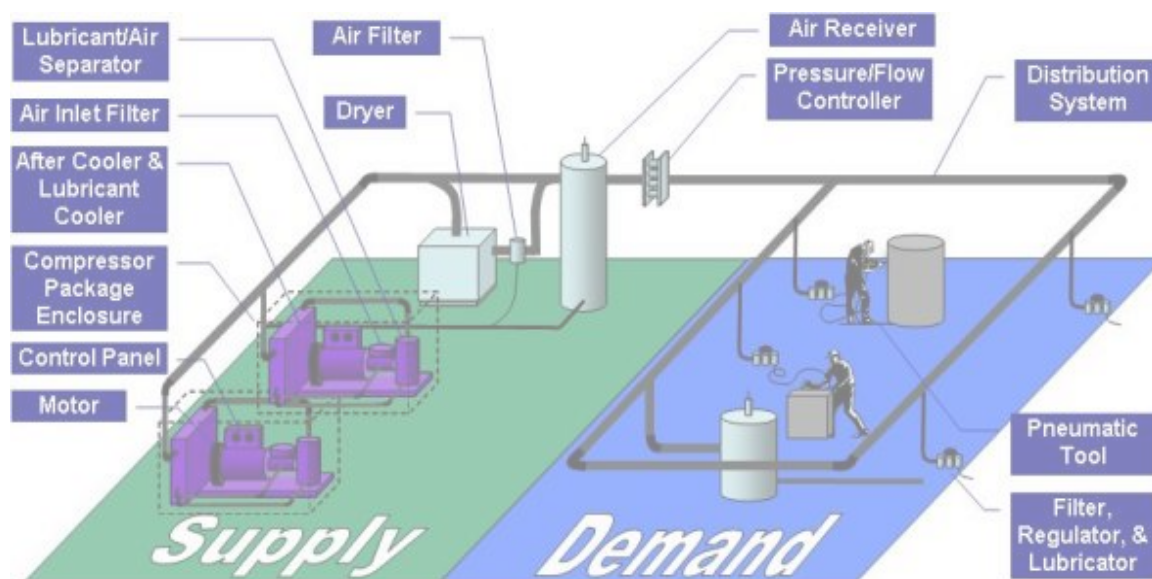
- Segregate the hot water system according to the various temperature requirements to reduce unnecessary tampering. Consider setting up a system where discrete hot water boilers feed loads of similar temperature so that the highest temperature does not dictate all loads.
- Install water meters in different process areas to monitor consumption on an ongoing basis. Use the data to identify zones that have equipment and either inconsistent or inefficient performance to correct deficiencies and to set progressively tighter consumption targets.
- Can a once-through system be converted to a circulating system? Revise the water distribution system to incorporate multiple re-use (re-circulation) of process water wherever possible, employing suitable heat recovery regimes, and implement the measures.

- Make water management part of a computer-monitored and controlled system of overall brewery utilities management.
- Review pumps sizing, water pressure requirements and delivery distances versus the piping diameter. Often, smaller pumps but larger diameter piping to reduce friction losses provide for more energy efficiency and make better economic sense when all costs are considered.
- Streamline piping systems. Remove redundant, unused branches.
- Upgrade pumps.

17.2 COMPRESSED AIR SYSTEMS

Leaks of compressed air are the most common and major cause of inefficiency, typically accounting for about 70 percent of the total wastage. Energy losses in a poorly maintained air system arise from the additional energy needed to overcome equipment inefficiencies since the air may not be delivered at the correct pressure.

Long-term cost of compressed air generation is typically 75 percent electricity, 15 percent capital and 10 percent maintenance. Simple, cost-effective measures can



save 30 percent of generating electric power costs. Consequently, the effort to make compressed air system energy efficient is highly profitable. The work should include a thorough audit of the compressed air system (i.e. examinations of compressed air generation, treatment, control, distribution, end use and management). The costs of operating a compressed air system can be reduced in several ways, as described in the following.

17.2.1 ENERGY SAVING OPPORTUNITIES

17.2.1 Housekeeping ESO's

- Commit to a plant-wide awareness program about compressed air management and energy efficiency.
- Shut off compressed air delivery when not required.
- Avoid the expensive and wasteful practice of using compressed air for cleaning ("dusting off") and cooling duties.
- Prevent leaks in the distribution system. Losses usually occur at joints, valves, fittings and hose connections.
- Generate compressed air at the lowest pressure suitable for the task; never generate at too high a pressure only to reduce it to a lower operating pressure later. Higher pressures are often used to compensate for poor air tool maintenance or undersized air lines.
- Check that the system is not faulty (it requires higher than design pressure).
- Maintain air filters.
- Implement regular maintenance, inspection and preventive maintenance programs of the system as well as of the control and monitoring equipment.

17.2.1.1 Low-Cost ESO's

- Institute compressed air management, parts of which
 - are instituting metering of the usage by end-point users;
 - instituting user's fiscal accountability for the compressed air usage; and
 - Requiring the users to justify the compressed air use.
- Eliminate items such as hoses and couplings on air systems wherever practical in order to reduce the possibility of leakage.
- Ensure proper maintenance program for the compressed air-using equipment as well (proper lubrication, etc.).
- Check that there are no problems with piping that might cause system pressure drops, particularly if the system is to be expanded.
- Use intake air from the coolest location, possibly by direct ducting of fresh intake air from the outside.
- In air-cooled compressors, discharge the cooling air outdoors during the summer and use it indoors for space heating during the winter.
- Ensure that the system is dry: correct slopes of the piping, drainage points, and take-off points (always on top of piping). Beware of piping corrosion; it increases internal piping resistance and can lead to pitting and leaks. In winter, it may cause equipment freeze-ups.



- Remove obsolete compressed air piping to eliminate air losses, leak repair costs and other ongoing maintenance costs.
- Switch off compressors when production is down. If compressed air is needed for instrumentation, install a separate compressor for this function; it will save wear on the main compressors as well.
- When reciprocating compressors and screw compressors are used in parallel, always maintain screw compressors at full load. When partial loads are required, use the reciprocating compressor and shut down the screw compressor.
- Minimize the air dryer regeneration cycle by installing a controller based on dew point measurement.
- Enclose compressors (if applicable) to prevent heat infiltration into buildings if not desired.
- If compressors are water-cooled, look for ways to recover heat from the cooling water circuit and/or for recycling the water for use elsewhere.
- Make piping changes necessary to shut off production areas where and when there is no demand (off shifts, weekends).
- Minimize the system's constant losses through minor leaks and continuous consumption of various pieces of measuring equipment by fitting section valves.

17.2.1.2 Retrofit ESO's

- Consider improving the efficiency of the total system by integrating independent compressed air generating/distributing circuits where possible.
- Consider installing an intelligent control system to control air compression installations and to achieve about 10 percent energy savings by maintaining the compressor's output pressure at the lowest possible level and minimum idle running time.
- Evaluate installation of a combustion engine-driven compressor unit as it provides a less expensive energy input and has better part-load efficiency than electrical motors. It also affords heat recovery from the engine jacket and exhaust.
- Upgrade the compressed air dryer for an energy-efficient version (energy savings of up to 85 percent may be possible).
- On older compressors, consider installing a generously sized buffer tank to improve compressor loading.
- In large facilities, consider installing an automatic leak-measuring scheme run by a central control, regulation and monitoring system.

- Consider installing an airtight plastic pipe distribution network to replace old steel pipe and corroded and leaking circuits, particularly for buried installations.

17.3 FANS

Centrifugal fans are most commonly used for industrial air handling and HVAC applications. All centrifugal fans operate according to laws related to performance variables, as follows:

- Airflow varies in proportion to fan speed.
- Total differential pressure is proportional to the square of fan speed.
- Power requirement is proportional to the cube of fan speed.

The fan laws show that changes in airflow and resistance to airflow can significantly affect the amount of power required by the fan. This highlights the importance of ducting that does not restrict airflow. Energy consumption by fans is influenced by many other variables, some of them



related to operating and maintenance tasks. Other factors that affect energy use by fans are related to the air-conveying system in which the fan is installed. Correcting inefficiencies in the air-conveying system can be expensive; however, such measures tend to pay back quickly. The energy consumed by the driving motor represents the total of the energy required by the fan to move air and the energy lost in the fan, the motor and the drive. Therefore, it is desirable to choose high-efficiency fans, drives and motors.

17.3.1 ENERGY SAVING OPPORTUNITIES

17.3.1.1 Housekeeping ESO's

- Implement a program of inspection and preventive maintenance to minimize component failures.
- Check and adjust belt drives regularly.
- Clean and lubricate fan components.
- Correct excess noise and vibration.
- Clean or replace air filters regularly.
- Clean ductwork and correct duct and component leaks to reduce energy costs.



- Shut down fans when no longer required.

17.3.1.2 Low-Cost ESO's

- Streamline duct connections for fan air entry and discharge to reduce losses.
- Optimize or reduce fan speed to suit optimum system airflow, with balancing dampers in their maximum open positions for balanced air distribution.

17.3.1.3 Retrofit ESO's

- Add a variable speed motor to add flexibility to the fan's performance in line with changing requirements.
- Replace outdated units with more efficient equipment, correctly sized.
- Replace oversized motors with high-efficiency motors, correctly sized.
- Where a central system must satisfy the requirements of the most demanding sub-system, consider decentralizing the major system into local sub-systems, each serving its own unique requirements.
- Consider controlling the local ventilation system with ultrasonic occupancy sensors.

18. PUMPS

Pumps belong to one of two types, depending on their operating principle:

- *Centrifugal or dynamic pumps*, which move liquids by adding kinetic energy to the liquid; and
- *positive displacement pumps*, which provide a constant volumetric flow for a given pump speed by trapping liquid in cavities in the pump and moving it to the pump outlet. Pump operation resembles fan

operation in that both devices move a substance through a distribution network to an end user. Both pumps and fans, and their drives, must be large enough to overcome the resistance imposed by the distribution system. However, the size of a pump must also take into account the difference in elevation between the pump and the end user, which influences the power requirement of the pump significantly. As in fan systems, the cost of energy to operate a pump system can be reduced by installing high-efficiency pumps, motors and drives.



18.1 Pump Seals

The type of shaft seals installed on a pump and the quality of maintenance performed on the seals can have a significant effect on energy consumption. The two most common types of seals are mechanical and packing-gland seals. Both increase shaft friction and, hence, the amount of power the pump requires; however, the increase in power requirement imposed by packing gland seals is, on average, six times greater than that imposed by mechanical seals.

18.2 Options for Energy-Efficient Pump Operation Flow Control

Pumps should be carefully sized to suit the flow requirements. If a review shows that a pump is capable of producing more flow or head than the process requires, consider the following measures:

- In applications where the flow is constant, reduce the size of the impeller on a centrifugal pump, if possible. This usually permits use of a smaller motor.
- Install a variable speed drive on pumps where the load fluctuates.
- Optimize pump impellers (change-out) to ensure that the duty point is within the optimum zone on the pump curve.
- Maintain pumps through regular inspection and maintenance to monitor performance for an early indication of failure.

18.3 OTHER ENERGY SAVING OPPORTUNITIES

18.3.1 Housekeeping ESO's

- Shut down pumps when they are not required.
- Ensure that packing glands on pumps are correctly adjusted.
- Maintain clearance tolerances at pump impellers and seals.
- Check and adjust the motor driver regularly for belt tension and coupling alignment.
- Clean pump impellers and repair or replace if eroded or pitted.
- Implement a program of regular inspection and preventive maintenance to minimize pump component failures.

18.3.2 Low-Cost ESO's

- Replace packing gland seals with mechanical seals (see preceding).
- Trim the pump impeller to match system flow rate and head requirements.

18.3.3 Retrofit ESO's

- Install a variable speed drive to address demand for liquid flow with flexibility.
- Replace outdated/unsuitable equipment with correctly sized new units.
- Replace oversized motors.
- Consider installing a computerized energy management control system.
- Consider installing variable voltage, variable frequency inverters to allow motor speed to be continuously varied to meet load demand (power savings range from 30 to 60 percent).

19. COMPRESSORS AND TURBINES

19.1 COMPRESSORS

Compressors are widely used in industrial settings to supply motive power for tools and

equipment and, in controls, as the source of air for transmitting signals and actuating valves and other devices. Like steam, water and electricity, compressed air is a plant utility that is easily wasted if certain basic precautions are not taken, such as the following:

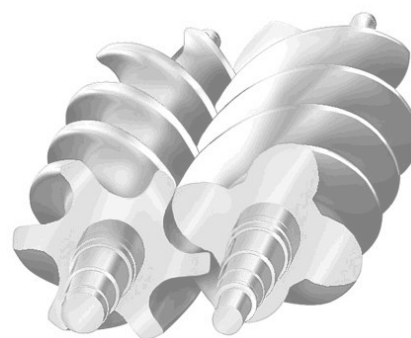
- Use as little compressed air as possible.
- Use compressed air at the lowest functional pressure.
- Maintain compressors at maximum efficiency.

The energy consumed by the driving motor of a compressor represents the total power required by the compressor to compress the air or gas, plus energy losses from the compressor, drive and driver. Therefore, it is desirable to select the compressors, drives and driving motors with the highest energy efficiency to obtain the most efficiently operating whole.



19.1.1 Reduce Compressed Air Consumption

Reducing consumption of compressed air reduces the amount of energy required to run the compressor. This is accomplished by maintenance measures such as promptly repairing leaks in the distribution system and by ensuring that compressors and compressed air equipment are shut off when not in use.



19.1.2 Reduce Pressure in the Compressed Air System

Since the power required by the compressor is directly proportional to the operating pressure, operating at the lowest pressure needed to satisfy system requirements can reduce energy costs.

19.1.3 ENERGY SAVING OPPORTUNITIES

19.1.3.1 Housekeeping ESO's

The following operating and maintenance items should be reviewed regularly to ensure that compressors are operating at maximum efficiency:

- Inspect and clean compressor air-intake filters regularly to maintain the lowest resistance (pressure drop) possible and reduce the compressor's energy use.
- Ensure that the compressor is supplied with the coolest intake air possible.
- Check the operation of compressed air system coolers – maintain cleanliness of heat-transfer surfaces on both air- and water-cooled compressors to ensure that they do not run hot.
- Monitor the compressor plant's coefficient of performance (COP) regularly and correct deviations from the standard.
- Maintain mechanical adjustments – ensure that drive belts are kept at the correct tension, that sheaves and couplings are aligned (correct vibrations), and that drive components are properly maintained and lubricated.
- In multiple-compressor installations, schedule the use of the machines to suit the demand, and sequence the machines so that one or more compressors are shut off rather than having several operating at part-load when the demand is less than full capacity.

19.1.3.2 Low-cost ESO's

- Modify or relocate air intakes to cooler locations.
- Modify or replace outdated components with high-efficiency units (e.g. lower-resistance air intake filters, larger-diameter piping).
- Install flow-control devices on cooling system heat exchangers to provide stable operating temperatures and prevent excess water flow.
- Invest in a leak detector or air leak tester to measure total volumetric leakage throughout the compressed air system and the compressor capacity.

19.1.3.3 Retrofit ESO's

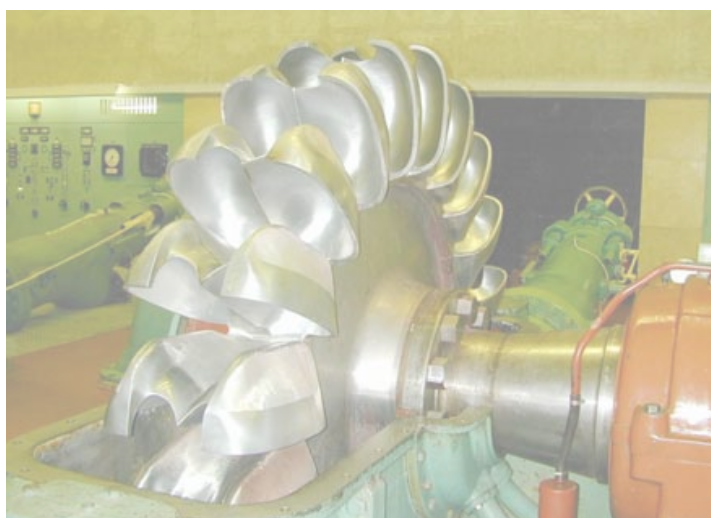
Other efficiency improvement measures for compressors involve capital expenditures and most of these require a detailed analysis by specialists.

- Replace energy-inefficient units such as single-stage air compressors with higher efficiency two-stage compressors.
- Review the compressor plant in use, the type and output of the compressors and the structure of the end-use demand, and consider upgrading them to the most energy-efficient units. This may include a mix of smaller and larger compressors of different types fitted with variable speed drives.

- Consider the economics of decentralizing a major compressed air distribution system that supplies air at the highest pressure required and instead using a sub-system with multiple compressors located near the endues points, which may have lower pressure requirements.
- If only low-pressure air is needed, replace air compressors with pressure blowers.
- Install variable speed controls on compressors to optimize energy consumption.
- Use a large-capacity air receiver or install large-diameter distribution piping in part of the system to serve the same purpose so as to improve air compressor efficiency under fluctuating loads.
- Recover heat from compressor inter-cooler and after-cooler systems and use the heat elsewhere in the facility.
- Consider installing air-cooled compressed air after-coolers in series with water-cooled units to reduce cooling water consumption and assist the plant heating system.
- Where required, enclose the compressor to trap and exhaust unwanted hot or moist air directly outdoors.
- Review and upgrade compressor control (particularly the unloading systems) for situations when its full output is not required.
- In large facilities with massive compressed air requirements and large compressor plants, consider outsourcing the production of compressed air, as some large organizations have done profitably, with attendant energy savings.

19.2 TURBINES

For many years, steam turbines have been used instead of electric motors; in plants with suitable supplies of high-pressure steam, steam turbines are significantly less expensive to run than large electric motors.



As in a compressor system, the energy consumed by a turbine represents the total power required by the driven equipment (e.g. a generator) and the energy losses from the driven equipment, the drive and the turbine. Therefore, it is desirable to select high-

efficiency turbines, drives and driven equipment. Gas turbines are used in applications that require their particular operating characteristics:

- Small size with a high power-to-weight ratio;
- No requirement for external cooling;
- Low requirement for maintenance;
- Low failure rate; and
- Relatively clean emissions.

19.2.1 Operating and Maintenance

Well-maintained, correctly operated steam and gas turbines generally improve the energy efficiency and reduce energy costs. Operating and maintenance improvements usually cost little or nothing. The efficiency of gas turbine operation is influenced by the installation altitude, inlet air temperature and pressure and outlet pressure, as shown in the following. Although little can be done about altitude, the other factors can be affected by ancillary equipment such as intake filters, silencers and waste heat boilers.

- Inlet temperature – each 10 K rise will decrease power output (PO) by 9 percent.
- Inlet pressure – each 10 Pa drop will reduce PO by 0.2 percent.
- Outlet pressure – each 10 Pa increase will reduce PO by 0.12 percent.
- Altitude – each 100 m increase will reduce PO by 1.15 percent.

A gas turbine can generate more power when the intake air is cold. To improve the performance of a gas turbine installed indoors, simply route the combustion air intake to use outdoor air. In warm conditions, chillers and evaporative coolers can also be effective. Both gas and steam turbines should be insulated to reduce heat losses and, consequently, the volume and pressure of the steam or combustion gases. Gas turbines present several opportunities to recover heat for other uses. The hot gas may be used directly for drying and other applications, or a heat recovery boiler may be used to generate steam or hot water.

19.2.2 ENERGY SAVING OPPORTUNITIES

19.2.2.1 Housekeeping ESO's

- Shut steam and gas turbines down when conditions are less than optimum – that is, when the turbines must operate at less than 50 percent capacity (gas turbines) or 30 percent capacity (steam turbines).
- Check and maintain turbine clearances at turbine rotating elements and seals to minimize leakage and ensure maximum energy extraction from the steam or gas stream.
- Check and clean or replace air intake filters regularly.
- Regularly check for vibrations.
- Ensure that steam turbines are operated at optimum steam and condensate conditions.
- Ensure that gas turbines are operated at optimum inlet and outlet conditions.
- Ensure that all speed control systems are functioning properly.

19.2.2.2 Low-Cost ESO's

- Modify or relocate air intake to provide cool air to gas turbines.
- Recover the heat produced by the oil cooler on a gas turbine.
- Install optimum insulation on equipment.
- Optimize the system's operation by adding or relocating control components (e.g. temperature and pressure sensors).

19.2.2.3 Retrofit ESO's

- Preheat gas turbine combustion air with exhaust gas (e.g. with a regenerator).
- Utilize heat from the exhaust of gas turbines.
- Utilize heat from the surface of turbines.
- Modify inlet and outlet pipe work to reduce pressure (i.e. flow) losses.
- Upgrade turbine components for improved efficiency.
- Consider installing an active clearance control system to maintain tolerances and improve the heat-rate efficiency by 0.3 to 0.5 percent.
- Install a back pressure turbine to act as a steam pressure reducing device.
- Increase the efficiency and capacity of a steam turbine, for example, by
 - rebuilding the steam turbine to incorporate the latest steam path technology;
 - letting low-pressure steam directly into the turbine; and



- using a portion of the warm condenser cooling exhaust stream for boiler make-up water rather than cold water from the mains.
- Consider innovative uses of exhaust heat recovery for such purposes as steam generation or absorption refrigeration for sub-cooling.
- Where practicable, consider upgrading the gas turbine system to a full fledged combined heat and power (CHP) (i.e. co-generating) plant.

20. PROCESS FURNACES DRYERS AND KILNS

Many facilities contain fired equipment (e.g. furnaces, dryers and kilns) that consumes fuel directly to heat the process, rather than transferring it from a medium such as water or steam. In these units, the heat is applied directly or indirectly from the flame to the process material.



Furnaces, dryers and kilns, which operate at very high temperatures, may offer many heat-recovery and energy-saving opportunities. Before considering heat recovery options, however, consider the following:

- Examine current practices – is the high heat actually needed?
- Ensure that these systems are operating at maximum efficiency. First, deal with energy losses through excess air, flue-gas temperatures, radiation and conduction.

After examining the above points, consider applying one of the many methods available today to minimize energy requirements and extract heat from exhaust air.

20.1 HEAT LOSSES

20.1.1 Excess Air

The amount of excess air used in a furnace, dryer or kiln varies according to the application; for example, a direct-fired drying oven requires large quantities of excess air to remove vapours quickly from it (see the example preceding). Excess air carries heat away from the process and up the stack, so this air should be monitored and adjusted to the minimum quantity necessary to do the job.

Even small (0.16-cm, or 1/8-in.) gaps around doors, etc. quickly add up to a large open area, and substantial amounts of cold air can infiltrate. The excess air takes away from the heat required to heat the product. Savings will result when the excess air is reduced. Proper maintenance can reduce but seldom eliminate cold air infiltration (except in new equipment); instead, use furnace pressurization and burner flame management and control. Maintaining positive pressure at all times inside the furnace will prevent cold air infiltration through leaks. Technologies that regulate the chimneystack opening and a variety of pulse-fired combustion methods,

together with maintaining steady heat levels (high fire is on most of the time), can also prevent cold air from entering. Combined energy savings may be as high as 60 percent along with substantial emissions reductions.

20.1.2 Radiation and Convection Heat Loss

Heat losses due to radiation and convection from a furnace, dryer or kiln can be high if the enclosure is not properly maintained. Heat loss can occur because of deficiencies such as

- damaged or missing insulation;
- missing furnace doors and covers;
- damaged, warped or loose-fitting furnace doors and covers; and
- openings in the furnace enclosure that allow passage of air.

20.2 CONTROLS AND MONITORING

Without adequate controls, energy efficiency improvement efforts will fail. Monitoring equipment should be installed so that operators can determine energy consumption per unit of output. They can then identify deviations from this standard and take corrective action.

Furnace efficiency can often be improved by upgrading burner controls and their type, as mentioned above. Automating systems that include fuel and airflow meters, gas pressure control, flue damper control through pressure sensors, and tight in furnace conditions monitoring for sloping control will permit closer energy consumption control and lower levels of excess air. Systems with oxygen trim allow for even better control of excess air.

In drying or kilning, the meters can measure final moisture content of dried solids, product quality and heat and power input to the equipment.

The controlling and monitoring technologies incorporate proportional integral derivative controllers, feedback and feed forward control, process integration control, dynamic modeling and expert computer control systems. Generally, the benefits of monitoring and controlling industrial furnaces, ovens and kilns include the following:

- reduced product losses;
- improved product quality and consistency;
- improved operational reliability; and
- energy efficiency improvements of 50 percent or more.

20.3 DRYING TECHNOLOGIES

This section points out briefly the range of technologies currently available for upgrading or retrofitting existing equipment to improve process energy efficiency. To remove water or organic solvents by evaporation, a gas (normally air) is used to transfer the necessary heat to the substrate to be dried in a variety of industrial equipment. The air also carries away the vapour produced. The heating is usually indirect. Drying heat can also be supplied by other means such as dielectric heating (including microwave and radio frequency techniques), electromagnetic induction, infrared radiation, heat conduction through the walls of the dryer and combinations of these methods.

20.3.1 Direct Heating

Direct heating incorporates a mixture of hot combustion gases from a burner, recycled air and fresh air. It eliminates the use of heat-transfer equipment in indirect drying. Hence, the conventional heat losses are reduced from about 40 to 50 percent in steam-using systems to 10 percent in direct heating. Employing hot exhaust gases from a gas turbine in a combined heat and power system further improves the overall efficiency. Since natural gas is the most commonly used fuel, products are not contaminated with exhaust gases; direct heating may be used to dry food products.

Direct heating can be cost-effective. It may be included at the process design stage or retrofitted into an existing dryer. The benefits include more precise temperature control, improved uniformity of heating, increased throughput (i.e. reduction of energy use per unit of production) and the possibility of integrating it into an existing control system.

20.3.2 Electric Heating



This method aims the heating effect of electromagnetic energy precisely to the solid or to the moisture in the solid, thereby avoiding the need to heat a stream of drying air. Efficiency is 100 percent at the point of use, and the efficiency of generation from AC power is 50 percent for radio frequency and 60 percent for microwave energy. Induction drying can be used only when a substrate is an electrical conductor. The benefits of electric heating include precise control of oven temperatures, improved product quality, short startup times, and simpler maintenance of the ovens and reduced environmental impact from the overall process.

The speed of drying also improves dramatically (e.g. to as little as 3 percent of what a conventional process would take, as in ceramics drying). That fact results in short payback periods of one to three years. The energy savings derived from installing an electrically heated dryer depend on the energy efficiency of the dryer being replaced.

20.3.3 Other Measures

To improve the efficiency of dryers and kilns, supplemental processes can be employed:

- Mechanical dewatering, such as with presses;
- De-saturation – by gravity draining, centrifuging or use of an air knife to remove surface moisture; and
- Thermal insulation to system parts that are not insulated or that have insufficient insulation (e.g. burner compartments, ductworks, heat exchangers).

Using superheated steam as the drying medium eliminates the use of air and allows the evaporated water to be used as a source of heat for other processes. Compared with a conventional dryer, the use of superheated steam results in 20 percent less energy being used. With heat recovery techniques, the energy savings can reach 80 percent.

20.4 HEAT RECOVERY

Estimate the economics of a heat recovery system for the given dryer by following these steps:

- Determine the input/output air temperatures and humidities.
- Evaluate the quantity of heat recoverable through process integration.
- From the contractor's quotations, derive value for total cost per kWh of heat recovered to estimate the total cost of the project.
- From local prices, determine the value of each saved kWh.
- Derive the simple payback period.

In a dryer installation, heat recovery may apply to the transfer of exhaust heat to the input air (e.g. by a heat exchanger or by mixing part of the recycled exhaust with fresh input air), to the product or to another process stream or operation. Each heat recovery system must be correctly selected for a given application and for the dryer used. Such systems may include heat pumps (electrically or gas engine-driven), exhaust air recycle systems, heat pipes, direct contact heat exchangers, gas-to-gas plate and tubular recuperators, runaround coils and heat wheels. Seek the advice of a knowledgeable and unbiased consultant for the best solution to your particular problem because you may not receive unbiased advice from a vendor.

Furnace and kiln stack temperatures are generally higher than boiler stack temperatures. Higher temperatures provide several opportunities to recover and re-use heat. The type of heat-reclaim system implemented is driven by how the reclaimed heat will be used. Among the methods for furnace or kiln heat reclaim are heat exchangers (recuperators). They transfer the heat from hot flue gas to combustion air. Regenerative air heaters use two separate sets of refractory bricks, which are alternately heated by the hot flue gas and cooled by the incoming combustion air. In wood-processing plants, which use biomass burners, the heat may also be used to pre-dry the wet bark to be burned.

Another method to improve energy efficiency, particularly in the cement, lime and alumina calcination industries, is with dual fuel burners. These can complement temporary shortages of the primary fuel – carbon monoxide (CO) – with natural gas; plants can therefore avoid energy-wasting kiln shutdowns when CO supply is low.

The energy potential of furnace or kiln waste gases, such as CO, can be put to good use in a variety of industries (primary metals, petrochemical, recycling) by

recovering the heat from the flares. This heat can be used for boiler combustion air pre-heating or even for micro-turbine generator operation.

20.5 ENERGY SAVING OPPORTUNITIES

These ideas are in addition to those presented above:

20.5.1 Housekeeping ESO's

- Paying proper attention to the drying equipment and upstream processes can save 10 percent of the total energy load.
- Implement a program of regular inspection and preventive maintenance.
- Maintain proper burner adjustments and monitor flue gas combustibles and oxygen.
- Keep heat exchanger surfaces clean.
- Schedule production so that each furnace/kiln or drying oven operates near maximum output.
- Maintain equipment insulation.

20.5.2 Low-cost ESO's

- Upgrade or add monitoring and control equipment.
- Relocate combustion air intake to recover heat from other processes (or from within the building).
- Replace warped, damaged or worn furnace doors and covers.

20.5.3 Retrofit ESO's

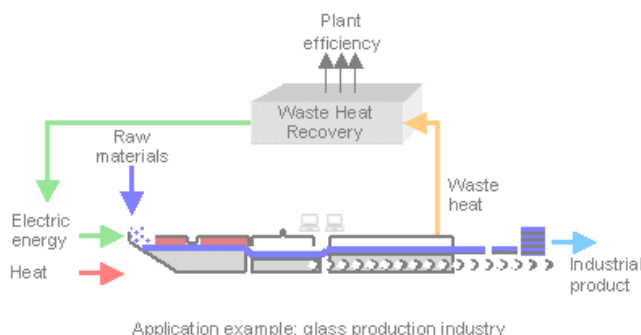
- Install an air-to-liquid heat exchanger to heat process liquids such as boiler make-up water (large systems may permit the use of a waste-heat boiler).
- Install a scrubber to recover heat while removing undesirable particles and gases (captured and recycled particulate matter may help reduce raw material cost).
- Examine other types of drying heat delivery (i.e. modern product heating/drying technologies already described), for replacing outdated drying/curing ovens.
- Examine the use of supplementary fuels for kiln furnace operations.
- Integrate and automate operational control for optimum energy efficiency.
- Change the method of conveying product through an oven to facilitate rapid heat transfer to the product (e.g. exchanging wagons for open heat resistant racks/platforms, etc.).



- Optimize electric arc furnace operations by continuously analysing off-gas combustible hydrogen and CO and by linking it with the regulation of burner ratios, oxygen injections and carbon additions.
- In iron foundries, optimize the use of coke oven gas, blast furnace gas and natural gas by optimizing the distribution system capability, automation and computer control, to minimize flare-offs and natural gas purchases.

21. WASTE HEAT RECOVERY

Waste heat (or surplus heat) recovery is the process of recovering and re-using rejected heat to replace purchased energy. Heat recovery opportunities arise in the process and environmental systems of almost every facility. Recovery and re-use of waste heat can reduce energy costs and improve the profitability of any operation.



Usable energy may be available from

- Hot flue gases;
- Hot or cold water drained to a sewer;
- Exhaust air;
- Hot or cold product or waste product;
- Cooling water or hydraulic oil;
- Ground-source thermal energy;
- Heat collected from solar panels;
- Superheat and condenser heat rejected from refrigeration equipment; and
- Other sources.

In contemplating waste heat recovery, take into account the following considerations:

- Compare the supply and demand for heat.
- Determine how easily the waste heat source can be accessed.
- Assess the distance between the source and demand.
- Evaluate the form, quality and condition of the waste heat source.
- Determine whether there are any product quality implications of the waste heat recovery project.
- Determine the temperature gradient and the degree of heat upgrade required.
- Determine any regulatory limitations regarding the potential for product contamination, health and safety.
- Perform suitability and economic comparisons (using both the payback period and annuity method evaluations) on the short-listed heat recovery options.

21.1 HEAT RECOVERY TECHNOLOGIES

The types of technology that are commonly used to recover waste heat and make it available for re-use are the following:

- Direct usage and heat exchangers make use of the heat “as is.”
- Heat pumps and vapour recompression systems upgrade the heat so that it can perform more useful work than could be achieved at its present temperature.
- There are multi-stage operations such as multi-effect evaporation, steam flashing and combinations of the approaches already mentioned.

21.1.1 Direct Usage

Direct usage involves using the waste heat stream as it is for another purpose. Examples of direct use include using boiler flue gas for drying and using warm exhaust air from a mechanical room to heat an adjacent area. Direct usage techniques require precautions and controls to ensure that the untreated waste stream does not cause harmful effects, such as contaminating the product or endangering health and safety.

21.1.2 Heat exchangers

Heat exchangers and heat pumps have the widest range of applications, regardless of the industry type. Heat exchangers transfer heat from one stream to another without mixing the streams. Heat exchangers belong to one of the following categories, according to use:

- Gas-to-gas (plate type, heat-wheel type, concentric tube, metallic radiation recuperator, Z-box, runaround systems, heat pipes, furnace burner heat recuperation);
- Gas-to-liquid, liquid-to-gas (finned tube, spiral, waste-heat boilers);
- Liquid-to-liquid (plate type, spiral, shell and tube types); and
- Fluidized bed (for severely fouling environments, such as in pulp and paper mills).

A vast array of designs suited to varied needs is available. Due consideration should be paid to selecting proper materials to prevent corrosion or fouling; these may

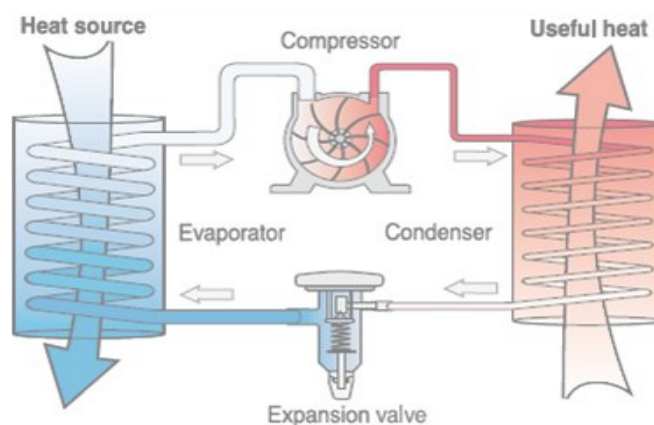
include stainless steel, nickel, special alloys, borosilicate glass, ceramics, graphite, polytetrafluoroethylene (PTFE), enamels and polyester for some applications.

The newly released compact heat exchangers (CHE's) are still at the stage of active development but are being greeted enthusiastically. Their volumes are less than half of those of comparable shell-and-tube heat exchangers, they are more versatile, and they allow more energy to be transferred between the streams (sometimes even multiple streams). A CHE also offers the possibility of combining functions with other unit operations, thus changing the process design radically.

Through the possibility of combining a CHE with reactors and separators, additional applications of energy efficiency opportunities have arisen in fuel cells, absorption cycle machines, gas turbines and reformers. A CHE achieves high heat transfer coefficient in small volumes, usually through extended surfaces. It offers tighter process control. Other techniques, such as rotation, led to the development of compact heat pumps, separators and reactors, also allowing faster processing – all contributing to making process operations more energy efficient.

21.1.3 Heat pumps

Heat pumps enhance the usefulness of a waste energy stream by raising its temperature (a mechanical refrigeration system adds mechanical energy to the stream of recovered heat). A heat pump is most beneficial where heat from a low-temperature waste stream can be upgraded economically.



21.1.4 Vapour recompression

Vapour recompression systems upgrade the thermal content of low temperature vapours by one of two methods:

- **Mechanical vapour recompression (MVR)** – Centrifugal or positive displacement compressors are used to raise the pressure (and thus the temperature) of a vapour stream.

- **Thermal vapour recompression (TVR)** – The temperature of a vapour stream is increased by injecting it with hotter vapour.

21.1.5 Multi-stage operations

Multi-stage operations derive greater energy efficiency through the energy cascading effect in applications that involve heating or cooling. Examples include the sugar, distilling, petrochemical and food industries. In evaporation, energy usage can be reduced by two thirds when a single-effect evaporation is replaced with triple-effect technology.

21.1.6 Absorption heat transformer

The **absorption heat transformer (AHT)** is the newest heat reclamation technology, which until now has been deployed mostly in Japan and Europe.

As the difference between electrical energy and fuel prices grows, this technology will become more widely used. The initial applications were in the rubber, brewing, alcohol, abattoirs and meat packing and ethylene amine production industries; other opportunities are indicated for food, chemical and pulp and paper industries. Application in other industries is being assessed.

An AHT is driven by waste heat only (i.e. no primary energy is used except for a small amount of electricity needed to drive pumps). The transfer medium used is invariably a 60 percent solution of lithium bromide. AHT's have a remarkably rugged COP of about 0.45 to 0.48 and are practically unaffected by temperature conditions.

The COP indicates that about one half of the heat in a waste stream can be upgraded to a usable temperature level. Hence, AHT's are ideally suited to applications in which

- The supply of waste heat considerably exceeds the demand for heat at the higher temperature by a factor of at least two.
- The heat source should have a temperature of 60–130°C, with the heat output approximately 20–50°C higher. Heat can be upgraded to about 15 percent of the

temperature gradient. The maximum possible value of heat demand level is approximately 150°C (because of corrosion concerns).

- Ideally, the heat source is in the form of latent heat and is available in abundance – in the megawatt range. AHTs offer excellent performance even under partial load conditions. It can compete with a boiler and, primarily, with MVR. With due consideration of megawatt size of the installation, the AHT system is favoured economically in comparison with MVR when
 - the electricity/fuel cost ratio is at or above three;
 - the heat source has a temperature of approximately 100°C, with the heat output approximately 40–50°C higher; and
 - there is less sensitivity to temperature conditions.

A very important consideration that may well enhance the AHT application potential is the positive impact of the technology on the environment. As AHT's are driven by waste heat only, emissions from an industrial plant can be substantially reduced.

21.2 ENERGY SAVING OPPORTUNITIES

21.2.1 Housekeeping ESO's

- Identify sources of waste heat.
- Eliminate as many sources of waste heat as possible.
- Reduce the temperature of remaining waste heat.
- Improve equipment inspection and maintenance to minimize the production of waste heat.

21.2.2 Low-cost ESO's

- Capture waste heat from a clean waste stream that is normally discharged to the atmosphere or drain by piping the waste stream to the point of use.
- Utilize the waste process water as a heat source for a heat pump.
- Utilize the heat of the plant effluent being treated in a wastewater treatment plant (where applicable) as a heat source for a heat pump.
- Re-use hot exhaust air for drying purposes.
- Install improved automatic controls.



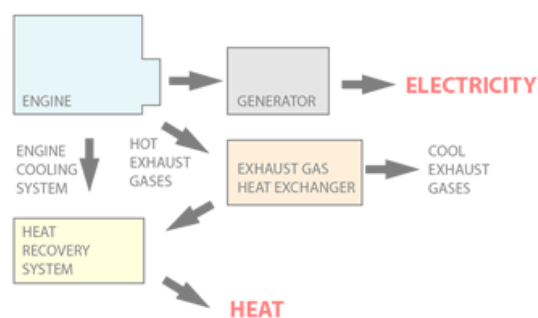
- Consider re-using heat from cooling hydraulic oil circulating (e.g. within moulding machines and the injection moulds themselves); it reduces the electrical load on the production process as well.

21.2.3 Retrofit ESOs

- Install waste heat reclamation equipment (e.g. replacing a cooling tower circulation loop with a shell-and-tube heat exchanger).
- Consider upgrading or replacing outdated waste heat reclamation equipment.
- Consider combining a flue gas heat recuperator with a heat pump and neutralization of an alkaline effluent by the flue gas.
- Consider deploying AHT's.
- Consider installing a CHE and integrating it with other processes.
- In a large computer centre, consider capturing the heat generated by, for example, using cold and hot thermal storage, or by using a double-bundle turbo refrigerator to recover the heat generated by refrigeration.
- Consider converting high-temperature flue gas heat (e.g. from metallurgical furnaces) into superheated steam for steam turbine power generation.

22. COMBINED HEAT AND POWER (CHP)

The units for the simultaneous production of heat and power achieve much greater efficiencies than in the case of separate generation, giving primary fuel savings of 35 percent, with overall efficiencies of 85 percent and more. Combined heat and power (CHP) systems employ a single unit to produce



electricity and heat or sometimes provide shaft power to drive other equipment. They can be economical in situations where heat at an appropriate temperature level is required and a demand for power also exists. The energy efficiency aspect of CHP and its environmental benefits in reduction of CO₂ and NO_x emissions are reasons for a mounting interest in this rapidly developing technology.

A CHP unit typically consists of a prime mover – for generation of electricity –and a heat recovery steam generator.

Before a decision on CHP project initiation can be made, there must be adequate knowledge of the following:

- the electrical and thermal load profiles of the facility that also take into account seasonal variations;
- the price relationship between electricity and fuel;
- the potential for energy conservation and energy efficiency projects;
- the outlook for future energy demand of the facility; and
- investment costs involved and possible financial incentives/assistance.

This will help in selecting the type of prime mover for the system and in selecting the appropriate size. The greatest energy efficiency is obtained when a unit is operating at full load. Hence, situations of extended part-load operation or long shutdowns that may result from using an oversized unit should be avoided.

22.1 TECHNOLOGY

CHP systems are evolving rapidly, and manufacturers offer units that have a great range of outputs, from tens of MW all the way down to the 1-kW level. A lot of effort is devoted to the development of small-scale CHP technologies. They are based

mainly on the Rankin or steam turbine cycle, reciprocating engine cycle or gas turbine cycle.

Gas and steam turbines are better suited to industries where a steady and high demand for high-pressure steam exists, such as in wood and paper and petrochemical facilities. Gas engines are used mostly for <1–3 MW installations in industries that have a demand for low-pressure steam and/or hot water, such as in the food industry. Steam turbines are used in locations where steam surplus to demand is available.

The energy source is mainly natural gas, although waste, biomass, biogas, diesel, gasoline, coal and oil may be used in some installation configurations. The power-to-heat ratio of generation is improving, from the earlier value of 0.5 to the current 0.6-0.7 and is still rising, toward 1.0, for a total efficiency of 80 percent. The simple paybacks for CHP installations may range from 11/2 to 10 years, with 41/2 years being the average.

Improvements in automatic monitoring and controls enable most CHP systems to operate without any permanent staff at the plant; one person can look after several units.

The biggest potential of CHP systems is in replacing the thousands of small, aging boilers with units that produce both power and heat with greater efficiency. As well, companies that have power needs in the range of 300 kW to 1 MW and that must replace their outdated chillers are an important growth segment.–

New developments are notable in gas microturbines (output of 500 kW or less) and fuel cells. Their compact size offers the possibility to eliminate transmission and distribution losses by locating the power/heat source close to the point of intended use.

The capital costs of microturbines currently well exceed those systems that have reciprocating engines as prime movers. The higher initial cost of these systems is offset, however, by their virtually maintenance-free design. Also, their overall efficiency is further increased because the turbine, compressor and permanent magnet are mounted on a single shaft, avoiding mechanical losses.

The fuel cells convert chemical energy directly into electricity. They are virtually non-polluting, quiet and have low maintenance requirements. Industrial installations include 200 kW phosphoric acid fuel cells and the recently introduced 250 kW proton exchange membrane power unit.

Although the heat output is relatively low grade (80°C), future increases of up to 150°C are expected, which should allow easier steam generation.

22.2 ENERGY SAVING OPPORTUNITIES

22.2.1 Housekeeping ESO's

- Ensure regular inspection and preventive maintenance.

22.2.2 Low-cost ESO's

- Analyse your current heat and power demand situation and perspectives; evaluate the economic potential of a possible CHP installation.
- Add an economizer for feed water preheating to improve total efficiency.

22.2.3 Retrofit ESO's

- Install a CHP unit.
- Upgrade your CHP installation to a combined cycle where, for example, steam is expanded in a steam turbine to produce additional electricity.
- Complement your CHP with daytime (diurnal) heat storage to improve electricity production and its profitability during high-tariff and peak demand periods for use against subsequent demand.
- Consider alternative uses of CHP where the unit's shaft is used to drive other equipment (e.g. refrigeration compressor, HVAC compressor or air compressor) instead of using a steam generator.
- Consider using the recovered heat through an absorption chiller for cooling purposes instead of water heating or for air heating for dryer or space heating.
- Consider integrating your CHP with a heat pump to utilize a lowtemperature heat source for a highly energy-efficient system.

23. BUILDINGS

A comprehensive energy management program is not complete until the buildings themselves are evaluated for their impact on overall energy use. Older buildings, when energy was comparatively cheap, are often inadequately insulated and sealed. Modern building codes (to be proposed soon) set minimum requirements for energy conservation in new buildings. These new requirements also apply in full to repair, renovation or extensions of older buildings.



These and many other regulations and standards that cover industrial buildings' construction and operation (e.g. insulation, heating/cooling and ventilation) also ensure that health, safety and occupational comfort requirements are met. In any consideration of building energy efficiency improvements, these aspects must be carefully examined.

The heat lost from a building in winter gained in summer must be overcome by the HVAC systems, which adds to the cost of operating the facility. Heat loss and gain through the building envelope can be reduced in two major ways:

- reducing heat transfer (gain or loss) through building components (e.g. walls, roof and windows); and
- reducing air leaks – both infiltration and ex-filtration – through openings (e.g. doors and windows).

23.1 REDUCING HEAT TRANSFER

23.1.1 Walls and roofs

In many buildings, upgrading wall insulation is difficult and expensive because of the original construction technique or because activities inside the building would be disrupted. In such cases, it is often possible to add insulation to the exterior of the building and cover it with new weatherproof cladding. Buildings with large south or southwest-facing walls can be retrofitted with a type of "solar wall" (see Section "Heating, ventilating and air conditioning systems," for even greater energy efficiency. Industrial buildings that have large, flat roofs benefit particularly from

roof insulation upgrades because most of the winter heat loss and summer heat gain occur through the roof. A new, insulated roof membrane can be covered with heat reflecting silver-coloured polymeric paint to help minimize the heat transmission. Good construction practices must be observed, such as provision for ventilation of ceiling and roof cavities and prevention of water vapour from entering the insulated cavity as specified in building codes.

23.1.2 Windows

Many older buildings, especially factories, have single-glazed, inadequately sealed windows. Short of replacing them with modern sealed-glass windows, plastic or glass fiber window panels can be used. Some panels are manufactured as double glazed units that allow the passage of light but are unbreakable and more energy efficient than single-glazed glass windows.

- Standard triple glazing adds an extra air space (and also weight) and thus insulation.
- Glass coatings reduce heat emissivity and reflection. Low-emissivity (Low-E) coating reduces radiant heat through the glass and achieves about the same insulation as uncoated triple glazing.
- Gas fill – filling the inter-pane space with argon or krypton – further increases the insulation.
- High-performance triple glazing may utilize Low-E as well as gas fill. The insulating value is almost five times as great as that of a single-paned window.

23.1.3 Reducing air leaks

Examine all openings (vents, windows and outside doors) for cracks that allow air to leak in and out of the building. Block the cracks with caulking or weather stripping. Vestibules, revolving doors and automatic door closers all help reduce losses from open doors. Door seals at loading docks should be inspected regularly; worn or damaged seals leave large gaps between the dock and the trailer. The most energy efficient door is an unglazed insulated door with double weather stripping. Refrigerated spaces require special doors.

23.1.4 Energy Recovery

Building codes recommend that systems that recover energy should be considered when rejected fluid, including air, is of adequate temperature and a simultaneous need for energy exists for a significant number of operating hours. Recently, many case studies have been posted on the Internet to show that commercial and industrial buildings can reduce energy consumption significantly by applying heat exchangers and heat pumps (including ground-source heat pumps), often achieving savings of greater than 50 percent.

Building codes also recommend that a central energy monitoring and control system in a building should, as the minimum, provide readings and retain daily totals for all electric power and demand and for external energy, water and fossil fuel use.

23.2 OTHER ENERGY SAVING OPORTUNITIES

In addition to the examples and ideas discussed in the preceding, consider using the following, if applicable:

- a thermography consultant to discover areas that need (additional) insulation or air-leakage control;
- additional insulation as economically feasible, with a long-range view to saving energy costs; and
- innovative use of passive or active solar heating technology for space and/or water heating, especially when combined with improved insulation, window design and heat recovery from vented air.

ANNEXURE

Annexure 1 **Registration of Energy Audit Firm**

1. Energy Management Centre- Kerala (EMC) intends to empanel BEE accredited energy auditors/ ESCOS as well as competent firms having experience and expertise in Energy audit. The eligibility criteria for registration are given in this notification. The EMC Registered Energy Audit firm's (EMCREA) , as they will be termed, to carry out periodical Energy Audits mandated by G.O.(Rt) No. 2/2011/P.D dated 01-01-2011 as well as to form a data base of Energy Auditors available for Energy Audit in the State.
2. Registration Fees: - ₹ 5000/-. The fees will be non-refundable and would be utilized for organizing meetings, workshops and printing directory. Certificate of Registration as EMC Registered Energy Audit firm's will be issued by EMC after detailed scrutiny and evaluation of the firm's credibility. Registered Energy Auditors will be governed by the terms and conditions given below.
3. Eligibility Criteria for Registration
 - a. The applicant firm should have minimum one BEE certified Energy Auditor with at least 2 years experience in the field of energy auditing.
 - b. Application for empanelment may be submitted as per the Form A.
 - c. The applicant must have relevant experience in Energy efficiency, Energy conservation & Management and should have experience in conducting actual energy audit in HT/ EHT installations and commercial high rise building. Necessary documents / certificates / proofs and Energy Audit Report prepared by the applicant should be produced.
 - d. The firm should have conducted at least 3 energy audits in the last three years. Copy of three latest Energy Audit Reports, indicating name and Certification Number of Certified Energy Auditor and Team of professionals employed by the firm shall be clearly indicated in the report.
 - e. The firm must possess the basic instruments for required for conducting energy audit. In case, the applicant does not possess costly equipment, necessary



proof of understanding with an equipment supplier/ provider may be submitted. List of instruments are as follows

- Power Analyzer Kit (kVA, kW, kWh, V, A, pf, THD, etc)
- Tachometer
- Lux Meter
- Flue Gas Analyzer
- Ultrasonic flow meter
- Thermometer (contact/ noncontact)
- Hygrometer
- Anemometer
- Manometer/ pitot tube

f. The firm must have the following infrastructure facilities:

- Office Premises (permanent office address) with phone / fax
- PC System
- E-mail ID

g. Personal interview of applicants, wherever found necessary, will be taken prior to granting registration.

4. Terms & Conditions of Registration

a. The registration shall be only valid for within the State of Kerala for a specified period of 3 years from the date of issuance of Registration Certificate.

b. The registration is subject to yearly review and renewal by EMC and shall be liable for cancellation in case of non-performance or violation of any of the terms & conditions of registration by the consultant, specified herein.

c. The EMC Registered Energy Audit firm (EMCREA) shall be obliged to submit yearly Work Report pertaining to their overall activity, as EMCREA, including relevant work done by them privately or under any other schemes anywhere in the country.

d. The EMCREA shall respond to all or any bids, RFPs, RFQs, Tenders or quotation invited by HT/ EHT installations and commercial high rise buildings covered under G.O.(Rt) No. 2/2011/P.D dated 01-01-2011 in Kerala.



- e. EMCREAs may themselves identify and motivate prospective clients for undertaking energy audit.
- f. The EMCREA shall abide by the scope of work and submit Energy Audit Report as per prescribed Report Template and also abide by the terms & conditions of the Energy Audit Guidelines issued by EMC or BEE.
- g. The assignments have to be completed within time frame as agreed upon with the client in professional manner.
- h. The EMCREA shall be required to participate in all the meetings and workshop convened by EMC.
- i. EMCREA along with the representative of industries should present the finding of the Energy audit before the expert committee and any modification suggested during the presentation should be incorporated in the energy audit report.
- j. No individual Certified Energy Auditor can register with/employed / represent more than one Energy Audit Firm. If same Certified Energy Auditor is found registered with/employed by / represented by more than one firm the firm may be disqualified from Empanelment.
- k. Certificate of Employment, duly signed by the Signatory of the Energy Audit Firm, with employment service history, shall be submitted with the application for empanelment.



Energy Audit Firms Empanelment (FORM –A)

**Application for Empanelment as EMC Registered Energy Audit Firms
(EMCREA)**

PART A: Details of Applicant

1. Name of Organization: _____

2. Category (Please "" mark at appropriate place)
(Attach registration certificate of the firm)
- a) Individual/ proprietorship
 - b) Partnership
 - c) Private Limited
 - d) Govt, PSU, Autonomous body
3. Address (Postal) _____

- Pin code : _____
- Telephone/s (with STD code): _____
- Fax No. _____ / _____
- email ID _____
- URL (website /blog) _____
4. Name of the CEO and contact details _____
- Tele/Fax/Email:
5. Name/s of BEE Certified Auditors (Please specify BEE certification no :)
- 1. _____
 - 2. _____
6. Registered with any other _____

- Organisation, if yes name of the organisation(attached copy of proof).
7. Are you registered with BEE, if yes specify whether as ESCO or AEA



7. Details of Support Facilities (Instruments, computer, etc.)
- a. Instruments
 - b. Computer
 - c. Others (Pl specify)
- (attach list with detailed specification)
-
-

Part B : Manpower and Experience

1. Table I : Details of Technical Manpower

SI No.	Name & Designation	Professional Qualification & year of passing	Post qualification Experience (years)	Years of experience in Energy Auditing	Whether BEE Certified Auditor Specify BEE certification no
1.					
2.					
3.					

(Attach resume of each of the team member. Use separate sheet if required)

2. Table II: Projects undertaken during last three years.

SI No	Energy Audit (*)	Sector	Name of the Organisation	Month & year of Audit
1.				
2.				
3.				
4.				
5.				

* - Electrical/Thermal/Both (Use separate sheet, if required)

4. Provide documentary evidence in support of your Energy Audit experience :

(Attach seperatly) eg. Copy of minimum three energy audit report or Copy of Completion cerificate from client.

5. Additional information if any (attach separately)



Declaration

- The information provided in this form is accurate and true to the best of my knowledge.
- We agree to abide by the terms & conditions of empanelment.
- Kindly enroll our name as EMC Registered Energy Audit firms for carry out periodical Energy Audits mandated by G.O.(Rt) No. 2/2011/P.D dated 01-01-2011..
- Please find enclosed DD of Rs. 5000/- drawn in favour of EMC payable at ..., as Annual Registration Fee. (Bank: _____ Date: _____)

Name & Designation of the authorized signatory: _____

(Signature)

(Seal of Organization)

Date: _____

(for office use only)

Date of Receipt : _____

Date of Completion of Evaluation : _____

Approved or not approved : _____

EMCREA no allotted : EMCREA/2011/_ /_

Annexure 2

Registered Energy Manager (REM)

The High level Apex Committee for looking after the Kerala State Energy Conservation Programme, in its first meeting held on 14th June 2010 advised that the Energy Managers in case of HT and EHT consumers need not be a Certified Energy Manager but only have to register with the State Designated Agency – Energy Management Centre (EMC), in view of the reported shortage of such expertise.

Registration of Energy Manager

- Qualified personnel may apply to EMC in Form-1 through proper channel enclosing all relevant documents for registration
- For the purpose of registration of energy managers, EMC shall issue a certificate in Form-2 to the person who has registered with us, with copy to the organisation
- On being registered REM shall be issued identity card in Form-3
- EMC shall maintain a register of REMs in Form-4 and include the name of person to whom certificates have been issued under the said register

Qualifications

1. A person shall be qualified to become a registered energy manager, if he –
 - a. has registered at EMC
 - b. has been issued a certificate by EMC to that effect
2. No candidate shall be eligible for registration unless he is—
 - a. a graduate Engineer or equivalent with three years of work experience involving use of energy in operation, maintenance, planning, etc. ; or
 - b. a post-graduate Engineer or equivalent with two years of work experience involving use of energy in operation, maintenance, planning, etc. ; or
 - c. a graduate Engineer with post-graduate degree in Management or equivalent with two years of work experience involving use of energy in operation, maintenance, planning, etc. ; or
 - d. a diploma Engineer or equivalent with six years of work experience involving use of energy in operation, maintenance, planning, etc. ; or



- e. a post-graduate in Physics or Electronics or Chemistry (with Physics and Mathematics at graduation level) with three years of work experience involving use of energy in operation, maintenance, planning, etc.

(For definitions on qualifications, refer Annexure A)

Validity of registration: - The registration shall be valid for a period of two years and renewable after two years on an application made to the EMC in Form-5. Provided that no such renewal shall be made unless the REM has attended a short term refresher training course conducted by the EMC, as the case may be, and has produced a certificate of participation issued in that behalf.

Cancellation of registration: - EMC may cancel the certification of an energy manager on a complaint made against him for -

- a. any commission or omission amounting to professional misconduct
- b. any misrepresentation of facts, data or reports on energy consumption
- c. any act amounting to fraud
- d. failure to attend the refresher course,

provided that no such cancellation shall be done by the EMC without giving an opportunity of being heard to such energy manager. On cancellation of registration of energy manager, his name shall be removed from the register and thereafter, the registered energy manager shall not be eligible for designation or appointment as energy manager.

Issue of duplicate certificate or identity card: -

1. where the certificate or identity card issued respectively has been lost by the energy manager, EMC may, on an application made by him in this behalf, duly supported by a copy of first information report lodged with the concerned police station, issue a duplicate certificate or identity card, as the case may be, on a payment of a fee of rupees one hundred by demand draft drawn in favour of Energy Management Centre, payable at Thiruvananthapuram
2. where any certificate or identity card issued by EMC is damaged, EMC may on a application made in this behalf and on surrender of damaged certificate or



identity card, issue duplicate certificate or identity card on payment of a fee of rupees one hundred by demand draft drawn in favour of Energy Management Centre, payable at Thiruvananthapuram

Annexure A

Definitions*

- a. "diploma engineer" means a person who has obtained a diploma in Engineering from a University or Board or Institution incorporated by an act of the Central or State Legislature in India or other educational institutions established by an Act of Parliament or any diploma recognized by All India Council for Technical Education as equivalent or has obtained a diploma in engineering from such foreign University or College or Institution recognized by the Central Government, and under such conditions as may be laid down for the purpose, from time to time;
- b. "graduate engineer" means a person who has obtained a graduation degree in Engineering from a University incorporated by an act of the Central or State Legislature in India or other educational institutions established by an Act of Parliament or declared to be deemed as Universities under Section 3 of the Universities Grant Commission Act, 1956 or any degree recognized by All India Council for Technical Education as equivalent or has obtained a graduation degree in engineering from such foreign University or College or Institution recognized by the Central Government, and under such conditions as may be laid down for the purpose, from time to time;
- c. "post-graduate in engineering" means a person who has obtained a post-graduate degree in Engineering from a University incorporated by an act of the Central or State Legislature in India or other educational institutions established by an Act of Parliament or declared to be deemed as Universities under Section 3 of the Universities Grant Commission Act, 1956 or any degree recognized by All India Council for Technical Education as equivalent or has obtained a graduation degree in Engineering from such foreign University or College or Institution recognized by the Central Government, and under such conditions as may be laid down for the purpose, from time to time;
- d. "post-graduate" means a post-graduate of University incorporated by an act of the Central or State Legislature in India or other educational institutions established by an Act of Parliament or declared to be deemed as Universities under Section 3 of the Universities Grant Commission Act, 1956 or any degree recognized by All India Council for Technical Education as equivalent or has obtained a post-graduate degree in Engineering from such foreign University or



College or Institution recognized by the Central Government, and under such conditions as may be laid down for the purpose, from time to time.

**Reference: Energy Conservation Act 2001*



Form – 1

Application for Registration for Energy Manager
(Through proper channel)

Name of the applicant:					
Sex (Male/Female):					
Present Address:					
Permanent Address:					
Mobile & Land line No:					
E-mail:					
Date of Birth:					
Designation:					
Total work experience:					
Name of the Present Employer:					
Address of Present Employer:					
Telephone & Fax of Present Employer:					
Web site & Email of Present Employer:					
Years of experience in present company:					
Requisite Educational Qualifications					
Sl no	Name of degree/diploma	Subjects/Branch	Year of passing	Board/University	
Requisite experience for fulfilling the eligibility criteria					
Sl no	Name of employer/organisation	Designation	From (date)	To (date)	Nature of work (max 50 characters)



Declaration by the candidate

I hereby declare that all the information given in the application form and enclosures are true to the best of my knowledge. I agree to the condition that if any information or any statement is found to be incorrect, my registration may be cancelled.

Forwarded by (Name)

Designation

Signature

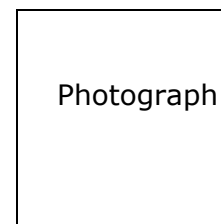
Date:



Form – 2

CERTIFICATE FOR REGISTERED ENERGY MANAGER

Certificate Registration No:



This is to certify that Mr/Mrs/Ms _____ is certified as Registered Energy Manager. This certificate shall be valid for two years with effect from the date of award of this certificate and shall be renewable subject to attending the prescribed refresher training course once in every year.

His/Her name has been entered in the record of Registered Energy Manager at Sl. No. _____ being maintained by the Energy Management Centre.

Given under the seal of the Energy Management Centre, this _____ day

(Signature and Seal)

Director

Energy Management Centre

Dates of attending the refresher course	Director's signature	Dates of attending the refresher course	Director's signature



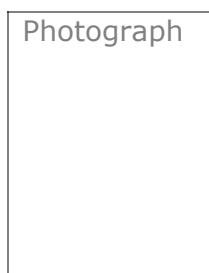
Form 3

Format for Identity Card

Energy Management Centre

Thiruvananthapuram

Registered Energy Manager



Registration No: _____

Name: _____

Son/Daughter of: _____

Address: _____

Signature of Registered Energy Manager

(Backside of Identity Card)

Date of Issue: _____ Validity up to: _____

Issuing Authority: _____

Name: _____

Designation: _____

Office address: _____

Signature





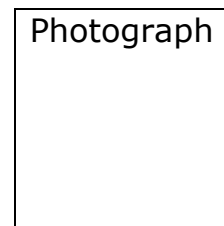
Form 4

Energy Management Centre

Photograph

Record of Registered Energy Managers

As on: _____ (DD/MM/20YY)



A. Registration Information					
Name of registered energy manager:					
Sex (Male/Female)					
Date of Birth:					
Nationality:					
Registration Number:					
Date of entry in the register					
Date of issue of registration:					
Date of re-validation of registration:					
Revalidation record		1.			
		2.			
		3.			
B. Communication Links					
Postal address with Pin code:					
Email:					
Land line & mobile no with STD code:					
C. Work experience					
Sl no	Name of employer/organisation	Designation	From (date)	To (date)	Nature of work (max 50 characters)
D. Personal Information					
Sl no	Name of degree/diploma	Subjects/Branch	Year of passing	Board/University	
1					
2					
3					



Form – 5
Application for renewal of certification

Date: _____

From

Mr/Mrs/Ms _____

Registration No. _____

Postal Address: _____

through proper channel

To

The Director

Energy Management Centre

Srikrishna Nagar

Sreekaryam P.O, Thiruvananthapuram 695017

Kerala, India

Tel: +91-471-2594922, 2594924

Fax: +91-471-2594923

Dear Sir/Madam,

Subject: Renewal of certification as Registered Energy Manager

This is to inform that I have attended the short term refresher training course and enclose herewith the certificate of participation issued in this behalf.

I hereby apply for renewal of my application as Registered Energy Manager. The certificate is enclosed for doing the needful.

Yours faithfully,

(Signature) _____

(Name) _____

Annexure 3

Energy Audit Guidelines

The Energy Management Centre - Kerala (EMC) is established in 1996 by the Government of Kerala as an autonomous centre under the Department of Power with the objective of promotion of Energy Conservation. The industrial and commercial sectors consume large share of commercial energy and there is evidently a good potential for conserving 25%-30% energy by following good energy management practices.

The Government of Kerala in order to encourage energy efficiency in the industrial and commercial sectors has passed a resolution to make energy audits mandatory once in every three years for all HT and EHT installations and Commercial and non-domestic high rise buildings (having more than four floors and or 15 metres of height from ground level), hereinafter referred as Designated Energy Consumers (DEC).

Energy Audit Study helps to understand and analyse energy utilisation and identify areas of energy wastage, decide how to budget energy use, plan & practice feasible energy conservation methods that will enhance energy efficiency, curtail energy wastage and substantially reduce energy costs. Energy Audit is thus the key to a systematic approach for decision-making in the area of Energy Management. Energy Audit (EA) 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 & vital information generated through these activities.

An Energy Audit Study includes *(also refer content sheet of an EA Report – Annexure 1)*

- Auditing of Energy Consumption (including any heat and power generated)
- General examination of work place (including physical condition of organization, 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.
- 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.

Steps for undertaking energy audit

1. Consultants, for conducting the energy audit, must be selected from the list of EMC authorized consultants.
2. One hard copy of the Draft EA Report and a soft copy in MS Word format along with
 - the plan of action on the EA recommendations (as per the Form I)
 - latest Annual Report (wherever applicable) and
 - latest electricity billmay be submitted to EMC before the specified date of completion of audit.
3. This report has to be presented jointly by the Consultant and the DEC before an expert team constituted by EMC either in the premises of the DEC or in another convenient location, with prior intimation, on a mutually convenient date.
4. EMC would send its comments on the acceptance of the EA Report, with modifications, if any, after the formal presentation.
5. The DEC may submit 2 hard copies Final EA Report and the soft version and EC implementation program/ schedule with details of savings (revised Form I).
6. Every DEC shall furnish to EMC every year, the details of progress made in consequence of the action taken by it together with details of energy efficiency improvement measures implemented and consequent savings achieved in Form II, within three months of the close of that financial year.

Annexure 4

Report on DETAILED ENERGY AUDIT

Table of Contents

- I. Acknowledgement**
- II. Executive Summary**
 - Energy audit options at a glance and recommendations
 - 1.0 Introduction about the plant.**
 - 1.1 General plant details and descriptions
 - 1.2 Energy Audit team
 - 1.3 Component of production cost (Raw materials, energy, chemicals, manpower, overhead, others)
 - 1.4 Major energy use and Areas
 - 2.0 Production Process Description.**
 - 2.1 Brief description of manufacturing process.
 - 2.2 Process flow diagram and Major unit operations.
 - 2.3 Major raw material inputs, Quantity and cost.
 - 3.0 Energy and utility System Description.**
 - 3.1 List of Utilities
 - 3.2 Brief description of each utility.
 - 3.2.1 Electricity
 - 3.2.2 Steam
 - 3.2.3 Water
 - 3.2.4 Compressed Air

3.2.5 Chilled Water

3.2.6 Cooling Water

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 & 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

Note: - Format for capturing energy/ production/ service details or figures as used in the Award application format can be given here for reference.



Details of action taken on recommendations of Registered energy auditor for improving energy efficiency.

Form I

	Energy efficiency improvement measures – (suggested categories of areas of energy efficiency improvement for obtaining details of energy savings – See annexure-3)	Investment Millions Rupees	Reasons for not implementing the measure	Date of completion of measure/likely completion	Life cycle Years ¹	Annual energy ² savings				
						Oil	Gas	Coal	Electricity	Other
1.										
2.										
3.										
4.										
5.										
6.										
7.										
8.										
9.										
10.										

Signature
Name of the energy manager
Name of the company
Full address
Contact person
Email address
Telephone/Fax numbers
Plant address

Signature
Name of the accredited energy auditor
Accreditation details
Seal

1. Estimate the predicted life of the measure, meaning the number of years the level of first year energy savings or even larger amounts will materialize.
2. Life commercial units of litre, kg, tonnes, normal cubic meter , kWh or MWh and the unit indicate the anticipated potential in energy savings



Details of energy efficiency improvement measures implemented, investment made and savings in energy achieved and progress made in the implementation of other recommendations.

A. Implemented:

Sl No	Description of energy efficiency improvement measure	Category ³	Investment (Rupees)	Verified savings ⁴ (Rupees)	Verified energy savings	Units ⁵	Fuel	Remarks
1.								
2.								
3.								

B. Under implemented:

Sl No	Description of energy efficiency improvement measure	Category	Investment (Rupees) Estimated	Verified savings (Rupees) Estimated	Verified energy savings Estimated	Units	Fuel	Remarks
1.								
2.								
3.								

Signature
Name of the energy manager
Name of the company
Full address
Contact person
Email address
Telephone/Fax numbers
Plant address

Signature
Name of the accredited energy auditor
Accreditation details
Seal

3. See annexure 2 for reference

4. First year

5. Use conventional energy, volume, or mass units with proper prefix k=10³, M=10⁶, G=10⁹

Annexure 5

Suggested categories of areas of energy efficiency improvement for obtaining details of energy savings

1. Better housekeeping measures
2. Installation of improved process monitoring and control instrumentation or software
3. Fuel handling System
4. Steam generation station
5. Steam distribution station
6. Electricity Generation system
7. Hot Water system
8. Compressed air system
9. Raw/Process Water system
10. Cooling water System
11. Process Cooling/Refrigeration system
12. Heating ventilation and Air conditioning
13. Electrical System
14. Lighting system
15. Melting/Heating/Drying equipment(e.g. Furnaces
Heaters,Kilns,Ovens,Dryers,Evaporators etc)
16. Heat exchangers
17. Pumps,Compressors,Fans,Blowers,Piping,Ducting
18. Process equipment(e.g.Reactors,Separation Equipment ,Material, Handling
Equipment etc.)
19. Transformers
20. Electric Motors and drives
21. Process Technology
22. Process Integration
23. Process control and automation
24. Other Non-equipment measures(eg Plant Operation/Scheduling,Tariff
Schedule,etc).
25. Recovery of waste heat for process heat or power generation
26. Retrofitting,modification or sizing of fans,blowers pumps including duct
system
27. Other